MACK INDUSTRIES

T-SHAPE WINGWALL SYSTEM

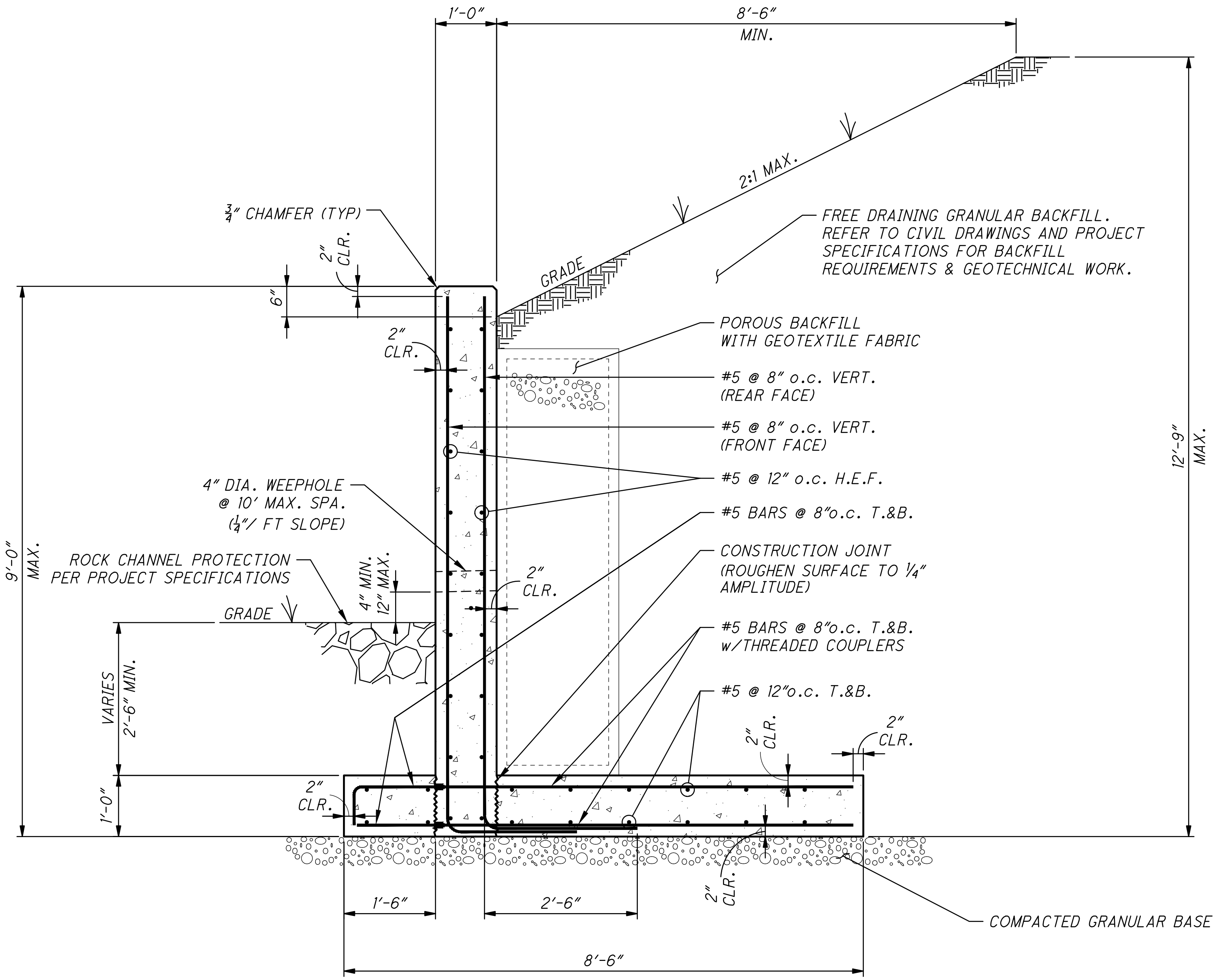
APPROVAL PACKAGE

Ohio Department of Transportation

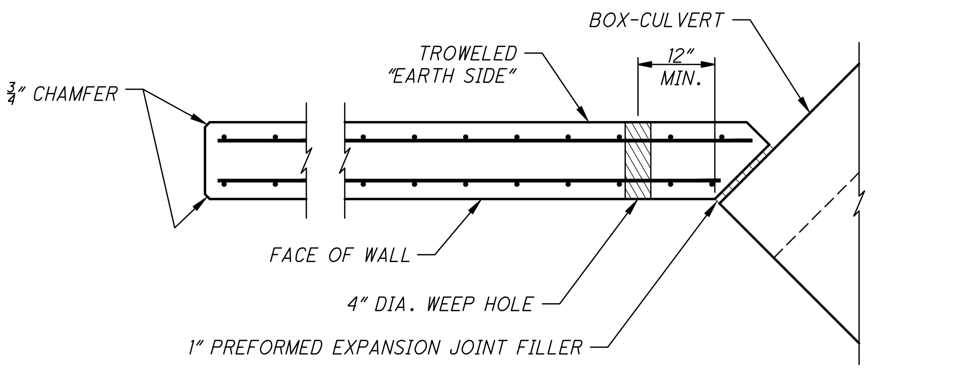
SAMPLE SHOP DRAWINGS

Ohio Department of Transportation

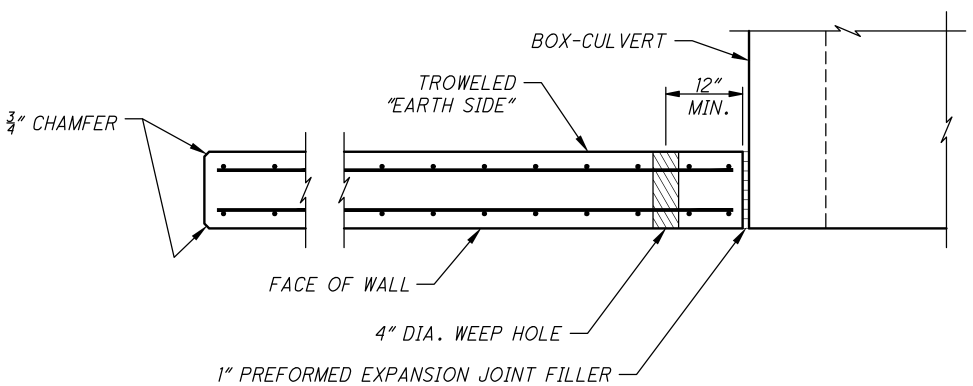
APPENDIX 6: STANDARD DETAILS



WINGWALL SECTION

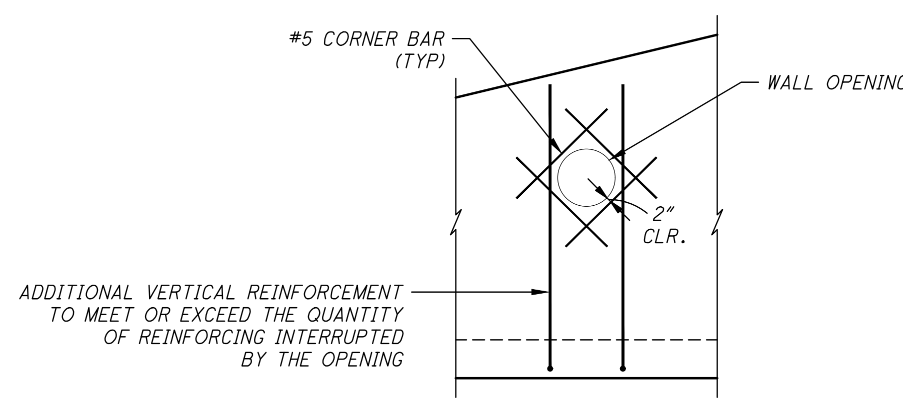


SKEWED WINGWALL



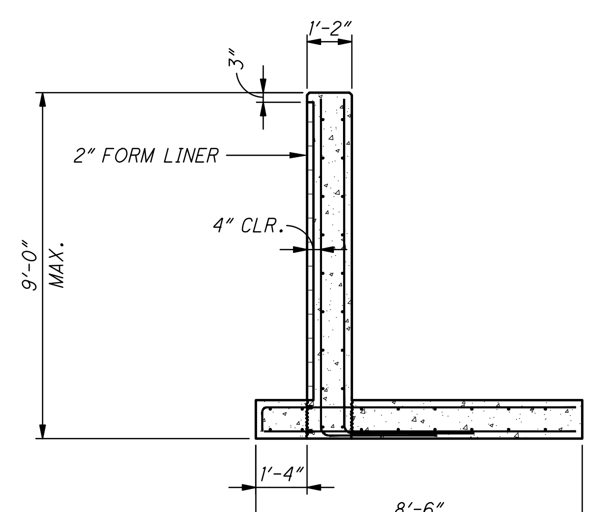
PARALLEL WINGWALL

END OF WALL DETAIL



WALL OPENING REINFORCEMENT DETAIL

(FOR OPENINGS GREATER THAN 6")



OPTIONAL FACE FINISH DETAIL

DESIGN AGENCY
OHLIN & REED, INC.
STRUCTURAL DESIGN CONSULTANTS

DESIGNED	DRAWN	REVIEWED	DATE
JMW	JMW	JJS	11/12/20
CHECKED	REVISED	STRUCTURE FILE NUMBER	
JJS	XXX	XXX	

STRUCTURAL DETAILS
ODOT PREFABRICATED RETAINING WALL SYSTEMS
APPROVAL PROCESS

PID No. #####

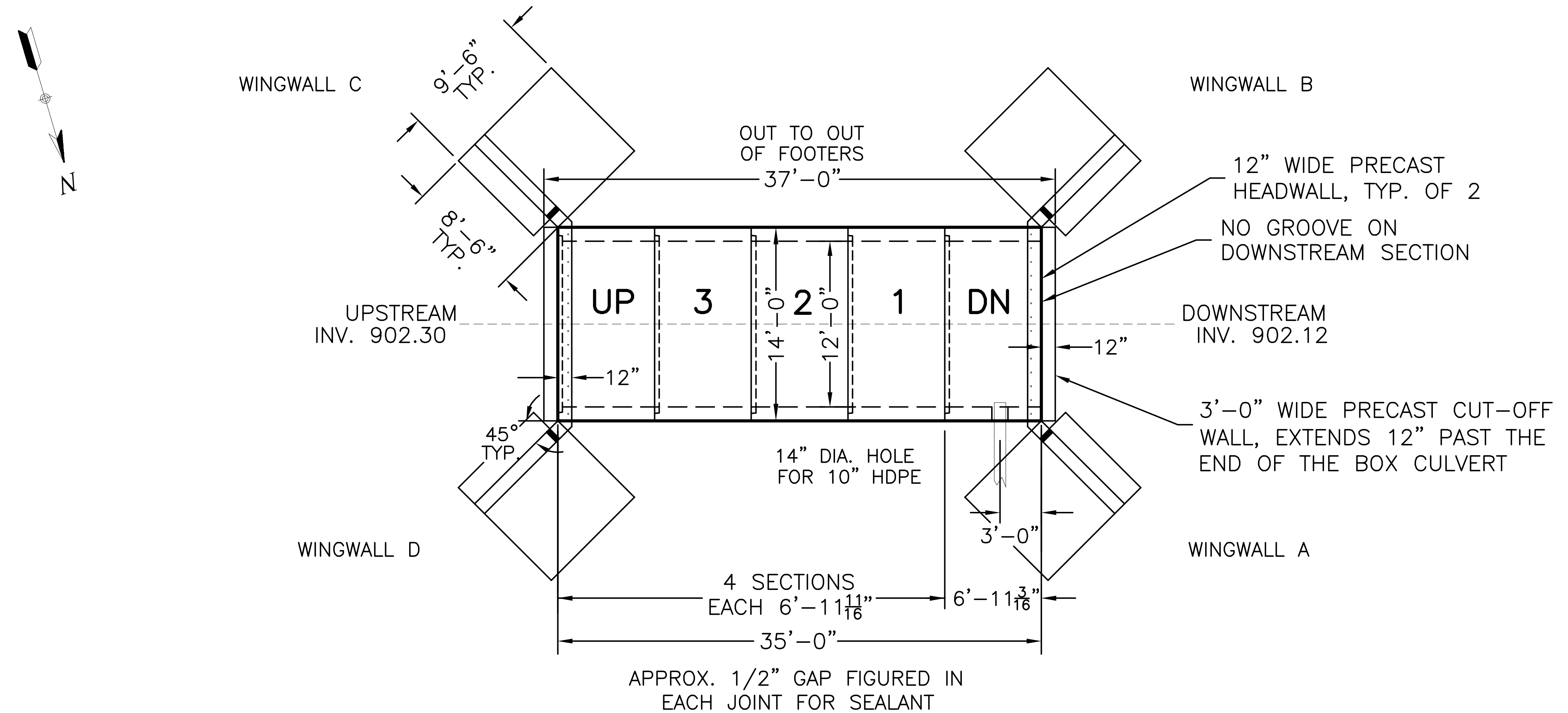
####

1/1

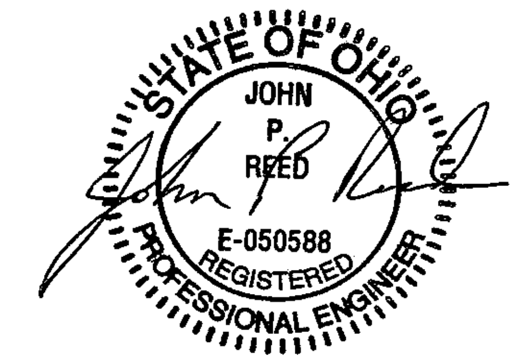
X/X

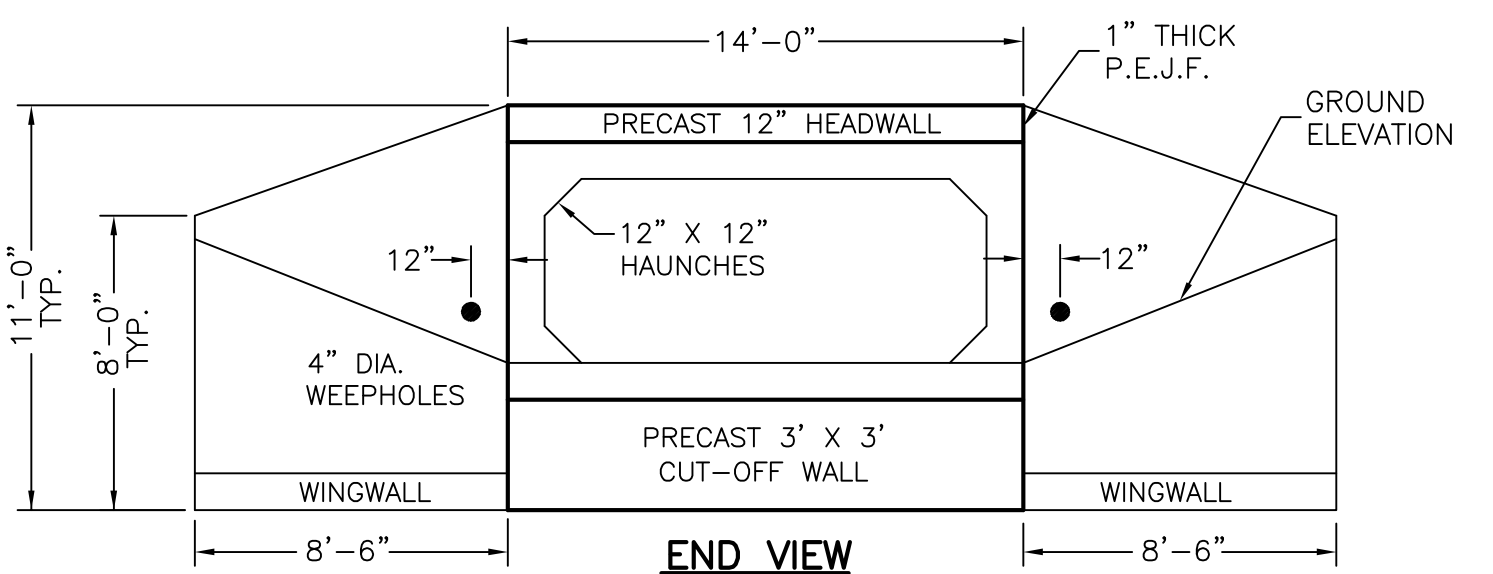
Item J

Sample Set of Shop Drawings



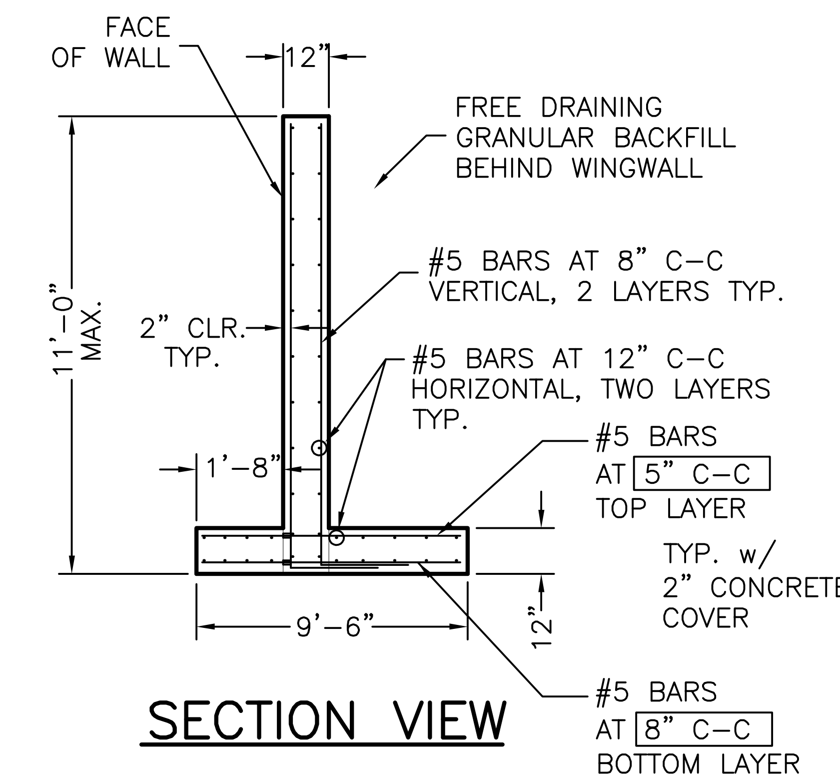
PLAN VIEW





END VIEW

TYPICAL



SECTION VIEW

NOTES:

1. REINFORCED PRECAST CONCRETE SHALL HAVE A COMPRESSIVE STRENGTH OF 5000 PSI AT 28 DAYS
2. STEEL MESH REINFORCING TO HAVE A MINIMUM YIELD STRENGTH OF 65,000 PSI AND CONFORM TO ASTM A1064 OR ASTM A615. PLAIN STEEL
3. CULVERT SECTIONS DESIGNED PER HL-93 LOADING WITH 0.06 KIPS/SQ. FT. FWS, 0' TO 2' EARTH COVER AND O.D.O.T. SPEC. TYPE A, 706.05
4. APPROX. WEIGHT OF HEAVIEST CULVERT SECTION = 44,000 LBS. (INCLUDES HEADWALL)

   CUT-OFF WALL (FOOTER)= 19,000 LBS.

   WINGWALL= 23,000 LBS.

12' X 5' BOX CULVERT WITH WINGWALLS

LAKE MEDINA

DRAWN BY: EJG	SCALE: NTS	DRAWING NO.: CV41388A
DATE: 6/30/20	REV:	

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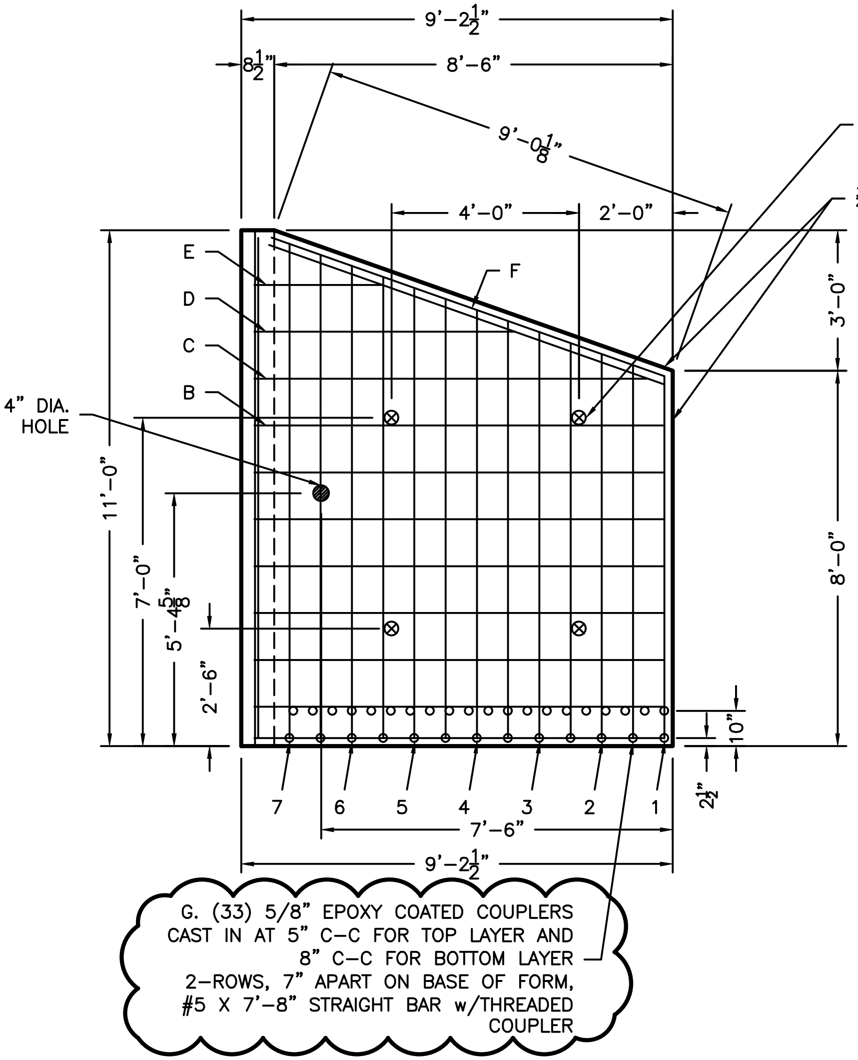
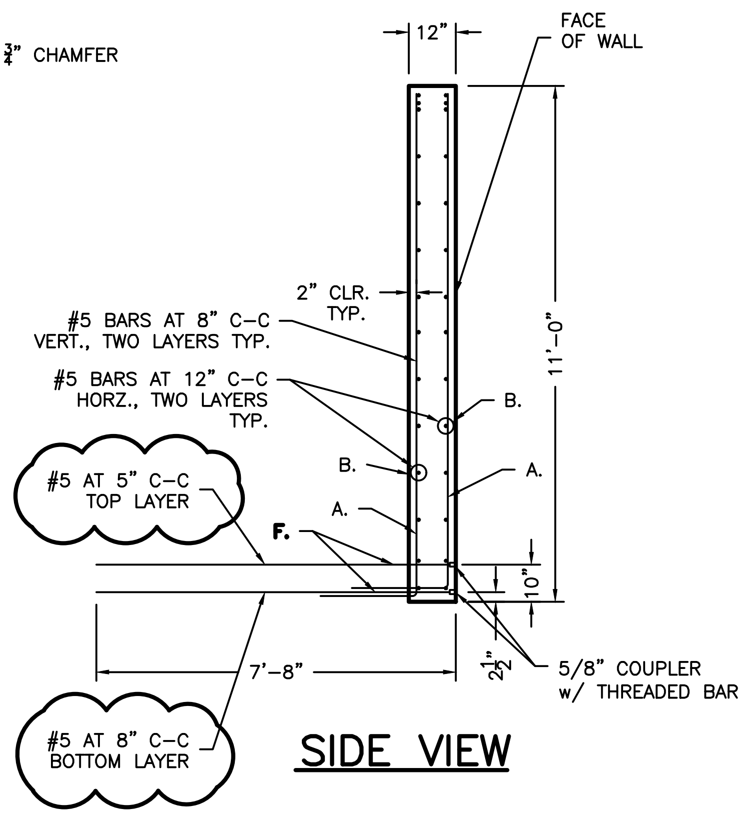
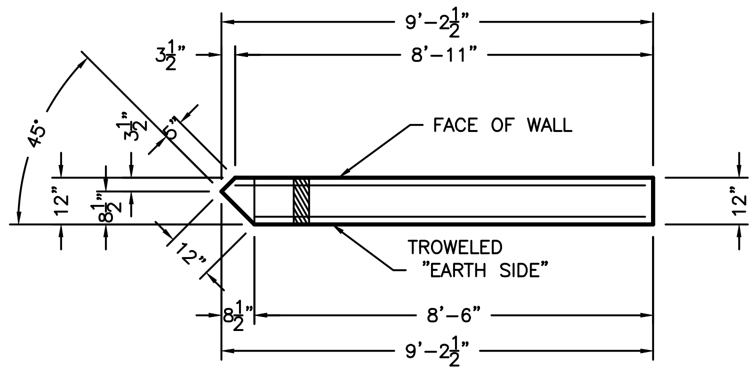


TOP VIEW



SIDE VIEW

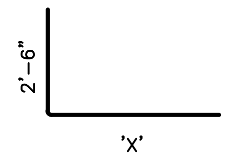


END VIEW

CUTTING LIST

ALL #5 GRADE 60 EPOXY COATED REBAR

		'X'
A1.	4 RODS, #5 X 10'-0"	7'-8"
A2.	4 RODS, #5 X 10'-6"	8'-2"
A3.	4 RODS, #5 X 10'-11"	8'-7"
A4.	4 RODS, #5 X 11'-5"	9'-1"
A5.	4 RODS, #5 X 11'-11"	9'-7"
A6.	4 RODS, #5 X 12'-4"	10'-0"
A7.	2 RODS, #5 X 12'-10"	10'-6"
A8.	2 RODS, #5 X 10'-8" STRAIGHT	



BOTTOM LAYER

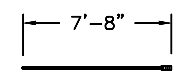
B. 8 RODS, #5 X 8'-4" – STRAIGHT
C. 1 RODS, #5 X 7'-11" – STRAIGHT
D. 1 RODS, #5 X 5'-1" – STRAIGHT
E. 1 RODS, #5 X 2'-3" – STRAIGHT

TOP LAYER

B. 8 RODS, #5 X 8'-9" – STRAIGHT
C. 1 RODS, #5 X 8'-4" – STRAIGHT
D. 1 RODS, #5 X 5'-6" – STRAIGHT
E. 1 RODS, #5 X 2'-8" – STRAIGHT

F. 4 ROD, #5 X 8'-10" – STRAIGHT

G. 33 RODS, #5 X 7'-8" – STRAIGHT
BAR WITH 5/8" COUPLER



POUR ON SMOOTH SURFACE

2" PLASTIC BAR CHAIRS
CHCU X 5 1/2" SPACERS

3.16 YDS. 5000 PSI
(4) 20 TON SWIFT LIFTS

JOB: LAKE MEDINA
JOB# CV41388
CUST: MARKS CONSTRUCTION

WINGWALL A, FIRST POUR		
LAKE MEDINA, 12' X 5' CULVERT		
DRAWN BY: AJK	SCALE: XXX	DRAWING NO.:
DATE: 7/22/20	REV:	CV4138812X5WW

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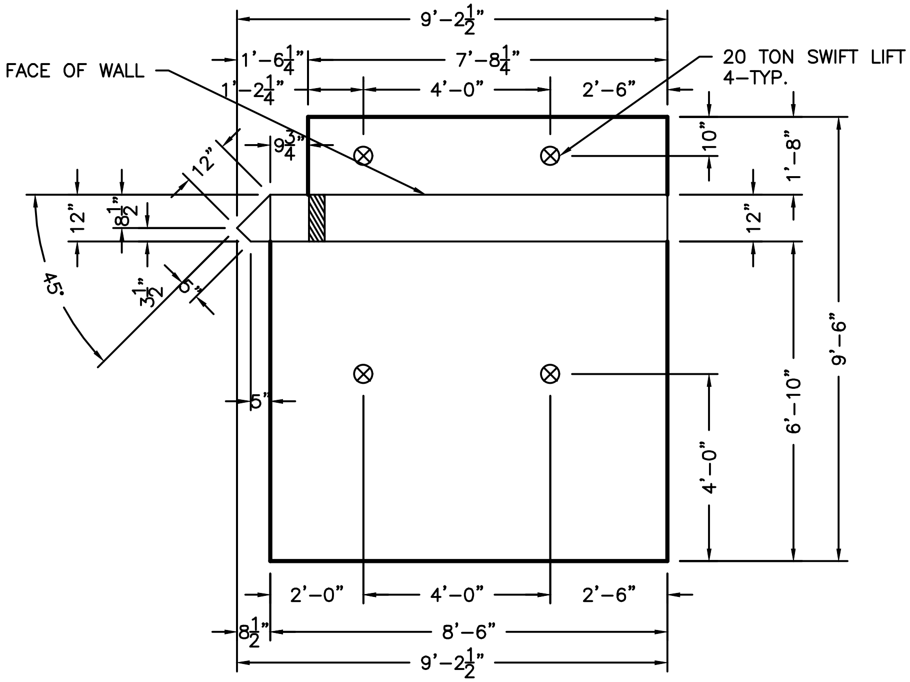
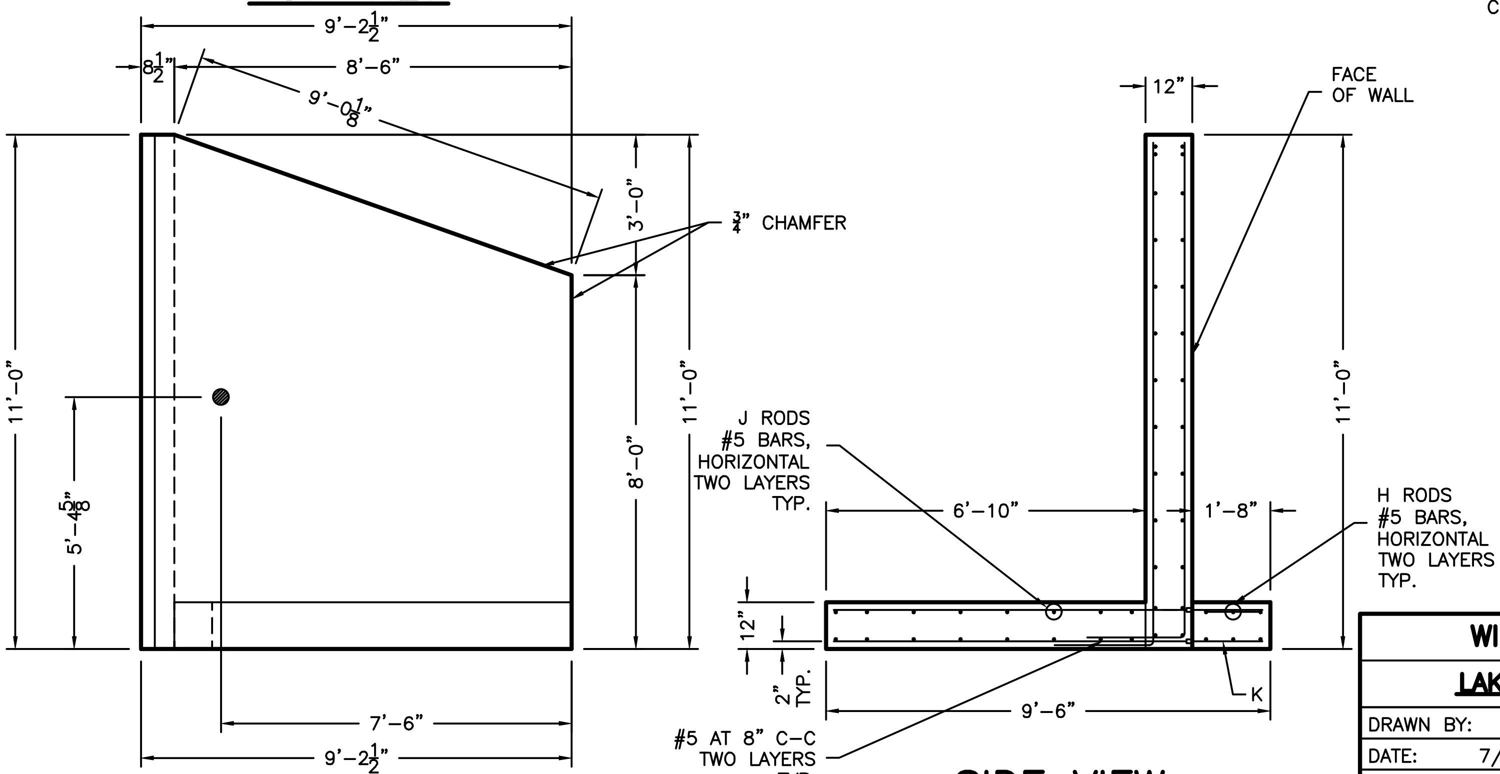


TOP VIEW



SIDE VIEW

CUTTING LIST

ALL TO BE EPOXY COATED

H. 6 RODS, #5 X 7'-4" – STRAIGHT

J. 16 RODS, #5 X 8'-2" – STRAIGHT

K. 30 RODS, #5 X 1'-6" – STRAIGHT, THREADED ONE END

2" PLASTIC BAR CHAIRS
CHCU X 5 1/2" SPACERS

2.13 YDS. 5000 PSI – SECOND POUR
(4) 20 TON SWIFT LIFTS

JOB: LAKE MEDINA
JOB# CV41388
CUST: MARKS CONSTRUCTION

WINGWALL A, SECOND POUR		
LAKE MEDINA, 12' X 5' CULVERT		
DRAWN BY: AJK	SCALE: XXX	DRAWING NO.:
DATE: 7/22/20	REV:	CV4138812X5WW

MACK INDUSTRIES, INC.

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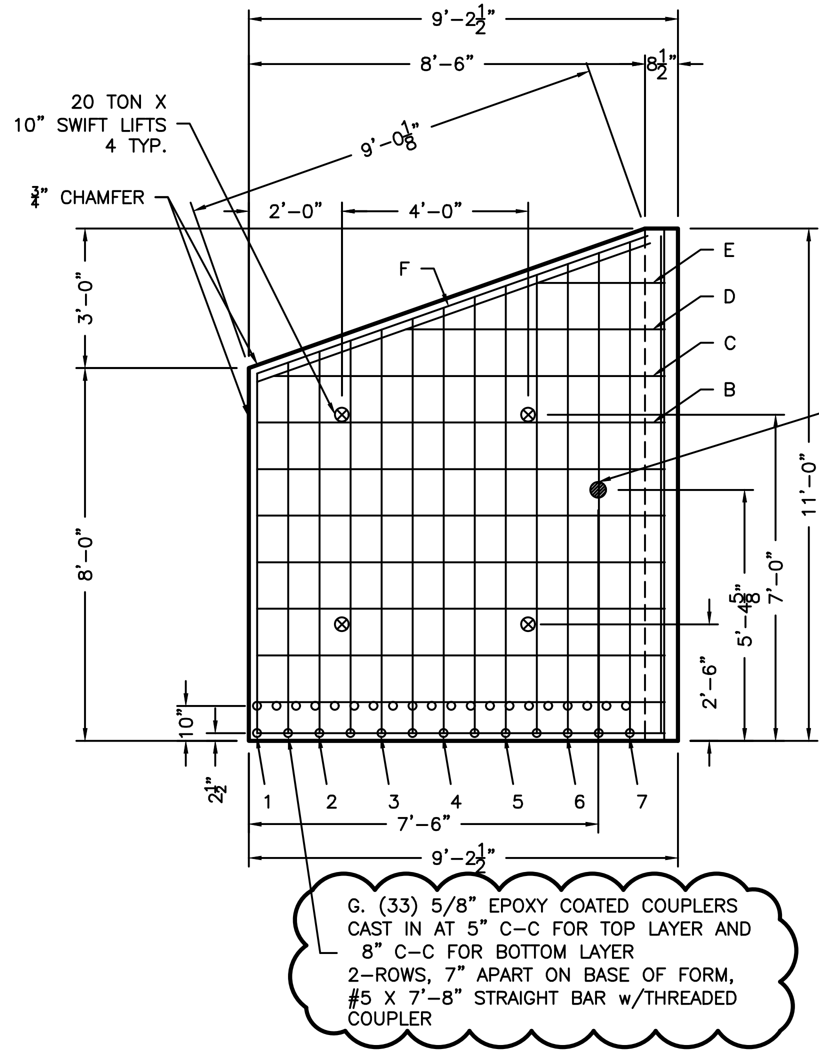
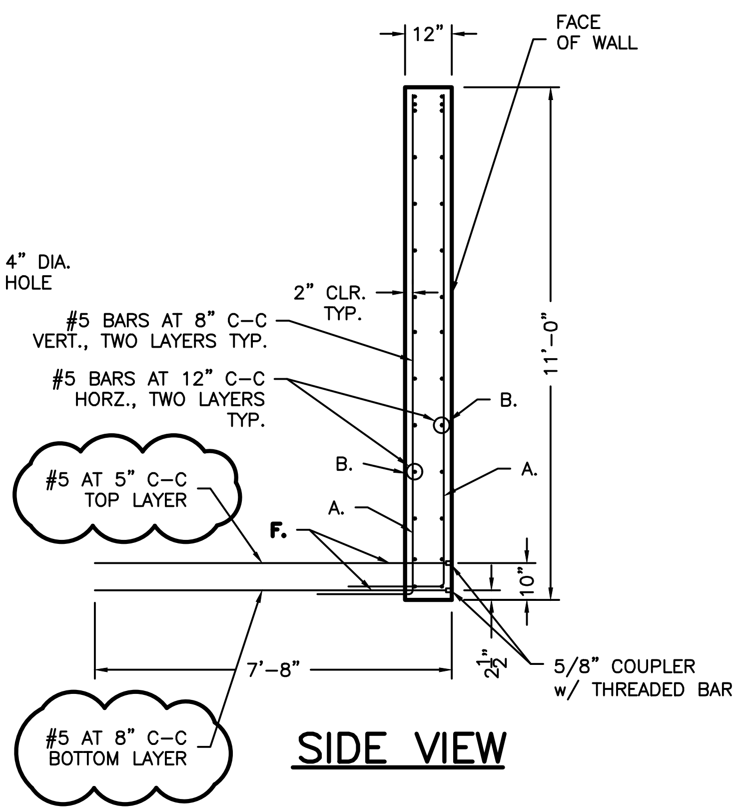
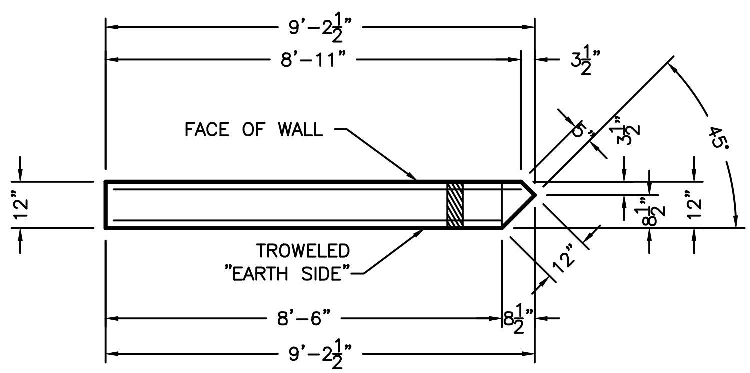


TOP VIEW



SIDE VIEW

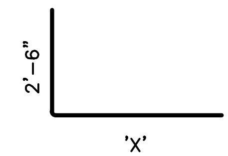


END VIEW

CUTTING LIST

ALL #5 GRADE 60 EPOXY COATED REBAR

	'X'
A1. 4 RODS, #5 X 10'-0"	7'-8"
A2. 4 RODS, #5 X 10'-6"	8'-2"
A3. 4 RODS, #5 X 10'-11"	8'-7"
A4. 4 RODS, #5 X 11'-5"	9'-1"
A5. 4 RODS, #5 X 11'-11"	9'-7"
A6. 4 RODS, #5 X 12'-4"	10'-0"
A7. 2 RODS, #5 X 12'-10"	10'-6"
A8. 2 RODS, #5 X 10'-8" STRAIGHT	



BOTTOM LAYER

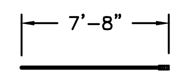
B. 8 RODS, #5 X 8'-4" – STRAIGHT
C. 1 RODS, #5 X 7'-11" – STRAIGHT
D. 1 RODS, #5 X 5'-1" – STRAIGHT
E. 1 RODS, #5 X 2'-3" – STRAIGHT

TOP LAYER

B. 8 RODS, #5 X 8'-9" – STRAIGHT
C. 1 RODS, #5 X 8'-4" – STRAIGHT
D. 1 RODS, #5 X 5'-6" – STRAIGHT
E. 1 RODS, #5 X 2'-8" – STRAIGHT

F. 4 ROD, #5 X 8'-10" – STRAIGHT

G. 33 RODS, #5 X 7'-8" – STRAIGHT BAR WITH 5/8" COUPLER



POUR ON SMOOTH SURFACE

2" PLASTIC BAR CHAIRS
CHCU X 5 1/2" SPACERS

3.16 YDS. 5000 PSI
(4) 20 TON SWIFT LIFTS

JOB: LAKE MEDINA
JOB# CV41388
CUST: MARKS CONSTRUCTION

WINGWALL B, FIRST POUR		
LAKE MEDINA, 12' X 5' CULVERT		
DRAWN BY: AJK	SCALE: XXX	DRAWING NO.:
DATE: 7/22/20	REV:	CV4138812X5WW

MACK INDUSTRIES, INC.
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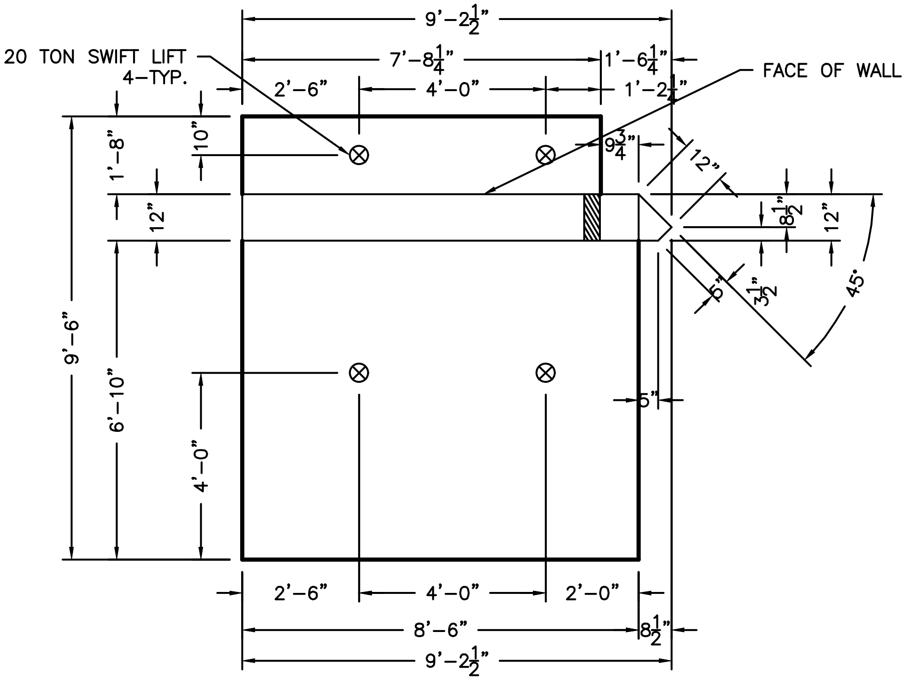


TOP VIEW

CUTTING LIST

ALL TO BE EPOXY COATED

H. 6 RODS, #5 X 7'-4" – STRAIGHT

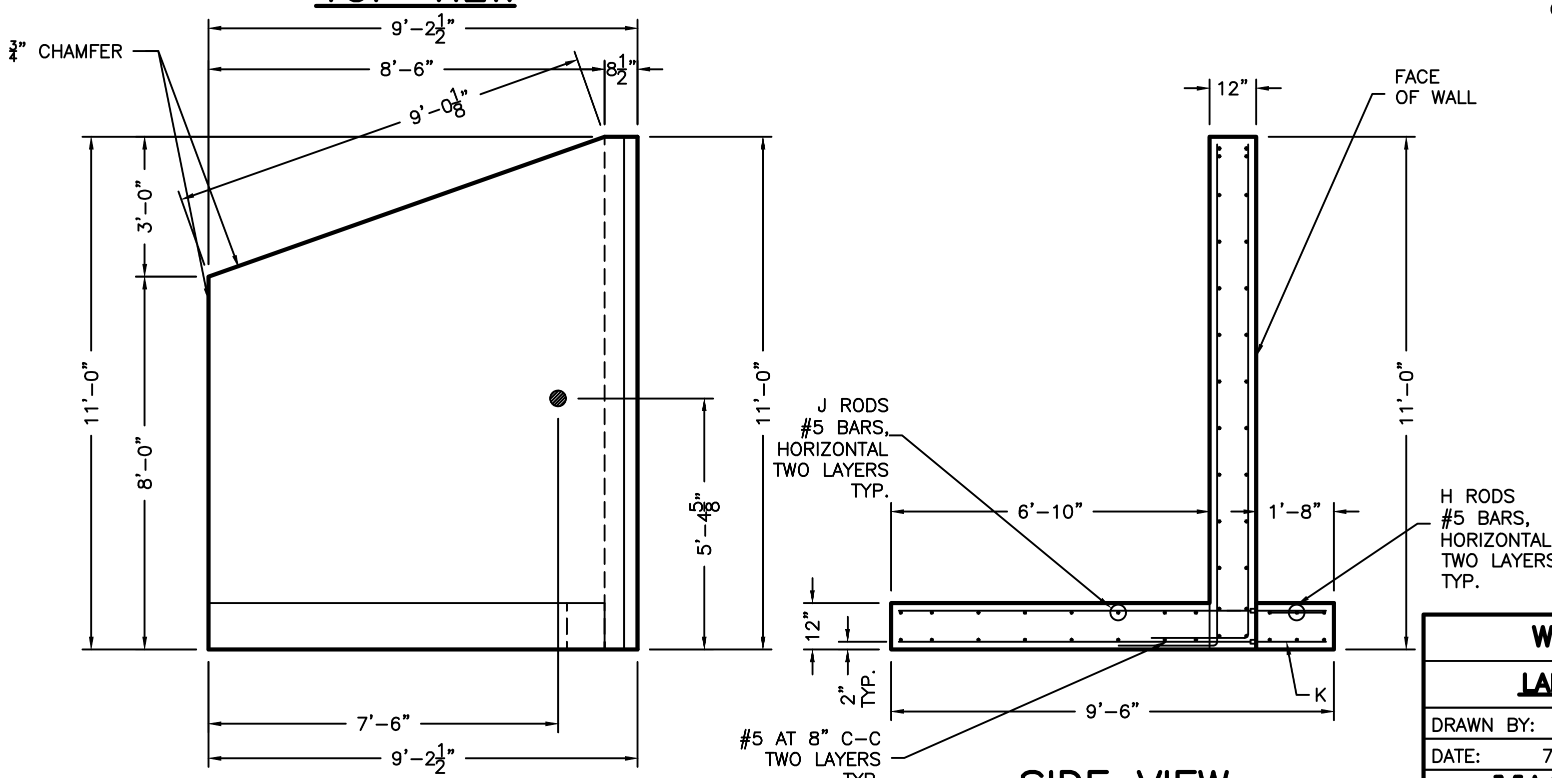
J. 16 RODS, #5 X 8'-2" – STRAIGHT

K. 30 RODS, #5 X 1'-6" – STRAIGHT, THREADED ONE END

2" PLASTIC BAR CHAIRS
CHCU X 5 1/2" SPACERS

2.13 YDS. 5000 PSI – SECOND POUR
(4) 20 TON SWIFT LIFTS

JOB: LAKE MEDINA
JOB# CV41388
CUST: MARKS CONSTRUCTION



SIDE VIEW

WINGWALL B, SECOND POUR		
LAKE MEDINA, 12' X 5' CULVERT		
DRAWN BY: AJK	SCALE: XXX	DRAWING NO.:
DATE: 7/22/20	REV:	CV4138812X5WW

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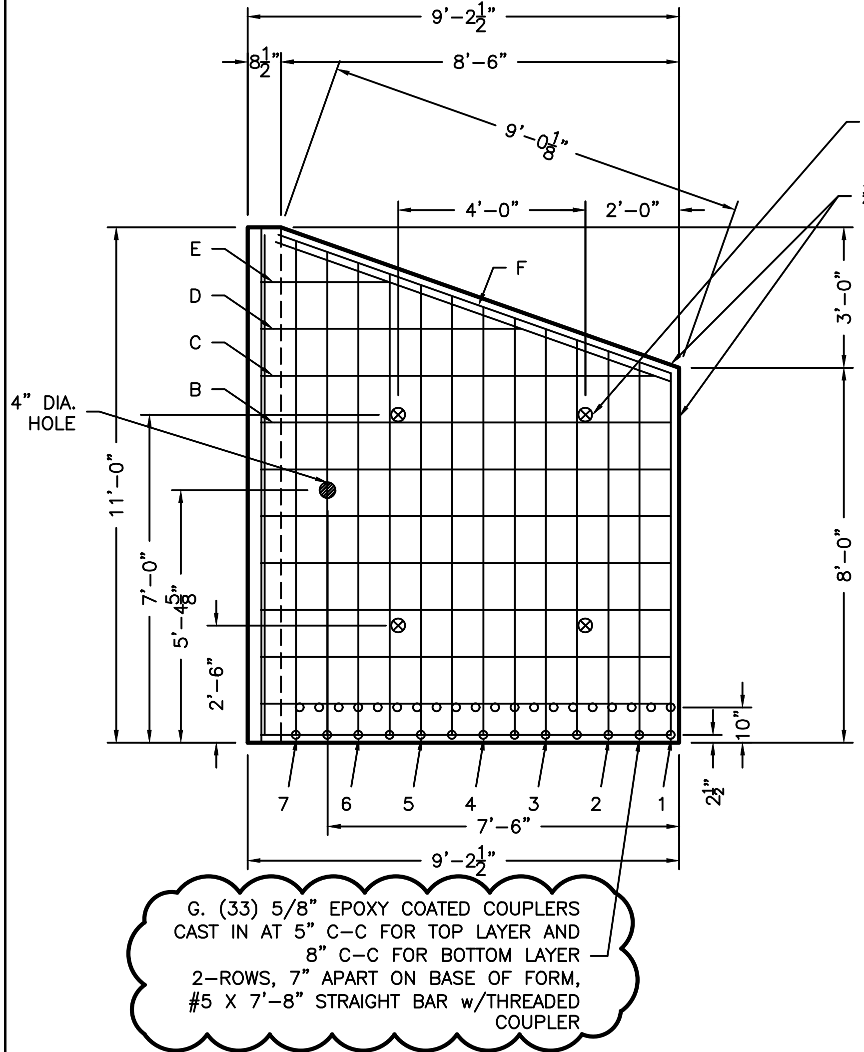
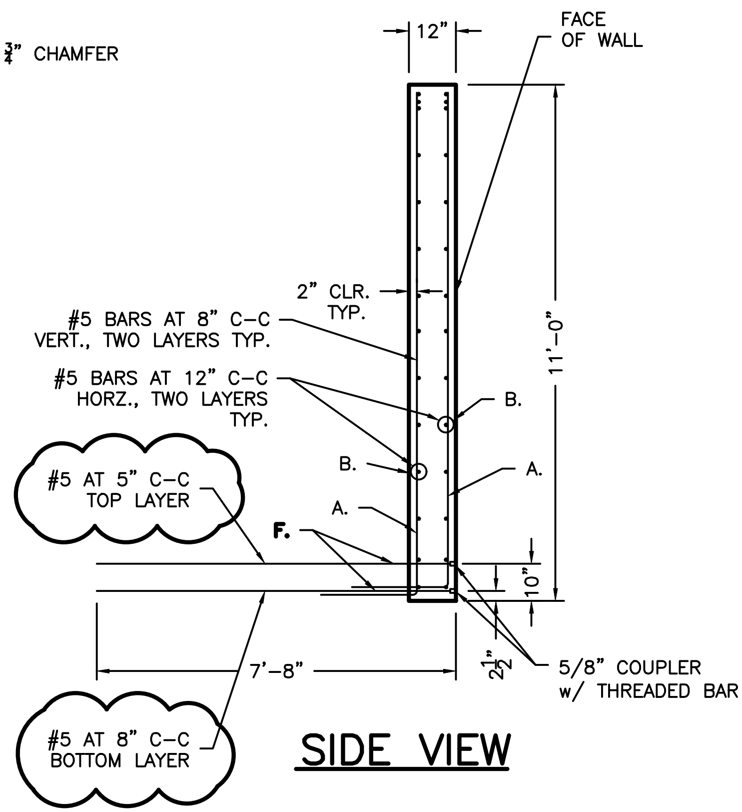
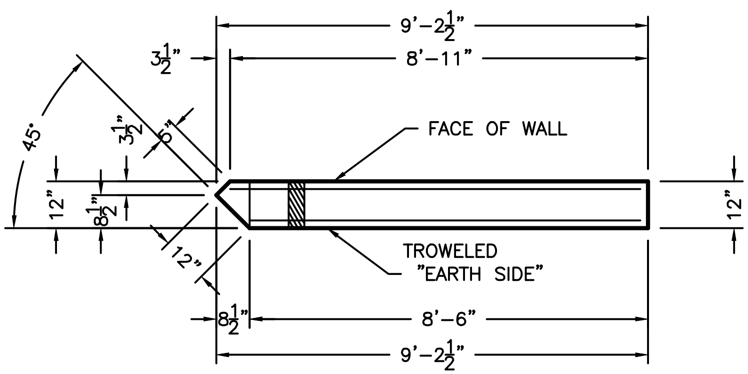


TOP VIEW



SIDE VIEW

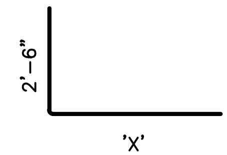


END VIEW

CUTTING LIST

ALL #5 GRADE 60 EPOXY COATED REBAR

	'X'
A1. 4 RODS, #5 X 10'–0"	7'–8"
A2. 4 RODS, #5 X 10'–6"	8'–2"
A3. 4 RODS, #5 X 10'–11"	8'–7"
A4. 4 RODS, #5 X 11'–5"	9'–1"
A5. 4 RODS, #5 X 11'–11"	9'–7"
A6. 4 RODS, #5 X 12'–4"	10'–0"
A7. 2 RODS, #5 X 12'–10"	10'–6"
A8. 2 RODS, #5 X 10'–8"	STRAIGHT



BOTTOM LAYER

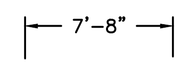
B. 8 RODS, #5 X 8'–4" – STRAIGHT
C. 1 RODS, #5 X 7'–11" – STRAIGHT
D. 1 RODS, #5 X 5'–1" – STRAIGHT
E. 1 RODS, #5 X 2'–3" – STRAIGHT

TOP LAYER

B. 8 RODS, #5 X 8'–9" – STRAIGHT
C. 1 RODS, #5 X 8'–4" – STRAIGHT
D. 1 RODS, #5 X 5'–6" – STRAIGHT
E. 1 RODS, #5 X 2'–8" – STRAIGHT

F. 4 ROD, #5 X 8'–10" – STRAIGHT

G. 33 RODS, #5 X 7'–8" – STRAIGHT
BAR WITH 5/8" COUPLER



POUR ON SMOOTH SURFACE

2" PLASTIC BAR CHAIRS
CHCU X 5 1/2" SPACERS

3.16 YDS. 5000 PSI
(4) 20 TON SWIFT LIFTS

JOB: LAKE MEDINA
JOB# CV41388
CUST: MARKS CONSTRUCTION

WINGWALL C, FIRST POUR

LAKE MEDINA, 12' X 5' CULVERT

DRAWN BY: AJK	SCALE: XXX	DRAWING NO.:
DATE: 7/22/20	REV:	CV4138812X5WW

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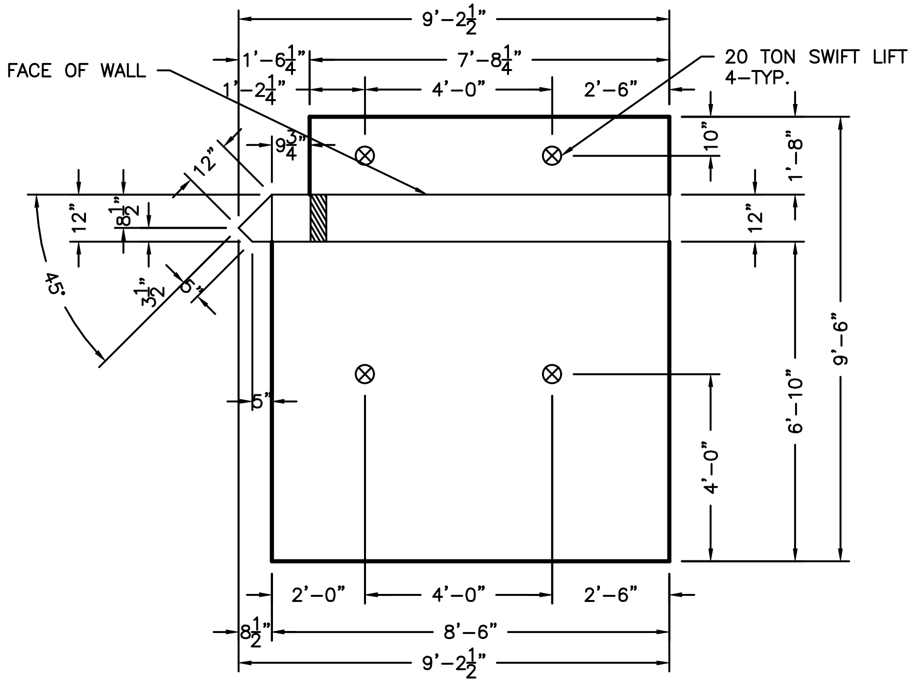


TOP VIEW

CUTTING LIST

ALL TO BE EPOXY COATED

H. 6 RODS, #5 X 7'-4" - STRAIGHT

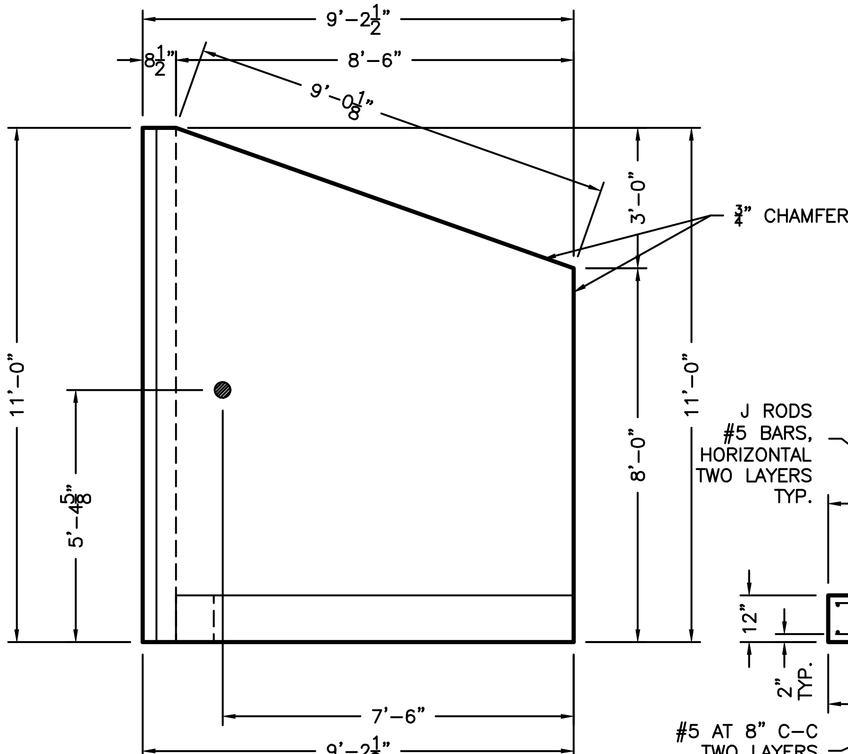
J. 16 RODS, #5 X 8'-2" - STRAIGHT

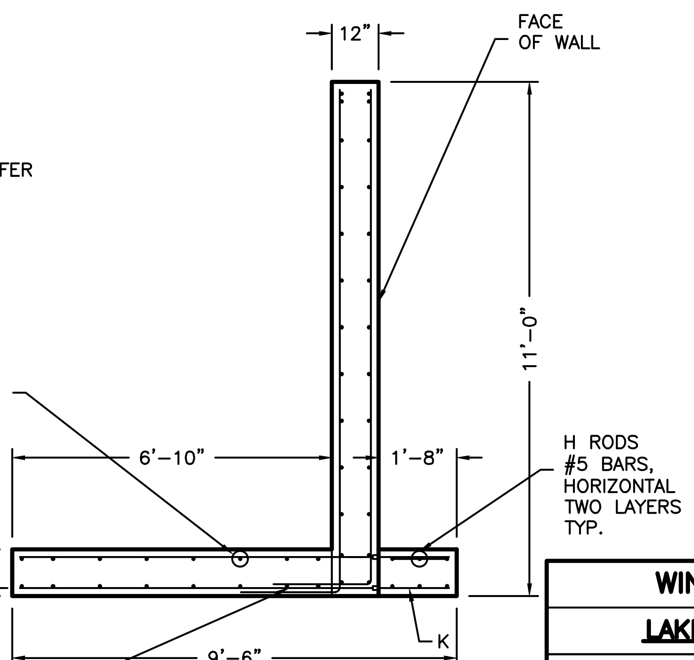
K. 30 RODS, #5 X 1'-6" - STRAIGHT, THREADED ONE END

2" PLASTIC BAR CHAIRS
CHCU X 5 1/2" SPACERS

2.13 YDS. 5000 PSI - SECOND POUR
(4) 20 TON SWIFT LIFTS

JOB: LAKE MEDINA
JOB# CV41388
CUST: MARKS CONSTRUCTION





SIDE VIEW

WINGWALL C, SECOND POUR		
LAKE MEDINA, 12' X 5' CULVERT		
DRAWN BY: AJK	SCALE: XXX	DRAWING NO.:
DATE: 7/22/20	REV:	CV4138812X5WW

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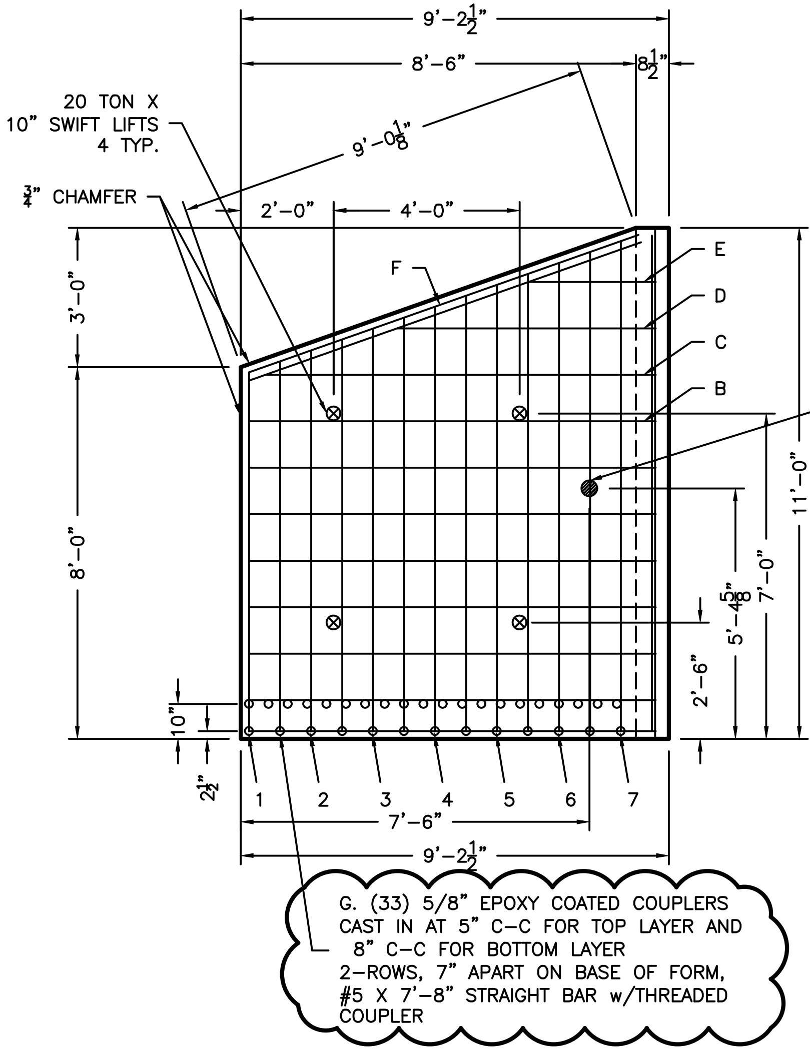
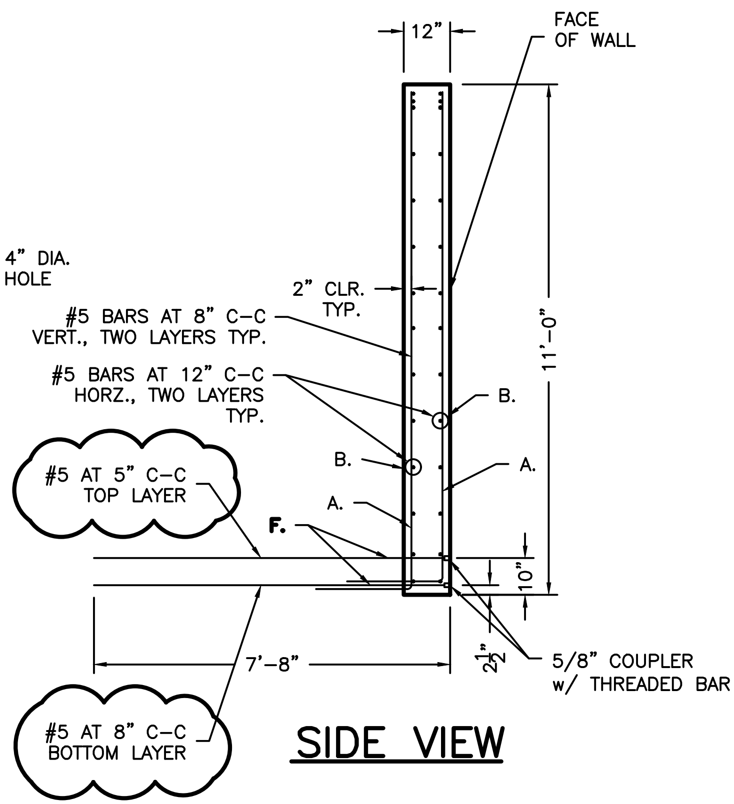
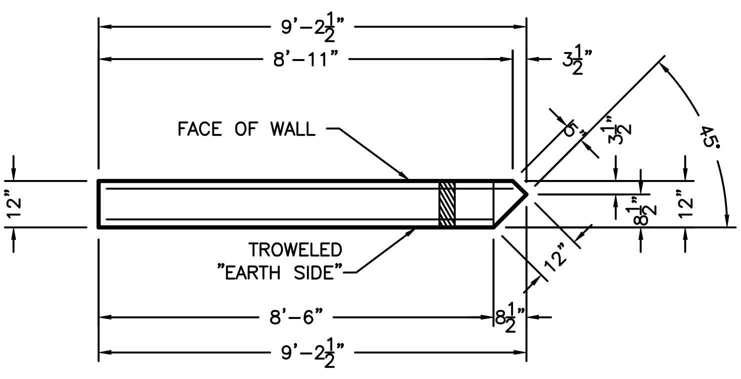


TOP VIEW



SIDE VIEW

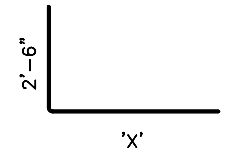


END VIEW

CUTTING LIST

ALL #5 GRADE 60 EPOXY COATED REBAR

	'X'
A1. 4 RODS, #5 X 10'-0"	7'-8"
A2. 4 RODS, #5 X 10'-6"	8'-2"
A3. 4 RODS, #5 X 10'-11"	8'-7"
A4. 4 RODS, #5 X 11'-5"	9'-1"
A5. 4 RODS, #5 X 11'-11"	9'-7"
A6. 4 RODS, #5 X 12'-4"	10'-0"
A7. 2 RODS, #5 X 12'-10"	10'-6"
A8. 2 RODS, #5 X 10'-8" STRAIGHT	



BOTTOM LAYER

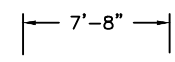
B. 8 RODS, #5 X 8'-4" – STRAIGHT
C. 1 RODS, #5 X 7'-11" – STRAIGHT
D. 1 RODS, #5 X 5'-1" – STRAIGHT
E. 1 RODS, #5 X 2'-3" – STRAIGHT

TOP LAYER

B. 8 RODS, #5 X 8'-9" – STRAIGHT
C. 1 RODS, #5 X 8'-4" – STRAIGHT
D. 1 RODS, #5 X 5'-6" – STRAIGHT
E. 1 RODS, #5 X 2'-8" – STRAIGHT

F. 4 ROD, #5 X 8'-10" – STRAIGHT

G. 33 RODS, #5 X 7'-8" – STRAIGHT BAR WITH 5/8" COUPLER



POUR ON SMOOTH SURFACE

2" PLASTIC BAR CHAIRS
CHCU X 5 1/2" SPACERS

3.16 YDS. 5000 PSI
(4) 20 TON SWIFT LIFTS

JOB: LAKE MEDINA
JOB# CV41388
CUST: MARKS CONSTRUCTION

WINGWALL D, FIRST POUR		
LAKE MEDINA, 12' X 5' CULVERT		
DRAWN BY: AJK	SCALE: XXX	DRAWING NO.:
DATE: 7/22/20	REV:	CV4138812X5WW

MACK INDUSTRIES, INC.
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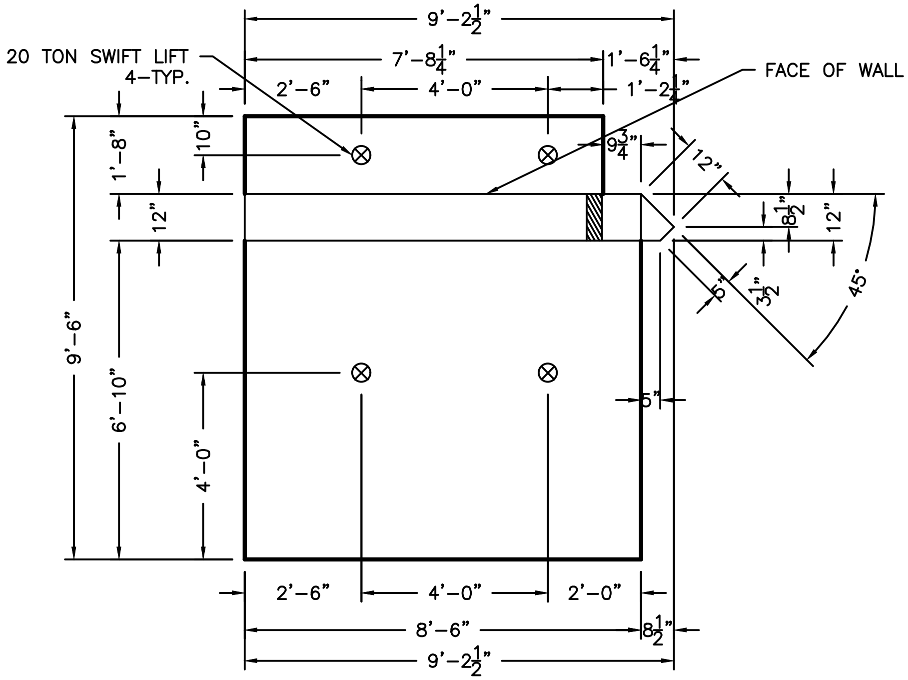
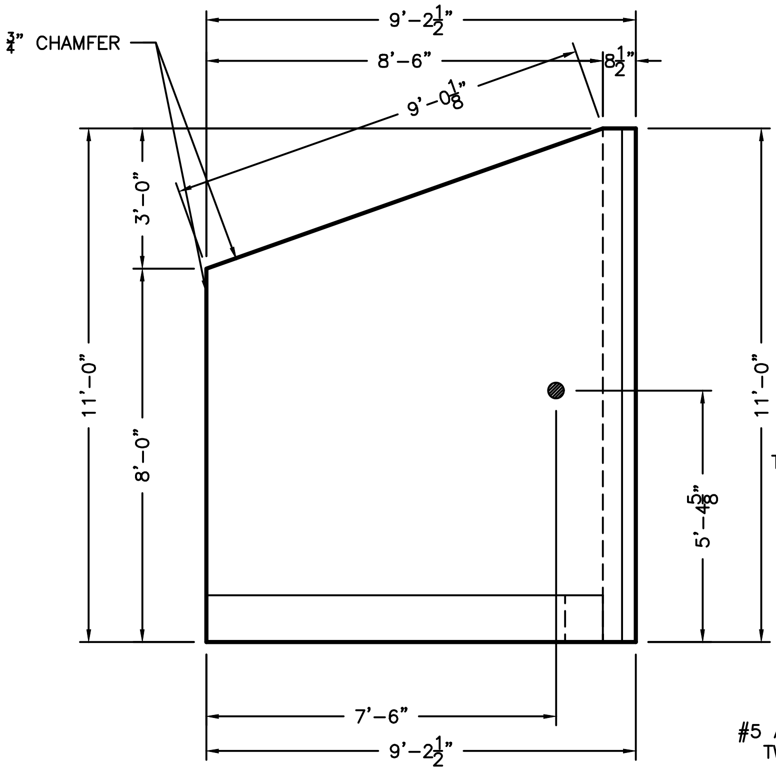
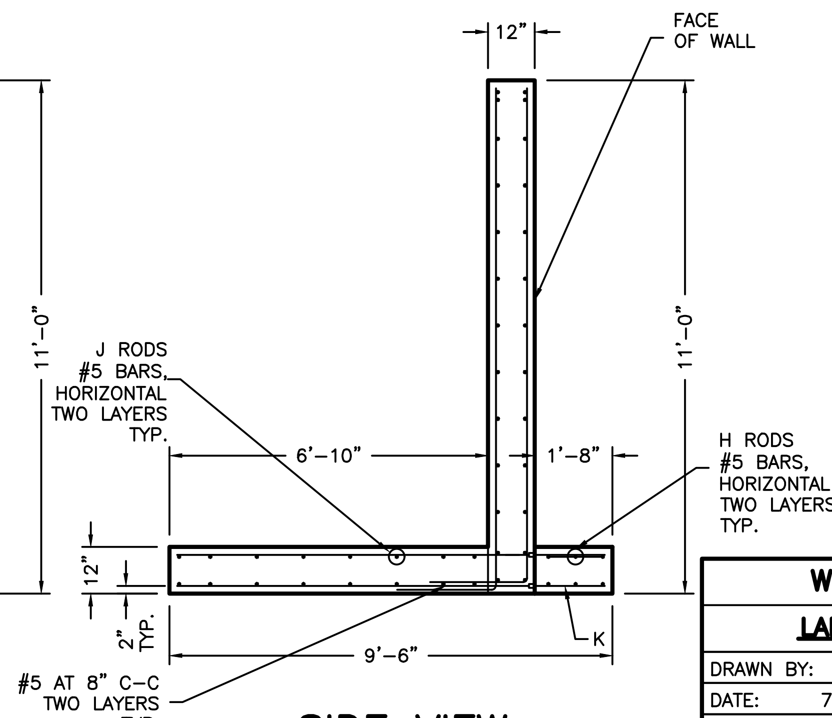


TOP VIEW





SIDE VIEW

CUTTING LIST

ALL TO BE EPOXY COATED

H. 6 RODS, #5 X 7'–4" – STRAIGHT

J. 16 RODS, #5 X 8'–2" – STRAIGHT

K. 30 RODS, #5 X 1'–6" – STRAIGHT, THREADED ONE END

2" PLASTIC BAR CHAIRS
CHCU X 5 1/2" SPACERS

2.13 YDS. 5000 PSI – SECOND POUR
(4) 20 TON SWIFT LIFTS

JOB: LAKE MEDINA
JOB# CV41388
CUST: MARKS CONSTRUCTION

WINGWALL D, SECOND POUR		
LAKE MEDINA, 12' X 5' CULVERT		
DRAWN BY: AJK	SCALE: XXX	DRAWING NO.:
DATE: 7/22/20	REV:	CV4138812X5WW

MACK INDUSTRIES, INC.

201 COLUMBIA ROAD, VALLEY CITY, OHIO 44280 (330) 483–3111

Item K: Sample Set of Design Calculations

See Section 2.4 of Attachment I.

Item L: Experimental Field and Laboratory Test Data

Not applicable to PRWS.

Item M: PRWS Design Requirements

- The Minimum Distance from The Top of The Stream Bed to The Bottom of The Footings Shall Meet Frost Depth.
- Precast Concrete Compressive Strength Shall Be A Minimum Of 5,000 psi At 28 Days
- Prior To The Placement of The Precast Wingwalls And Foundations, A Geotechnical Engineer Should Evaluate Foundation Excavations to Verify That an Adequate Bearing Material Is Present Prior To Precast Structure Placement.
- Wingwalls Shall Be Supported by A Minimum 12" Granular Base Compacted To 98% of the Standard Proctor (ASTM D698) Maximum Dry Laboratory Density.
- Bring Backfill Up Evenly on Both Sides of Wingwalls With No More Than A 1’-0” Differential in Elevation Until the Design Toe Backfill Elevation Is Reached.

Item N: Design Drawings and Structural Design Calculations

See Section 2.4 of Attachment I.

Item O: Recommend Construction Specifications

The PRWS shall meet the construction requirements of the following specifications. No revisions to the specifications have been made for this PRWS.

- AASHTO LRFD Bridge Design Specifications, latest edition with interims
- ODOT Construction and Materials Specification, latest edition
- ODOT Construction Manual of Procedures, latest edition

Item P: Design Exceptions

See Section 2.3 of Attachment I.

Item Q: PRWS Limitations

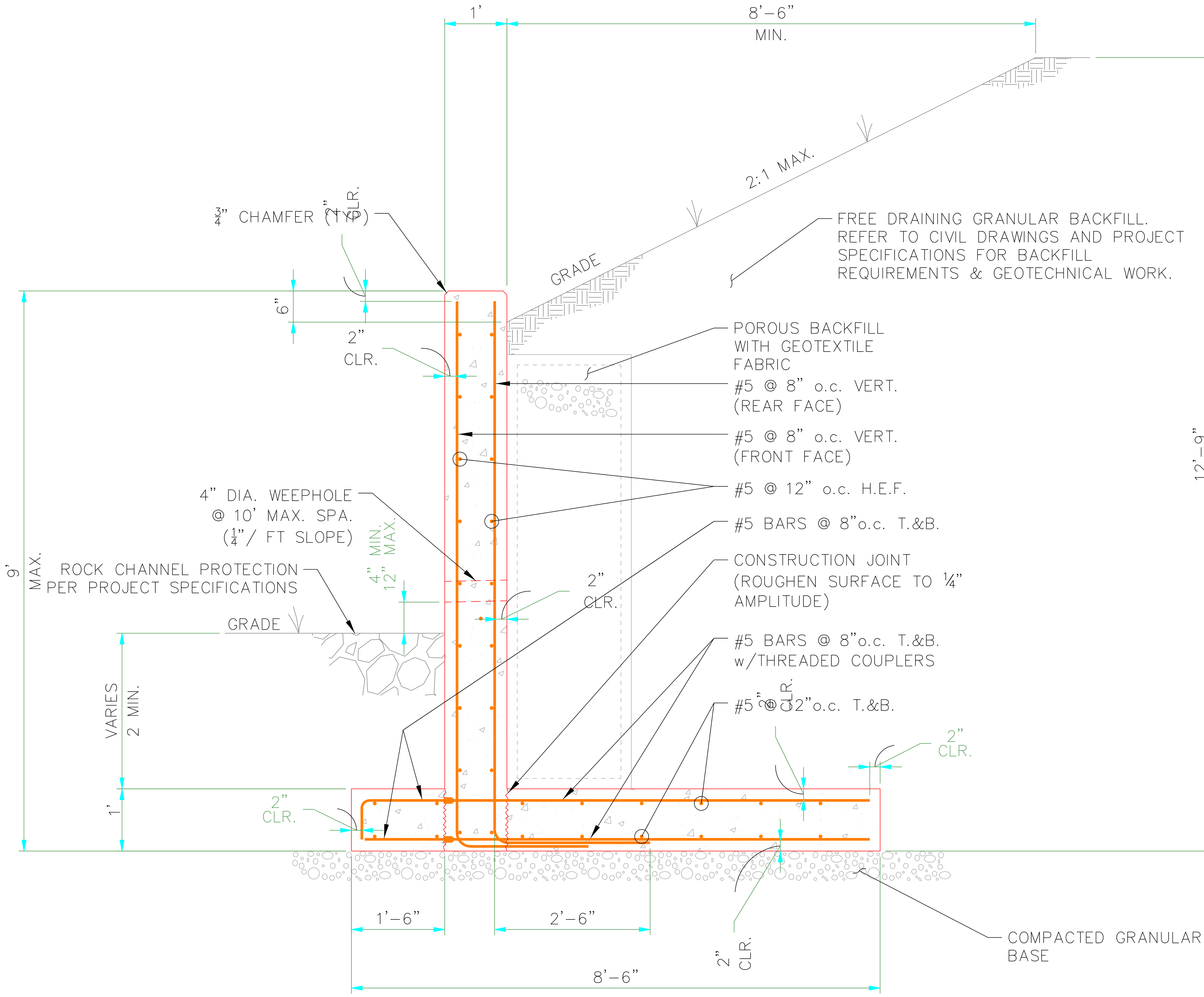
See Section 2.5 of Attachment I.

Section R: Frame Connections Utilized to Avoid Obstructions

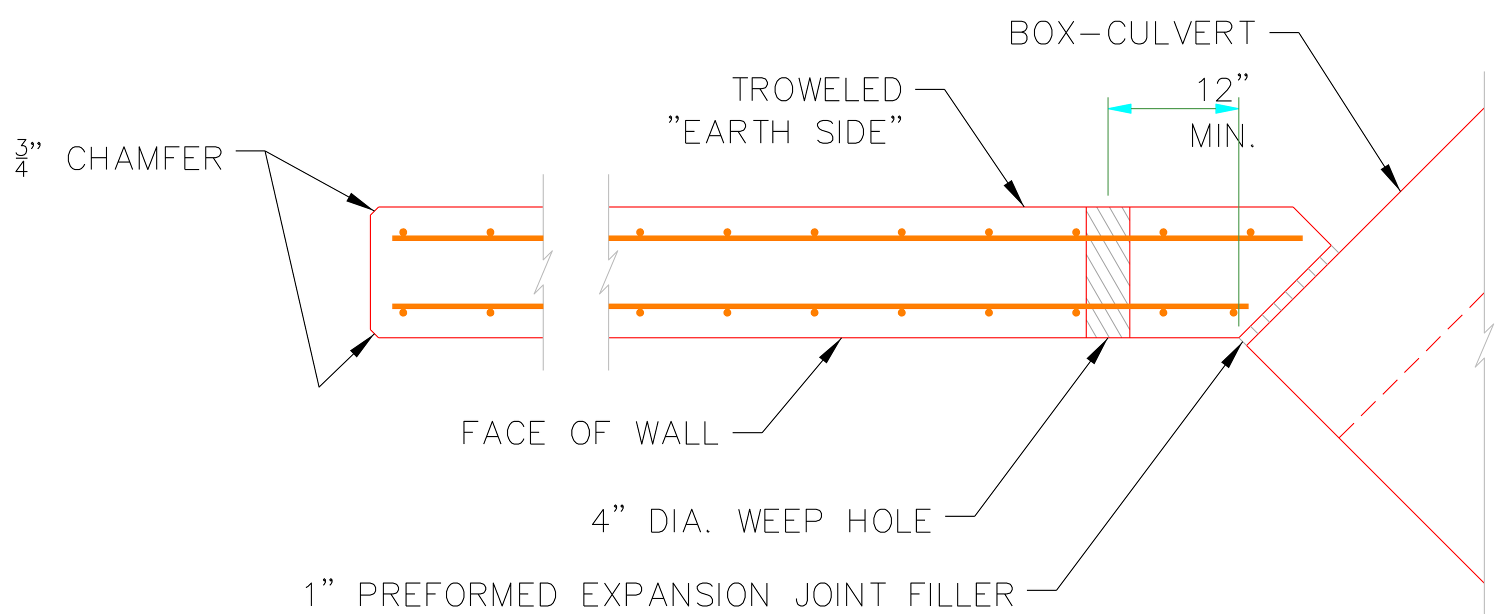
Not applicable to PRWS.

Section S: Repair Methods

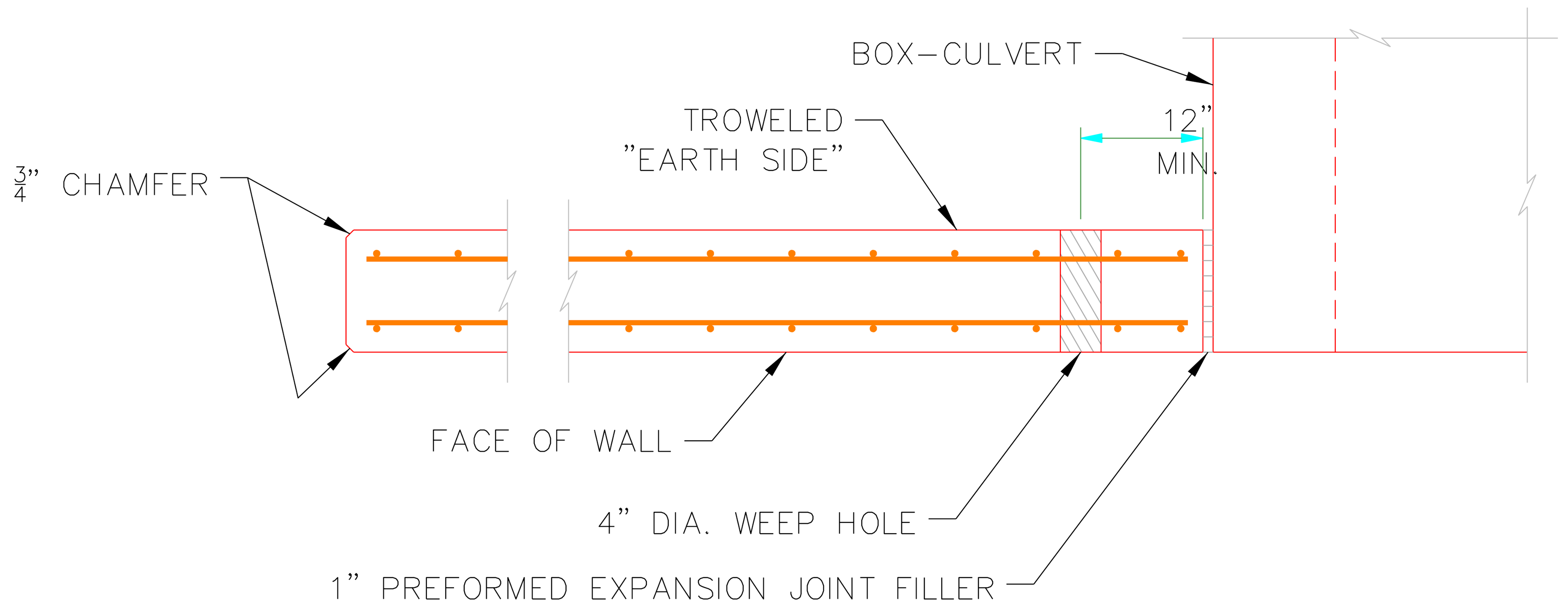
See Section 5.7 of Attachment I.



WINGWALL SECTION

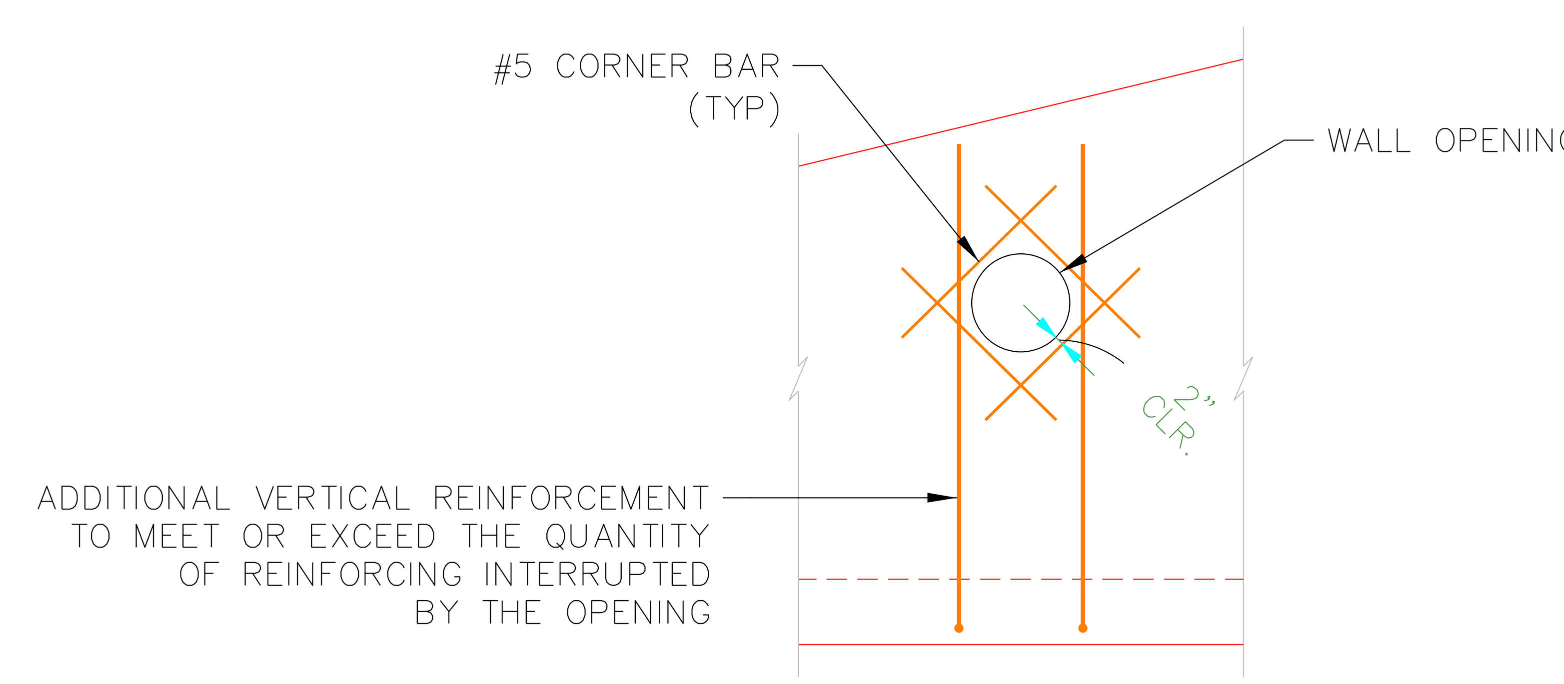


SKEWED WINGWALL



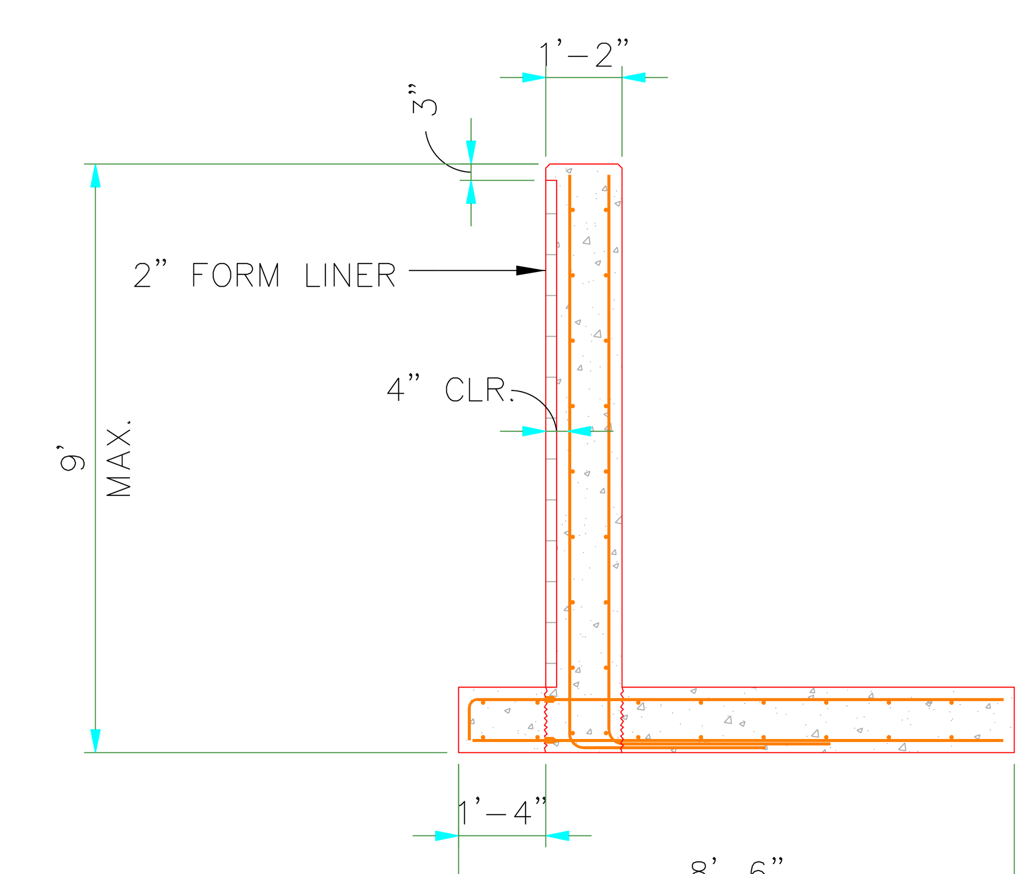
PARALLEL WINGWALL

END OF WALL DETAIL



WALL OPENING REINFORCEMENT DETAIL

(FOR OPENINGS GREATER THAN 6")



OPTIONAL FACE FINISH DETAIL

DESIGN AGENCY
OHLIN & REED, INC.
STRUCTURAL DESIGN CONSULTANTS

REVIEWED JJS | DATE 11/12/20
STRUCTURE FILE NUMBER XXX
DRAWN JMW | REVISED XXX
DESIGNED JMW | CHECKED JJS

STRUCTURAL DETAILS

ODOT PREFABRICATED RETAINING WALL SYSTEMS APPROVAL PROCESS

####

PID No. #####

1 / 1

X
X

DESIGN AND CONSTRUCTION SPECIFICATIONS

Department of Transportation

Ohlin & Reed
STRUCTURAL DESIGN CONSULTANTS
February 8, 2021 JOHN P. REED, P.E.

Christopher Merklin
Office of Geotechnical Engineering
Attn: Dorothy Adams
Ohio Department of Transportation
Mail Stop 5090
1980 West Broad Street 3rd Floor
Columbus, OH 43223

Subject: Precast "T" Wingwall

Dear Ms. Adams,

The submittal herein contains the technical portion of the subject Prefabricated Retaining Wall System (PRWS) for inclusion on the Ohio Department of Transportation (ODOT) Approved Product List (APL). Ohlin & Reed, Structural Design Consultants, will be the engineering firm performing the design calculations and preparing the structural drawings for the PRWS as a representative of Mack Industries, the ODOT certified precast concrete fabricator that will be supplying the PRWS.

The design is for a semigravity retaining wall consisting of a conventionally reinforced precast stem and spread footing placed on a well-compacted granular base. Figure 1 illustrates the PRWS for this submittal.

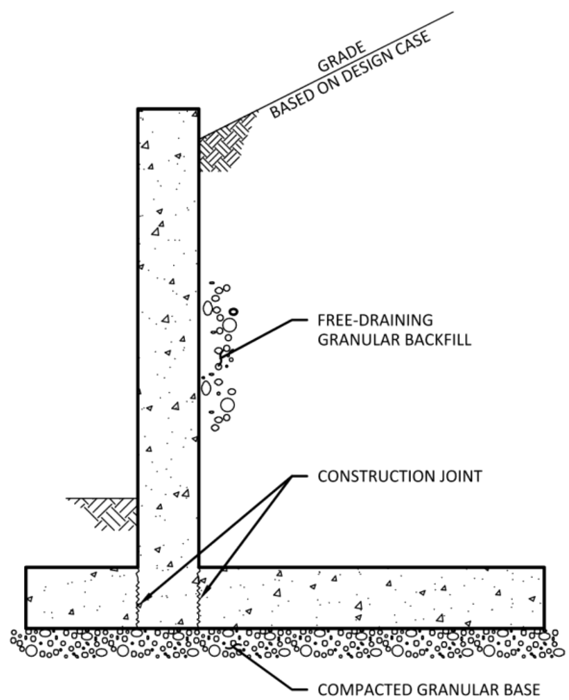


Figure 1: Geometry of prefabricated retaining wall system

The designer, preparer and checker for this submittal are listed in the table below:

	Name	Initials
Designer	Joshua Weaver, PE	JMW
Preparer	Joshua Weaver, PE	JMW
Checker	Jason Sues, PE	JJS
	John Reed, PE	JPR

Please call if you have any questions or need further information.

Submitted by:

John P. Reed, P.E.
Ohlin & Reed, Inc.

Attachment I

Submittal Requirements for
Approval of
Precast Gravity and Semigravity
Retaining Wall Systems

TABLE OF CONTENTS

1.0 SYSTEM

1.1 Description of System and Components

The Prefabricated Retaining Wall System (PRWS) herein is a semigravity retaining wall consisting of a conventionally reinforced precast stem and spread footing placed on a well-compacted granular base. Figure 1 illustrates the PRWS for this submittal.

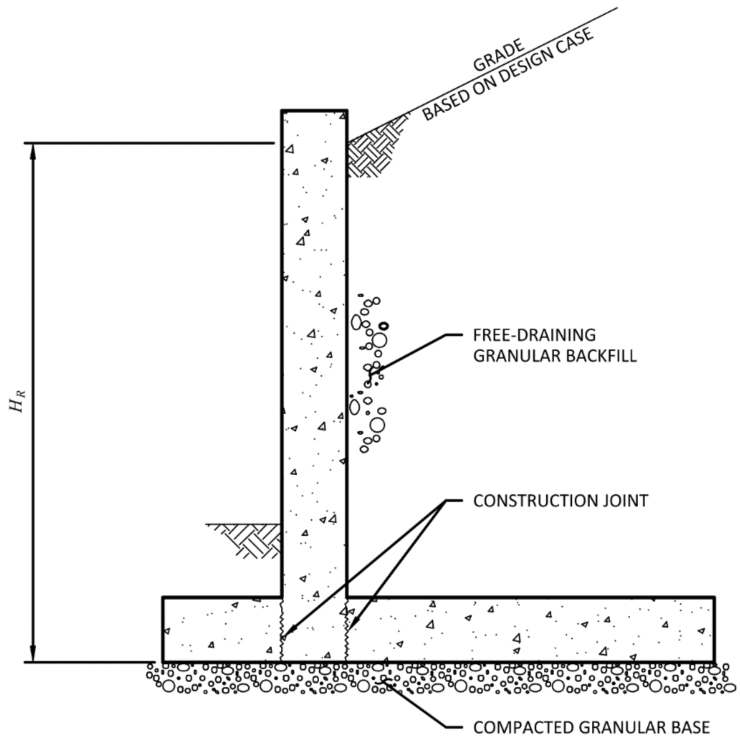


Figure 1: Geometry of prefabricated retaining wall system

The design of the PRWS will be influenced by project specific requirements for retained backfill and distance of the roadway from the wingwall. In the case of a breaking backfill, the break distance or roadway elevation and maximum slope of the backfill will be required. Nominal bearing strength of the on-site soil will also be considered in the design.

The material requirements for this PRWS are:

- Precast Concrete Compressive Strength: 5,000psi at 28 Days
- Reinforcing Steel: Epoxy Coated, 60ksi yield strength, and conforming to ASTM A615
- Foundation: Compacted granular base
- Backfill: Free-draining granular backfill conforming to project specifications

1.2 History, Performance, and Maintenance

This PRWS has been successfully used by Mack Industries, Inc. for over 15 years on box-culvert projects that require wingwalls. The design of this PRWS is of a traditional semigravity retaining wall. The use of a prefabricated keyway is not considered in the design due to constructability concerns.

The following figures are of a few projects that demonstrate the successful application of this PRWS for wingwalls.

Figure 2: Installed Wingwalls At Braun Rd.
PID No. MAD-TR232-1.02

Figure 3: Completed Wingwalls at Mack Industries Before Shipment

1.3 Ohio or other State Applications

The application of this PRWS for wingwalls has been successfully demonstrated on numerous ODOT and non-ODOT projects over the years. Non-ODOT projects include projects throughout Ohio as well as projects in Michigan, Pennsylvania, West Virginia, and Indiana.

Table 1 summarizes a few non-ODOT users, their contact information, and a list of projects where this system has been used.

Table 1: Non-ODOT Users

Company	Contact Name	Phone	Email	Projects
Kelly Brothers	Jim Kelly	(440) 653-3035	kellybrothers44035@hotmail.com	Mill Ridge CV40818
Haynes Const	Eric Gray	(419) 663-2457	eric@markhaynesconstruction.com	Bonnie Park CV41503
Hawbaker	Jon Martin	(330) 339-1212	jlm2@goh-inc.com	Cleveland Masslion Rd. CV40830
Digioia Sub	Mia Wagner	(440) 237-1978, x232	mia.wagner@digsubex.com	Shaker Blvd. CV40826
Park Construction	Tim Klingel	(740) 223-7275	tklingel@parkmail.com	Belfontaine Ave Marion County

1.4 System Warranties

Mack Industries, Inc. guarantees for 1 year, after the date of delivery, any work found to be defective and will promptly correct such defective work or remove and replace it with non-defective work. See Appendix 1 for a copy of the warranty statement for this PRWS.

1.5 Designated Responsible Parties

The responsible parties for the performance and details of this PRWS can be found below:

Table 2: Designated Responsible Parties

Feature	Responsible Party
System Performance	Mack Industries, Inc.
Material Performance	Mack Industries, Inc.
Design Details	Ohlin & Reed, Inc.
Construction Details	Mack Industries, Inc.

1.6 Insurance Coverage for Responsible Party

The following details the insurance coverage, limits, and basis for the responsible parties indicated in section 1.5. Certificates of insurance can be found in Appendix 2.

Table 3: Summary of Insurance Coverage

Insurance Type	Insured	Limits
Professional Liability	Ohlin & Reed, Inc.	$2,000,000/Occurrence
Commercial Liability	Mack Industries, Inc.	$2,000,000/Occurrence

2.0 DESIGN

2.1 Summary of Design Parameters and Design Approach

Design of the PRWS will be such to ensure stability against bearing capacity failure, overturning, and sliding. Strength and stability design of the PRWS will be in accordance with AASHTO LRFD and the ODOT BDM.

For external stability calculations, active pressure will be determined at a plane extending vertically from the heel of the wall base. The active pressure at the stem wall will also be determined and will be used for strength design of the wall. Any effects of offset or uniform surcharge load will be considered at both locations and will be calculated using Coulomb trial wedge analysis. Any passive earth pressure used to resist sliding will be calculated using Rankine Theory with a neglected height equal to the frost depth. Typical values for the design parameters of this PRWS are summarized in Table 4.

In order to determine the distribution of active pressure along the wall for complex loading conditions, a series of trial wedge analyses are conducted starting at the top of the wall and proceeding at depth increments to the bottom of the wall. The critical failure surface is determined at each depth to determine the lateral limiting force. The difference between the active force applied by the wedge and the wedge at the previous depth is used to calculate the average lateral earth pressure at each step (Hou, 2019).

Table 4: Design Parameters

Design Parameter	Design Value*	Description
Precast Wingwall		
Concrete Weight, γ_c	150 pcf	Unit weight of precast concrete
Compressive Strength, f'_c	5,000 psi	Concrete compressive strength at 28 Days
Reinforcing Steel, f_y	60,000 psi	Yield strength of epoxy coated rebar conforming to ASTM A615
Retained Soil		
Soil Unit Weight, γ	120 pcf	ODOT BDM Table 307-1
Internal Friction Angle, ϕ	30°	ODOT BDM Table 307-1
Cohesion, c	0 psf	ODOT BDM Table 307-1
Soil-Soil Interface Angle at End of Heel, δ_{ext}	0.67ϕ	ODOT BDM 307.1.1
Soil-Structure Interface Angle at Stem Wall, δ	0.5ϕ	ODOT BDM 307.1.1
Gradation of Backfill	2:1 Max.	Slope of backfill shall be determined based on project requirements and site plan
Foundation Soil		
External Friction Angle, δ	22°	AASHTO Table C3.11.5.3-1 Clean gravel, gravel-sand mixture, well-graded rock fill with spalls
Bearing Resistance, q_n	7,500 psf	Nominal Soil Bearing Resistance
Subgrade Reaction Modulus, k_s	100 pci	Modulus used for settlement calculations

* Design values indicated are presumptive and may vary based on project-specific information and requirements

2.2 Design Responsibility

Ohlin & Reed, Inc. is responsible for the project-specific design of this PRWS and is insured with professional liability insurance as detailed in Table 3 and Appendix 2. A copy of the quality control/quality assurance program for project designs can be found in Appendix 3.

Ohlin & Reed, Inc. will perform external stability and strength design calculations for the PRWS. Overall stability calculations are the responsibility of the engineer of record.

2.3 Summary of Design Procedures

The design of this PRWS is for a semigravity retaining wall as shown in Figure 1. The typical thickness of the stem and footing is 12" unless project specifications require otherwise. Project-specific information will be used to determine the geometry of the PRWS and calculations will be made to ensure external stability of the system. A complete strength design will be performed on the selected geometry and will be included with the stability calculations. A seismic design of this PRWS will not be performed as permitted by ODOT BDM 307.1.7 and AASHTO 11.5.4.2.

No design exceptions have been made to the requirements of the ODOT Design and Construction Specifications or the American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications.

2.4 Summary of Example Calculations

Appendix 5 contains an example set of calculations of this PRWS with the backfill matching design case 3 described in section 2.1 and design parameters listed in Table 4. The sample calculations include checks for bearing resistance, external stability (sliding, eccentricity and bearing) and strength design of the elements in the PRWS. The final page of the calculations includes a design drawing that is submitted along with the calculations.

2.5 Limitations

The following lists several design limitations for this PRWS:

- Face batter is not a feature of this PRWS and shall not be included
- Differential settlement of PRWS shall be limited to W/500 at the service level state
- Overall deflection of the stem wall shall be limited to H/120 at the service level state unless directed otherwise by the engineer of record
- See Figure 1 and Table 5 for limiting heights of the PRWS based on loading case. Design parameters indicated in Table 4 were used to determine the limiting heights.
- Impact/crash loads area not considered in the design

Table 5: PRWS Limiting Heights

Case	Limiting Retained Height 'H_R'[1]	
	No Surcharge	**250psf Surcharge[2]**
Level backfill	16'-0"	14'-6"
Backfill with an infinite 2:1 slope	--	--
Backfill with an infinite 4:1 slope	12'-6"	7'-6"
Backfill with a 2:1 slope that breaks to a level backfill at a distance equal to the design height of the stem wall	10'-6"	7'-6"
Backfill with a 4:1 slope that breaks to a level backfill at a distance equal to the design height of the stem wall	13'-6"	11'-0"

1. Limiting wall heights are based on presumptive values indicated in Table 4 minimum wall and footing thickness of 12in, and a maximum base width of 10'-0". Project-specific information and requirements will influence the maximum wall heights indicated.
2. For the breaking slope design cases, the 250psf surcharge load is applied to the flat portion of the backfill with a minimum 30psf surcharge applied to the sloping portion.

3.0 MATERIALS

3.1 Retaining Wall

The stem of this PRWS shall be at least 12" thick, have a 5,000 psi concrete compressive strength, and extend 6" beyond the retained backfill. Reinforcing will be grade 60 epoxy coated rebar and conform to ASTM A615. See Table 4 for a summary of the design parameters and values of this PRWS.

A textured finish for the front face of this PRWS may be specified. Architectural Polymers is the company that provides the stone patterns used by Mack Industries, Inc. and a variety of patterns are available for selection. The Small Aged Ashlar Stone #905 pattern is the most common pattern used. See Figure 4 for an example of a stone finish applied to the stem of a wingwall.

Figure 4: Wingwall With Stone Pattern

3.2 Retained Fill

The retained fill and design parameters shall be as indicated in the project specifications. If project documents do not provide design information for the retained soils, the guidance provided in BDM Table 307-1 will be used for design. Gradation of retained fill shall be per project documents. A maximum gradation of 2:1 may be used with this design. See Table 4 for a summary of the design parameters and values of this PRWS.

3.3 Wall Footing

The footing of this PRWS shall be at least 12” thick and have a minimum 5,000 psi concrete compressive strength. Reinforcing will be grade 60 epoxy coated rebar and conform to ASTM A615. See Table 4 for a summary of the design parameters and values of this PRWS.

3.4 Drainage Elements

Proper drainage of the PRWS shall be provided in accordance with project specifications. A porous backfill with geotextile fabric and weep holes must be provided in accordance with Item 518 of the Construction and Material Specifications (C&MS).

3.5 Traffic Railing / Barrier

The application of a traffic railing or barrier is not applicable to this PRWS.

3.6 Precast Connections to Appurtenances

The application of appurtenances to this PRWS as not a typical feature but shall be considered based upon project requirements.

3.7 Other Materials

A 1 inch thick preformed expansion joint filler is provided at the joint with the box culvert in accordance with C&MS Item 516.

3.8 Quality Control / Quality Assurance of Materials

A copy of the quality control/quality assurance of materials can be found in Appendix 4.

4.0 DETAILS

4.1 Standard Details

Standard details for this PRWS can be found in Appendix 6.

4.2 Example Details

Example details for this PRWS can be found in Appendix 6.

5.0 SPECIFICATIONS, CONSTRUCTION, AND MAINTENANCE

5.1 Fabrication of Precast Wall Units

Fabrication of this PRWS occurs in a controlled environment at Mack Industries. Typically, the cure time of the prefabricated concrete allows for forms to be removed after 24 hours. The sequence of construction for the PRWS is as follows:

1. Setup mold and reinforcing steel for stem wall
2. Pour concrete for stem wall
3. Finish and strip stem wall
4. Tilt stem wall to vertical orientation
5. Roughen construction joints to ¼" amplitude and clean
6. Setup mold and reinforcing steel for heel
7. Pour concrete for heel
8. Setup mold and reinforcing steel for toe
9. Pour concrete for toe
10. Finish and strip heel and toe
11. Ship to construction site

5.2 Field Construction Manual

The structural details sheet shown in the calculations provides a field construction sequence that is to be followed when constructing this PRWS. An example set of calculations can be found in Appendix 5.

5.3 Construction Specifications

The PRWS shall meet the construction requirements of the following specifications. No revisions to the specifications have been made for this PRWS.

- AASHTO LRFD Bridge Design Specifications, latest edition with interims
- ODOT Construction and Materials Specification, latest edition
- ODOT Construction Manual of Procedures, latest edition

5.4 Contractor or Subcontractor Prequalification Requirements

There are no specific prequalification requirements for contractors or subcontractors.

5.5 Quality Control / Quality Assurance of Construction

A copy of the quality control/quality assurance of construction can be found in Appendix 4.

5.6 Construction / In-Service Structure Problems

This PRWS has been usefully used on numerous projects and does not have a history of installation or in-service problems.

5.7 Maintenance

Periodic inspection should be made to ensure that scour has not removed cover on and in front of the toe of this PRWS. Any changes or deviations from the design conditions should be noted.

Repair of the PRWS shall be determined on a case-by-case basis as required by the type and extent of damage incurred. Standard concrete repair methods will be used. There has not been a history of repairs on this PRWS for projects that have followed project requirements and design conditions.

REFERENCES

AASHTO LRFD Bridge Design Specifications (2020). Washington, D.C. :American Association of State Highway and Transportation Officials.

ODOT Bridge Design Manual (2020), State of Ohio Department of Transportation

Hou, Guangxian & Shu, Shanzhi. (2019). Trial Wedge Approach to Determine Lateral Earth Pressures. International Journal of Geomechanics. 19. 06018035. 10.1061/(ASCE)GM.1943-5622.0001326.

APPENDIX 1: WARRANTY

MACK INDUSTRIES, INC.
201 COLUMBIA ROAD
VALLEY CITY, OHIO 44280
(330)483-3111 FAX: (330)483-3507
SERVICE EXTENSION 6106

WARRANTY

All concrete supplied by **MACK INDUSTRIES, INC.** carries a one (1) year warranty.

If within one year after the date of delivery or such longer as may be prescribed by laws or regulations any work found to be defective, Mack shall promptly, without cost to the owner, either correct such defective work, or, remove it from the site and replace it with non-defective work.

APPENDIX 2: INSURANCE CERTIFICATES

ACORD® CERTIFICATE OF LIABILITY INSURANCE

DATE (MM/DD/YYYY): 11/9/2020

THIS CERTIFICATE IS ISSUED AS A MATTER OF INFORMATION ONLY AND CONFERS NO RIGHTS UPON THE CERTIFICATE HOLDER. THIS CERTIFICATE DOES NOT AFFIRMATIVELY OR NEGATIVELY AMEND, EXTEND OR ALTER THE COVERAGE AFFORDED BY THE POLICIES BELOW. THIS CERTIFICATE OF INSURANCE DOES NOT CONSTITUTE A CONTRACT BETWEEN THE ISSUING INSURER(S), AUTHORIZED REPRESENTATIVE OR PRODUCER, AND THE CERTIFICATE HOLDER.

IMPORTANT: If the certificate holder is an ADDITIONAL INSURED, the policy(ies) must have ADDITIONAL INSURED provisions or be endorsed. If SUBROGATION IS WAIVED, subject to the terms and conditions of the policy, certain policies may require an endorsement. A statement on this certificate does not confer rights to the certificate holder in lieu of such endorsement(s).

PRODUCER
The James B. Oswald Company
1100 Superior Avenue, Suite 1500
Cleveland OH 44114

CONTACT NAME: Steven Galica
PHONE (A/C, No, Ext): 216-306-0047 | FAX (A/C, No): 216-839-2815
E-MAIL ADDRESS: sgalica@oswaldcompanies.com

INSURER(S) AFFORDING COVERAGE	NAIC #
INSURER A : Sentinel Insurance Company Ltd	11000
INSURER B :	
INSURER C :	
INSURER D :	
INSURER E :	
INSURER F :	

INSURED OHLIN-2
Ohlin & Reed Consulting Engineers, Inc.
525 N. Cleveland-Massillon Road
Suite 001
Akron OH 44333

COVERAGES **CERTIFICATE NUMBER:** 1586164655 **REVISION NUMBER:** 6-12-2013

THIS IS TO CERTIFY THAT THE POLICIES OF INSURANCE LISTED BELOW HAVE BEEN ISSUED TO THE INSURED NAMED ABOVE FOR THE POLICY PERIOD INDICATED. NOTWITHSTANDING ANY REQUIREMENT, TERM OR CONDITION OF ANY CONTRACT OR OTHER DOCUMENT WITH RESPECT TO WHICH THIS CERTIFICATE MAY BE ISSUED OR MAY PERTAIN, THE INSURANCE AFFORDED BY THE POLICIES DESCRIBED HEREIN IS SUBJECT TO ALL THE TERMS, EXCLUSIONS AND CONDITIONS OF SUCH POLICIES. LIMITS SHOWN MAY HAVE BEEN REDUCED BY PAID CLAIMS.

INSR LTR	TYPE OF INSURANCE	ADDL INSD	SUBR WVD	POLICY NUMBER	POLICY EFF (MM/DD/YYYY)	POLICY EXP (MM/DD/YYYY)	LIMITS	
A	X COMMERCIAL GENERAL LIABILITY	Y	Y	45 SBA NU7423 SA	7/9/2020	7/9/2021	EACH OCCURRENCE	$ 2,000,000
	CLAIMS-MADE [ ] OCCUR [X]						DAMAGE TO RENTED PREMISES (Ea occurrence)	$ 1,000,000
	X I Primary &						MED EXP (Any one person)	$ 10,000
	X Non-Contributory						PERSONAL & ADV INJURY	$ 2,000,000
	GEN'L AGGREGATE LIMIT APPLIES PER:						GENERAL AGGREGATE	$ 4,000,000
	POLICY [ ] PRO-JECT [X] LOC [X]						PRODUCTS - COMP/OP AGG	$ 4,000,000
	OTHER:							$
A	AUTOMOBILE LIABILITY	Y	Y	45 SBA NU7423 SA	7/9/2020	7/9/2021	COMBINED SINGLE LIMIT (Ea accident)	$ 2,000,000
	ANY AUTO						BODILY INJURY (Per person)	$
	OWNED AUTOS ONLY [ ] SCHEDULED AUTOS [ ]						BODILY INJURY (Per accident)	$
	X HIRED AUTOS ONLY; X NON-OWNED AUTOS ONLY						PROPERTY DAMAGE (Per accident)	$
	X AI Primary &							$
	UMBRELLA LIAB [ ] OCCUR						EACH OCCURRENCE	$
	EXCESS LIAB [ ] CLAIMS-MADE						AGGREGATE	$
	DED RETENTION $							$
A	WORKERS COMPENSATION AND EMPLOYERS' LIABILITY Y/N; ANYPROPRIETOR/PARTNER/EXECUTIVE OFFICER/MEMBER EXCLUDED? (Mandatory in NH) [ ]; If yes, describe under DESCRIPTION OF OPERATIONS below	N / A	Y	45 SBA NU7423 SA	7/9/2020	7/9/2021	PER STATUTE [X] OTH-ER	OH Stop Gap
							E.L. EACH ACCIDENT	$ 1,000,000
							E.L. DISEASE - EA EMPLOYEE	$ 1,000,000
							E.L. DISEASE - POLICY LIMIT	$ 1,000,000
A	Professional Liability Claims Made RetroDate:Full Prior Acts	N	Y	DPR9962674	7/9/2020	7/9/2021	Each Claim Aggregate Pollution & Envir.	$2,000,000 $4,000,000 Liab. Included

DESCRIPTION OF OPERATIONS / LOCATIONS / VEHICLES (ACORD 101, Additional Remarks Schedule, may be attached if more space is required)
Additional Insured and Waiver of Subrogation as designated above is provided when required of the Named Insured by written contract or agreement.

CERTIFICATE HOLDER

INFORMATION ONLY

CANCELLATION

SHOULD ANY OF THE ABOVE DESCRIBED POLICIES BE CANCELLED BEFORE THE EXPIRATION DATE THEREOF, NOTICE WILL BE DELIVERED IN ACCORDANCE WITH THE POLICY PROVISIONS.

AUTHORIZED REPRESENTATIVE
Steven Galica

CERTIFICATE OF LIABILITY INSURANCE

ACORD®

DATE (MM/DD/YYYY): 1/14/2021

THIS CERTIFICATE IS ISSUED AS A MATTER OF INFORMATION ONLY AND CONFERS NO RIGHTS UPON THE CERTIFICATE HOLDER. THIS CERTIFICATE DOES NOT AFFIRMATIVELY OR NEGATIVELY AMEND, EXTEND OR ALTER THE COVERAGE AFFORDED BY THE POLICIES BELOW. THIS CERTIFICATE OF INSURANCE DOES NOT CONSTITUTE A CONTRACT BETWEEN THE ISSUING INSURER(S), AUTHORIZED REPRESENTATIVE OR PRODUCER, AND THE CERTIFICATE HOLDER.

IMPORTANT: If the certificate holder is an ADDITIONAL INSURED, the policy(ies) must have ADDITIONAL INSURED provisions or be endorsed. If SUBROGATION IS WAIVED, subject to the terms and conditions of the policy, certain policies may require an endorsement. A statement on this certificate does not confer rights to the certificate holder in lieu of such endorsement(s).

PRODUCER
Hylant - Toledo
811 Madison Ave.
Toledo OH 43604

CONTACT NAME:
PHONE (A/C, No, Ext): 419-255-1020 **FAX (A/C, No):** 419-255-7557
E-MAIL ADDRESS: toledo_hmi@hylant.com

INSURER(S) AFFORDING COVERAGE	NAIC #
INSURER A : Travelers Prop Cas Co of Amer	25674
INSURER B : Cincinnati Specialty UW Ins Co	13037
INSURER C : National Fire & Marine Ins Co	20079
INSURER D : Charter Oak Fire Insurance Co	25615
INSURER E :	
INSURER F :	

INSURED DBMHOLD-01
DBM Holding Company
Mack Industries Inc.
1321 Industrial Parkway N - Suite 500
Brunswick OH 44212

COVERAGES **CERTIFICATE NUMBER:** 1925256245 **REVISION NUMBER:**

THIS IS TO CERTIFY THAT THE POLICIES OF INSURANCE LISTED BELOW HAVE BEEN ISSUED TO THE INSURED NAMED ABOVE FOR THE POLICY PERIOD INDICATED. NOTWITHSTANDING ANY REQUIREMENT, TERM OR CONDITION OF ANY CONTRACT OR OTHER DOCUMENT WITH RESPECT TO WHICH THIS CERTIFICATE MAY BE ISSUED OR MAY PERTAIN, THE INSURANCE AFFORDED BY THE POLICIES DESCRIBED HEREIN IS SUBJECT TO ALL THE TERMS, EXCLUSIONS AND CONDITIONS OF SUCH POLICIES. LIMITS SHOWN MAY HAVE BEEN REDUCED BY PAID CLAIMS.

INSR LTR	TYPE OF INSURANCE	ADDL INSD	SUBR WVD	POLICY NUMBER	POLICY EFF (MM/DD/YYYY)	POLICY EXP (MM/DD/YYYY)	LIMITS	
A	X COMMERCIAL GENERAL LIABILITY CLAIMS-MADE [ ] OCCUR [X] GEN'L AGGREGATE LIMIT APPLIES PER: [X] POLICY [X] PRO-JECT [ ] LOC OTHER:			TC2JGLSA475M094520	11/17/2020	11/17/2021	EACH OCCURRENCE	$ 2,000,000
							DAMAGE TO RENTED PREMISES (Ea occurrence)	$ 100,000
							MED EXP (Any one person)	$ 5,000
							PERSONAL & ADV INJURY	$ 2,000,000
							GENERAL AGGREGATE	$ 4,000,000
							PRODUCTS - COMP/OP AGG	$ 4,000,000
								$
A	AUTOMOBILE LIABILITY [X] ANY AUTO [ ] OWNED AUTOS ONLY [ ] SCHEDULED AUTOS [X] HIRED AUTOS ONLY [X] NON-OWNED AUTOS ONLY			TC2JCAP475M029920	11/17/2020	11/17/2021	COMBINED SINGLE LIMIT (Ea accident)	$ 2,000,000
							BODILY INJURY (Per person)	$
							BODILY INJURY (Per accident)	$
							PROPERTY DAMAGE (Per accident)	$
								$
C	[X] UMBRELLA LIAB [X] OCCUR [ ] EXCESS LIAB [ ] CLAIMS-MADE DED [X] RETENTION $ 25,000			42UMO30310705	11/17/2020	11/17/2021	EACH OCCURRENCE	$ 4,000,000
							AGGREGATE	$ 4,000,000
								$
D	WORKERS COMPENSATION AND EMPLOYERS' LIABILITY Y / N ANYPROPRIETOR/PARTNER/EXECUTIVE OFFICER/MEMBER EXCLUDED? (Mandatory in NH) [ ] If yes, describe under DESCRIPTION OF OPERATIONS below	N / A		UB0L3927212051H	11/17/2020	11/17/2021	[X] PER STATUTE [ ] OTH-ER	
							E.L. EACH ACCIDENT	$ 1,000,000
							E.L. DISEASE - EA EMPLOYEE	$ 1,000,000
							E.L. DISEASE - POLICY LIMIT	$ 1,000,000
B	Ohio Stop Gap			CSU0092470	11/17/2020	11/17/2021	$1,000,000/$1,000,000	/$1,000,000

DESCRIPTION OF OPERATIONS / LOCATIONS / VEHICLES (ACORD 101, Additional Remarks Schedule, may be attached if more space is required)

CERTIFICATE HOLDER

INFORMATION ONLY

CANCELLATION

SHOULD ANY OF THE ABOVE DESCRIBED POLICIES BE CANCELLED BEFORE THE EXPIRATION DATE THEREOF, NOTICE WILL BE DELIVERED IN ACCORDANCE WITH THE POLICY PROVISIONS.

AUTHORIZED REPRESENTATIVE

APPENDIX 3: QUALITY CONTROL/QUALITY ASSURANCE FOR PROJECT DESIGN

Ohlin & Reed, Inc. (O&R) Quality Control (QC)/Quality Assurance (QA) Program for Design of Mack Industries Prefabricated Retaining Wall Systems (PRWS)

1.0 Objectives and Overview

1.1 The QC/QA Program for PRWS shall be consistently followed on every PRWS project.

1.2 The primary objective of the QC/QA Program is to ensure that PRWS components and connections are designed and detailed correctly, efficiently, are constructible and that there are no errors or omissions in the design calculations or drawings.

1.3 The QC/QA Program is organized so that engineers involved in designing, preparing and checking of PRWS submittals are trained and prepared to systematically complete every task required of them and perform the highest quality of work.

1.4 The QC/QA Program defines the roles and coordination effort between all engineers involved in designing, preparing and checking calculations and drawings throughout the process of developing the submittal package.

1.5 The QC/QA Program outlines the frequency and methods of documenting QC activities and QA reviews.

2.0 Definitions

2.1 Quality Control (QC): refers to the design and drafting procedures that are put in place to control the quality and consistency of engineering methods and drawing development throughout the course of a PRWS project.

2.2 Quality Assurance (QA): refers to the review procedures that are put in place to certify that the calculations and drawings meet the established quality standards at strategic development points throughout the course of a PRWS project.

2.3 Designer: The engineer directly responsible for the development of the design calculations and drawings and for checking the shop drawings for conformance to the design calculations and drawings. The designer is responsible for QC. The designer must be an experienced engineer in performing design calculations for the PRWS and must be an Ohio registered professional engineer or working under the direct supervision of an Ohio registered professional engineer.

2.4 Preparer: The drafter responsible for the preparation of the drawings. The Preparer must be experienced in the preparation of the PRWS drawings and must be an Ohio registered professional engineer or working under the direct supervision of an Ohio registered professional engineer.

2.5 Checker: The engineer responsible for independently checking the design calculations and independently reviewing the drawings and performing a secondary review of the shop drawings. The Checker is responsible for QA. The Checker must be an Ohio registered professional engineer and preferably is more experienced than the Designer and Preparer in development of the submittal package for the PRWS.

2.6 Project Manager: The engineer that is responsible for managing the project and shall be either the Designer or preferably the Checker. The Project Manager should be the engineer with the most experience in development of the submittal package for the PRWS.

2.7 Contract Documents (CD): The set of legally binding construction documents that define the roles, responsibilities and work description for the project. Relevant CD include, but are not limited to Specifications, Drawings and Geotechnical Reports.

2.8 Submittal Package: The complete set of deliverable documents required to meet the demands of the CD. Typically includes, but is not limited to signed and sealed Design Calculations, Drawings & Shop Drawings.

3.0 Training

3.1 Prior to an engineer being involved as a Designer or Checker on a PRWS project, formal training shall be provided in the following areas:

3.1.1 QA/QC Program guidelines
3.1.2 Fundamentals of Reinforced Concrete Design
3.1.3 Design Codes (Ohio Building Code, AASHTO LRFD)
3.1.4 Use of Standard O&R Calculations for PRWS (MathCAD Program)
3.1.5 Standard O&R Drawings and Standard Mack Shop Drawings
3.1.6 Additional Design Resources (PCI Design Handbook, ACI Collection of Concrete Codes, Specifications and Practices; CRSI Design Guide for Cantilevered Retaining Walls)
3.1.7 Use of additional Retaining Wall Software Programs (RISA Foundation, Tedds, RetainPro)

4.0 Project Organization

4.1 The Project Manager shall take the lead on receiving the project documents at project start-up and identify who will be the Designer, the Preparer and the Checker. All project correspondence shall go through the Project Manager.

4.2 The Project Manager shall be responsible for developing and coordinating the project schedule and verifying that the project deadlines are met.

4.3 The Project Manager shall be responsible for creating and organizing the project file. The typical project file organization:

4.3.1 Checklists
4.3.2 Checker's Calculations
4.3.3 Contract Documents
4.3.4 Correspondence
4.3.5 Design Calculations
4.3.6 Drawings
4.3.7 O&R Redlines
4.3.8 QC/QA Records
4.3.9 Review Comments
4.3.10 Shop Drawings
4.3.11 Submitted Documents

4.4 File Naming Standards
  4.4.1 Folder Format: (Date YYYY-MM-DD) (Description)
  4.4.2 Document Format: (Proj #) (PRWS Document Type)
  4.4.3 Examples:
    4.4.3.1 Checklists => 2021-01-02 => 21001 T-Shaped Wingwall Design Checklist
    4.4.3.2 Contract Documents => 2020-12-01 => 21001 Geotechnical Report
    4.4.3.3 Design Calculations => 2021-01-03 => L-Shaped Headwall Design Calculations
    4.4.3.4 QC/QA Records => 2021-01-05 => T-Shaped Wingwall Drawing Details Design/Review Checklist

4.5 The Project Manager shall be responsible for thoroughly reviewing the CD at the start of the project and identifying project scope and which set(s) of standard calculations, standard details and design checklists are appropriate for the PRWS. The Project Manager shall also identify any errors or omissions in the CD and any deviations or conflicts between the CD and the O&R standard specifications, calculations or drawings.

4.6 If there are errors, omissions or conflicts in the CD, the Project Manager shall coordinate with Mack to get all issues resolved prior to approving the Designer to begin work.

4.7 The Project Manager shall initiate a start-up meeting with the Designer, Review & Checker to discuss schedule, CD, Design Criteria, applicability of standards and other concerns that could impact the QC/QA of the project.

5.0 Standards

5.1 All calculation and spreadsheet templates for use as company design standards are checked and verified by at least two independent engineers prior to becoming part of the company design library.

5.2 Equations and design methods in design standard calculations include references to the source design code.

5.3 All typical details for use as company drafting standards are reviewed by at least two independent engineers prior to becoming part of the company library.

5.4 Guides are developed for company design standards to aid engineers in finding and properly using calculation templates.

5.5 Comprehensive Codes, Specifications and References Index

5.6 PRWS Checklist Index for Design, Drawing and Review

5.7 All submittal documents, QC/QA Records must be signed and dated as appropriate by the Designer, Preparer and Checker.

6.0 Project Design

6.1 The Designer shall begin each project with the appropriate QC Checklists, documenting QC activities as they are completed.

6.2 The Designer shall thoroughly review the CD and verify that the project manager has correctly identified all of the appropriate PRWS standard calculations and details applicable to the project. The Designer shall notify the Project Manager of any change in scope or deviation from the standard calculations and details as soon as he/she discovers them throughout the course of project design.

6.3 The Designer shall follow the Design Guide for completing the standard design calculations. The Project Manager shall be notified immediately if there is a discrepancy between the Design Guide and the Design calculations.

6.4 All components and connections of the PRWS shall be included in the design calculations.

6.5 The Designer shall thoroughly review the completed calculations

6.6 The Designer shall sign the completed QC Checklist and shall deliver it to the Project manager with the completed calculations for Checking.

7.0 Drawing Preparation

7.1 The Preparer shall begin each project with the appropriate QC Checklists, documenting QC activities as they are completed.

7.2 The Preparer shall follow drafting standards and use standard details whenever possible. The Preparer shall notify the Project Manager of any discrepancies between the standard details and the drawings.

8.0 QA Review

8.1 The Checker shall begin each project with the appropriate QA Checklists, documenting QA activities as they are completed. The Checker shall sign the completed QA Checklist and shall file all QC/QA Record documents at the completion of the project.

8.2 The Project manager shall schedule periodic meetings to review the project status and the design direction. These meetings present an opportunity to discuss project schedule and unique features of the project.

8.3 QA Review check points: Project start-up, points where deviations or conflicts with standards arise, Completion of Calculations & Drawings, Backchecking prior to submittal, Shop Drawing Review. The design process should not advance to the next stage until the Checker has signed off on the QA for the previous stage.

8.4 Checker performs an independent hand calculation, run an independent design program and refer to resources for tabulated design tables to verify the accuracy of the calculations.

8.5 Checker performs an independent check to verify the drawings for completeness and conformance to the CD and O&R standards.

8.6 Checker backchecks redlines on calculations and drawings. Checker shall initial and date that redlines are picked up in the lower right corner of the document.

8.7 Designer and Checker sign checklists indicating that the QC/QA program was followed.

8.8 Project evaluation shall be performed after project completion to improve QC and to avoid repeating mistakes on subsequent projects. Job performance shall be evaluated to determine if more training is needed.

8.9 Project manager shall perform a constructability review with Mack Industries on any deviations from standard details.

8.10 Any disputes between the Designer, the Preparer and the Checker must be resolved to the Project Manger's satisfaction and shall be documented in the project file.

8.11 The Project Manager shall verify all QC Checklists, Redlines, calculations and drawings are completed, signed/initialed and filed at the completion of the project.

9.0 Project Delivery System

9.1 The project scope and schedule are clearly communicated to the Designer, Preparer and Checker at the beginning of the project.

9.2 A well-organized file, both hard copy and electronic, is maintained throughout the course of the project. The company standard for file organization is followed.

9.3 The Designer performs the calculations and sketches or redlines details for the Preparer.

9.4 The Preparer drafts the drawing details and returns redlines and the drafted details to the Designer (if a different person than the Preparer) for back-checking.

9.5 The Checker checks the calculations and delivers redlines to the Designer. The Designer shall update the calculations and returns the redlines and updated calculations to the Checker for back-checking.

9.6 The Checker reviews the drawings and delivers redlines to the Preparer. The Preparer updates the drawings and returns the redlines and updated drawings to the Checker for back-checking.

9.7 The design calculation and drawing package is sealed by the Checker and submitted to Mack Industries by the Project Manager once the submittal package is complete and the Designer, Preparer and Checker sign/initial all the appropriate QC/QA documents. The submittal package includes:

  9.7.1 Cover Sheet with Design Criteria

  9.7.2 Design Calculations

  9.7.3 Drawing Details

9.8 Once Shop Drawings are received, the Designer and the Reviewer review them for conformance to the design calculation and drawing package. If there are no comments, the Shop Drawings are sealed and returned to Mack Industries. If comments need to be addressed, the comments are returned to Mack Industries to be picked up and resubmitted. Once the resubmittal is received, the Shop Drawings are back-checked, sealed and returned to Mack Industries.

Ohlin & Reed

"T" WALL
PREFABRICATED RETAINING WALL SYSTEM
CALCAULTIONS
DESIGN/REVIEW CHECKLIST

Project Name:	
Project Number:	
Project Manager:	
Designer:	
Preparer:	
Checker:	

Acceptable?				**Checklist Review Number:**	1
	Yes	**No**	**N/A**	**Review Item**	**Comments**
Designer:	☐	☐	☐	**Overall Wall Height -** *Coordinate with MACK shop drawings and CD*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Retained Soil Height -** *Coordinate with CD Typically 6" below top of wall*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Fill Height Over Toe -** *Coordinate with CD and confirm that it meets local frost depth requirements (30" Typ.)*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Back Slope Run -** *Coordinate with CD grading plan. Review with project manager if greater than 2:1.*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**LL Surcharge -** *Coordinate with CD. Break distance (1' min.) and equivalent height (2' min.)*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Soil Properties -** *Coordinate with CD. If not provided, refer to Default Properties Guide.*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Precast Concrete Properties** *Typ. values: γ= 150 pcf, f'_c= 5,000 psi (6,500 Max.), f_y= 60 ksi*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Resistance Factors -** *Coordinate with CD & latest edition of AASHTO LRFD. (Typ. ϕ_b= 0.55, ϕ_T= 1.0, ϕ_{ep}=0.5)*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Load and Moment Tables -** *Check calculated and tabulated values*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Load Factors Table -** *Coordinate with latest edition of AASHTO LRFD*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**External Stability -** *Check eccentricity, bearing resistance, sliding, and settlement.*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Strength and Serviceability Design -** *Check flexure, shear, development of reinforcing, crack control and deflection.*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Construction Joint -** *Check that construction joint orientation matches calculation assumptions*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Summary Table -** *Check demand to capacity ratios match calculations and are < 1.0*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Cover Sheet -** *Summarize all applicable codes and design data utilized in the design. Note that the EOR is to verify design assumptions.*	
Checker:	☐	☐	☐		

Designer Signature:		**Date:**	
Checker Signature:		**Date:**	

Ohlin & Reed	"T" WALL PREFABRICATED RETAINING WALL SYSTEM DRAWING DETAILS DESIGN/REVIEW CHECKLIST	Project Name:	
		Project Number:	
		Project Manager:	
		Designer:	
		Preparer:	
		Checker:	

Acceptable?				Checklist Review Number:	1
	Yes	No	N/A	Review Item	Comments
Designer:	☐	☐	☐	**Overall Appearance -** *Drawn to scale & text size and line weights meet O&R Standards*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Stem Wall -** *All dimensions are shown and match design calculations*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Footing -** *All dimensions are shown and match design calculations*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Reinforcing Steel -** *All sizes and spaces are shown & size, spacing and layer orientation match design calculations*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Construction Joints -** *All joints are identified and surface roughening of 1/4" amplitutde is specified*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Concrete Cover -** *All clearances are shown and match the design calculations (2" TYP.)*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Chamfer -** *Chamfer at exposed edges is identified and matches CD (3/4" TYP.)*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Sub Base -** *Compacted granular base thickness is called out and matches CD*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Drainage -** *Soil Filter Fabric and free-draining granular backfill is noted and refers to Civil Drawings and Specifications*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Weep Holes -** *Weep holes are shown & size, spacing and slope indicated and match CD (4"⌀ @ 10'-0"o.c. TYP.)*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Backfill -** *Max. backfill height , max. slope, min. break distance and max. road height is shown and matches CD & design calculations*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Soil over Toe -** *Min. soil height over toe & slope shown. Rip Rap indicated and refers to Civil Drawings & Specifications*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Standard Details** - *Use standard details for end of wall, wall openings, and face finish as required.*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		

Designer Signature:		Date:	
Checker Signature:		Date:	

Ohlin & Reed	"T" WALL PREFABRICATED RETAINING WALL SYSTEM DRAWING NOTES DESIGN/REVIEW CHECKLIST	Project Name:	
		Project Number:	
		Project Manager:	
		Designer:	
		Preparer:	
		Checker:	

Acceptable?				Checklist Review Number:	1
	Yes	No	N/A	Review Item	Comments
Designer:	☐	☐	☐	*Wingwalls are noted "designed as free-standing and connections to box culvert are not required" & Calculations support this note*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*28 day compressive strength of concrete noted and coordinated with calculations? (5,000 psi TYP. and 6,500 psi MAX.)*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*Epoxy coating and steel yield strength of 60,000 psi is noted and coordinated with design calculations*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*Site and subgrade preparation is noted to refer to Specifications and CD & Soils report and date is referenced if available*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*Minimum 12" compacted granular base noted and not in conflict with CD*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*Note to bring backfill up evenly on both sides of wall until toe elevation is reached with 12" MAX. lifts*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*Local Frost Depth indicated and coordinated with CD and design calculations (3'-6" TYP.).*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*Retaining Wall Design Parameters (bearing pressure, friction angle) are indicated and are coordinated with design calculations*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*ODOT Specifications are referenced*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		

Designer Signature:		Date:	
Checker Signature:		Date:	

Ohlin & Reed	"T" WALL PREFABRICATED RETAINING WALL SYSTEM CONSTRUCTION DOCUMENTS DESIGN/REVIEW CHECKLIST	Project Name:	
		Project Number:	
		Project Manager:	
		Designer:	
		Preparer:	
		Checker:	

Acceptable?				Checklist Review Number:	1
	Yes	No	N/A	Review Item	Comments
Designer:	☐	☐	☐	*We have a complete set of readable CD, including a geotechnical report (if no geotechnical report, ask if available)*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*Site Grading Plan has sufficient information to determine the backfill slope and breaking distance*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*Retaining wall design parameters are provided (bearing capacity, soil friction angle, coefficient of friction)*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*Drawings and Geotechnical Report indicates shallow spread footings are acceptable (If no, meet with Project Manager to discuss)*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*No unique design codes specified other than ODOT Specifications and AASHTO LRFD (If yes, confirm we have the required documents)*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*No unique loading conditions such as adjacent building footings, heavy equipment, etc. (If yes, verify we have all the design information)*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	*No CD conflicts between drawings, specifications, geotechnical report (if yes, meet with Project Manager to discuss)*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		

Designer Signature:		Date:	
Checker Signature:		Date:	

Ohlin & Reed	"T" WALL PREFABRICATED RETAINING WALL SYSTEM SHOP DRAWINGS DESIGN/REVIEW CHECKLIST	Project Name:	
		Project Number:	
		Project Manager:	
		Designer:	
		Preparer:	
		Checker:	

Acceptable?				Checklist Review Number:	1
	Yes	No	N/A	Review Item	Comments
Designer:	☐	☐	☐	**Stem Wall** - *Thickness, dimensions and reinforcement match structural details.*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Footing** - *Thickness, dimensions and reinforcement match structural details.*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Backfill** - *Free draining granular backfill noted behind wingwall*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Wall Openings** - *Additional reinforcement around wall openings greater than 6" provided as indicated in structural details?*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐	**Misc. Details** - *Check that all applicable details indicated on the structural details sheet are incorporated in the shop drawings.*	
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
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Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		
Designer:	☐	☐	☐		
Checker:	☐	☐	☐		

Designer Signature:		Date:	
Checker Signature:		Date:	

PRWS Default Parameters Guide

Introduction

The soil properties for Prefabricated Retaining Wall Systems (PRWS) shall be coordinated with the Construction Documents (CD) for each project. If values are not provided in the CD, the following default values shall be used.

Soil Properties

Unit Weight

The default value for the unit weight for retained soil shall be γ = 120 lbs/ft^3. For ODOT projects, refer to ODOT BDM Table 307-1.

The value used for the unit weight of soil for toe cover shall consider the weight of rock channel protection. The default unit weight shall be γ = 120 lbs/ft^3. When determining the passive resistance, calculations shall use the buoyant weight of the soil in front of the toe: 120pcf – 62.4pcf = 57.6pcf.

Internal Friction Angle

The default value for the internal friction angle shall be ϕ = 30°. For ODOT projects, refer to ODOT BDM Table 307-1.

The incline of the active pressure loads on the retaining wall shall be the following:

$\delta = 0.67\phi$ for soil-on-soil (use for external stability of PRWS)

$\delta = 0.50\phi$ for soil-on-precast concrete (use for wall strength design)

The above values are in accordance with ODOT BDM 307.1.1.

External Friction Angle

The coefficient of friction shall be determined based on foundation soil and preparation. The friction angle between the foundation and precast concrete shall be determined using the guidance of AASHTO Table C3.11.5.3-1.

Precast footings for PRWS shall be placed on a minimum of 12” thick granular base, which will serve as a leveling pad as required by ODOT BDM 307.2.4.

Since a granular base is required for each PRWS, the default friction angle of δ = 22° shall be used. This is a minimum value for precast concrete interfacing with a clean gravel/ gravel-sand mixture per AASHTO Table C3.11.5.3-1. This results in a coefficient of friction of $\mu = \tan(\delta) = 0.40$.

Bearing Resistance

The nominal bearing resistance of the foundation soil shall be based on a default of q_n =7,500 psf unless indicated otherwise in the CD. This is similar to a 2,500psf allowable bearing pressure.

Subgrade Reaction Modulus

The minimum value for the subgrade reaction modulus used for the calculation of differential settlement shall be k_s = 100 pci.

Summary

Table 1: Default Design Parameters

Design Parameter	Design Value	Description
Precast Wingwall		
Concrete Weight, γ_c	150 pcf	Unit weight of precast concrete
Compressive Strength, f'_c	5,000 psi	Concrete compressive strength at 28 Days
Reinforcing Steel, f_y	60,000 psi	Yield strength of epoxy coated rebar conforming to ASTM A615
Retained Soil		
Soil Unit Weight, γ	120 pcf	ODOT BDM Table 307-1
Internal Friction Angle, ϕ	30°	ODOT BDM Table 307-1
Cohesion, c	0 psf	ODOT BDM Table 307-1
Soil-Soil Interface Angle at End of Heel, δ_{ext}	0.67ϕ	ODOT BDM 307.1.1
Soil-Structure Interface Angle at Stem Wall, δ	0.5ϕ	ODOT BDM 307.1.1
Gradation of Backfill	2:1 Max.	Slope of backfill shall be determined based on project requirements and site plan
Foundation Soil		
External Friction Angle, δ	22°	AASHTO Table C3.11.5.3-1 Clean gravel, gravel-sand mixture, well-graded rock fill with spalls
Bearing Resistance, q_n	7,500 psf	Nominal Soil Bearing Resistance
Subgrade Reaction Modulus, k_s	100 pci	Modulus used for settlement calculations

APPENDIX 4: QUALITY CONTROL/QUALITY ASSURANCE OF MATERIALS

MACK INDUSTRIES, INC.

Precast Concrete Products
Valley City, Ohio

Quality Control Program

MACK INDUSTRIES, INC.

Revised May 2020

QUALITY CONTROL PROGRAM
AND
PRODUCTION PRACTICES FOR
MACK INDUSTRIES, INC.
201 Columbia Road Valley City, Ohio 44280
Medina County
(Valley City) 330-483-3111

PLANT PERSONNEL

GENERAL MANAGER	TIM HAURY
QUALITY CONTROL	STEVE JESSEL MIKE DWYER TIM CLATTERBUCK JASON LUKE
NPCA CERTIFIED QC INSPECTOR	STEVE JESSEL TONY CRAWFORD JASON LUKE JOHN HAWLEY TIM CLATTERBUCK MIKE DWYER TIM PLUES
A.C.I. FIELD TESTING TECHNICIAN LEVEL I	STEVE JESSEL JASON LUKE TIM CLATTERBUCK JOHN HAWLEY MIKE DWYER
STRENGTH TESTING TECHNICIAN	STEVE JESSEL MIKE DWYER TIM CLATTERBUCK
SCC TESTING TECHNICIAN	STEVE JESSEL
PCI LEVEL I & II	MIKE DWYER

NPCA PLAQUE IS POSTED IN LOBBY.

It is the policy of Mack Industries to provide defect free products the first time, every time and to provide services to meet our customers' needs. The Mack Quality philosophy calls upon all employees to strive for continuous improvement in both process and product. We all set "zero defects" as the only acceptable goal for our level of performance. Each shift is staffed by a NPCA (Production and Quality School) and ACI (Field Testing Technician-Grade 1) certified QC Inspector. The QC inspector will be responsible for daily concrete testing, pre-pour inspections, post-pour inspections, and finished product inspections. The QC inspector will also be responsible for aggregate testing. The QC Inspector reports directly to plant management. Monthly department meetings are held, and quality concerns are addressed. Plant-wide quality meetings are held as needed when information not covered at department meetings needs to be discussed. Our safety committee meets every month and minutes of all meetings are kept on file.

CONCRETE BATCH FACILITY

Description of Batch Plant

The plant structure is manufactured by **Helco** and utilizes a spiral blade mixer for dry cast and a pan mixer for wet cast. Batching is controlled by **PSI Command Data-Eagle** digital computer controlled batching system. The plant is stationary and capable of batching Two (2) cubic yards in a single drop on the wet cast side and one (1) cubic yard for dry cast.

Material Storage Capacity

Cement	**150**	Ton Silo
	75	Ton Silo
	50	Ton indoor Storage
Fly Ash	**38**	Ton Silo
Coarse Aggregate #8	**1500**	Ground Storage
	75	Ton indoor storage
Coarse Aggregate #57	**1500**	Ton Ground Storage
	25	Ton Indoor Storage
Fine Aggregate	**3,500**	Ground Storage
	75	Ton Indoor Storage
Air Entrainer- Euclid Eucon Mac12	**1,500**	Gallons
Super Plasticizer – Euclid Plastol 6400	**1,500**	Gallons
Super Plasticizer – Euclid Plastol 6400	**1,500**	Gallons
Accelerator - Euclid Accelguard NCA	**1,500**	Gallons
Corrosion Inhibitor – Euclid Eucon CIA	**900**	Gallons
Retarder- Euclid Eucon Retarder 100	**600**	Gallons

All aggregates are stockpiled outside in bins with concrete pads to keep them clean and separated from contaminates. Coarse aggregates are kept moist by sprinklers during the summer months and all aggregates are steamed during the winter months. Steam is supplied to the aggregate hoppers by a low-pressure steam boiler.

Material Delivery to Plant

Cement – Received by truck pneumatically conveyed into a waterproof silo.

Fly Ash – Received by truck pneumatically conveyed into a waterproof silo.

Course Aggregate – Delivered by truck to ground storage. Moved by loader to ground hopper, and then loaded on conveyor belt to plant storage bin.

Fine Aggregate – Delivered by truck to ground storage. Moved by loader to ground hopper, and then loaded on conveyor belt to plant storage bin.

Euclid Air Mac12 – Pressurized feed (controlled by computer according to mix design).

Euclid Plastol 6400 – Pressurized feed (controlled by computer according to mix design).

Euclid Accelguard NCA– Pressurized feed (controlled by computer according to mix design).

Euclid Eucon CIA - Pressurized feed (controlled by computer according to mix design).

Euclid Eucon Retarder 100 - Pressurized feed (controlled by computer according to mix design).

Delivery to Weigh System

Cement – Gravity feed and auger delivery to weigh hopper.

Fly Ash – Delivered by screw auger to weigh hopper.

Coarse Aggregate – Gravity feed to weigh hopper from bin to mixer.

Fine Aggregate – Gravity feed to weigh hopper from in to mixer.

Eucon Air Mac12 – Pressurized feed – controlled by batch panel according to mix design.

Euclid Plastol 6400 – Pressurized feed – controlled by batch panel according to mix design.

Euclid Accelguard NCA – Pressurized feed – controlled by batch panel according to mix design.

Batching Operation

A Voler pan mixer (wet cast) with a two (2) cubic yard mix size capacity and a spiral blade mixer (dry cast) with a one (1) cubic yard mix size capacity is controlled by a fully automated Command Batch Data Digital Batching System. This operation utilizes automated moisture compensation for fine and coarse aggregate. Batch cycle time is 3 ½ minutes for wet cast and 3 ½ minutes for dry cast. Mixer components are periodically checked for cleanliness and wear and recorded.

Weighing of all materials is done by a scale platform where the mixer sits. Water/Cement ratio is not exceeded and posted in batch plant 0.45 for ODOT and NPCA, .47 for PENN DOT. Cement contents are stored in the batch computer this system is calibrated every time maintenance work is performed or at least once per year. Calibration is done by **Brechbuehler Scales Inc.** and results are kept on file in the Quality Control office.

Batching Sequence

Air entraining admixture (Air Mac12) is dispensed into the sand prior to discharge of the aggregate materials. Aggregates are then discharged into the stationary central mixer from the scaled weigh hopper. Coarse aggregate starts first then a combination of coarse aggregate and fine aggregate follows. Mixed aggregates flow into the mixer at a rate of 75 lbs. per second. Cementitious materials start dropping approximately 8 seconds after the aggregate and continue until total weighed cement has dropped into the mixer. Cement is discharged into the mixer at a rate of 50 lbs. per second. Water starts into the mixer 10 seconds after aggregate has been discharged, until full amount allocated in mix is discharged.

Batch Plant maintenance is performed by our maintenance crew under the supervision of our quality control manager. Any deficiencies are corrected. A major inspection of all batch plant areas is performed weekly and reports are kept in the quality control department.

Ready Mix Concrete

Ready Mix concrete will be utilized when production batch plant is down. Ready Mix concrete will be from an ODOT certified plant. Water added to Ready Mix will be documented on ticket. All Ready-Mix batch tickets will be kept in QC office.

TEST FACILITES & TEST METHODS

Test Facilities

Mack Industries Inc. Quality Control Lab is located centrally in the main production building (NO. 5).

Laboratory Equipment

1. Forney FT-40 Force 0-250,000 lbs. cylinder breaker.
2. Ohaus triple beam balance scale.
3. Forney cooker pot for capping cylinders.
4. Forney capping pedestal or stand.
5. Gilson #SP-2 Porta Splitter.
6. Humboldt Manufacturing Company sand sieve analyzer with Sieve No. 3/8"- #4 - #8 - #16 - #30 - #50 - #100 - #200 and pan.
7. Gilson stone sieve analyzer with Sieve No. 1 ½" – 1" – ¾" – ½" – 3/8" - #4 - #8 - #16 and pan.
8. Humboldt Manufacturing Company cooker oven.
9. A & D FG-30K 60 lb. Capacity digital scale.
10. Forney air pot meter (Type B).
11. Slump cone test set.

13. Steel 4x8
14. Humboldt steel yield bucket.
15. Concrete thermometer.
16. Assortment of pans, brushes, and cleaning tools.
17. Concrete Initial Set Penetrometer
18. J Ring Spread cone test set.

Material Testing Methods

Performed by Mack Industries Inc.

Aggregates	ASTM C33	"Specification for Concrete Aggregates"
Sampling	ASTM D75	"Standard Practice for Sampling Aggregates"
Gradation	ASTM C136	"Sieve Analysis for Fine & Course Aggregates"
Moisture	ASTM C566	"Total Moisture Content of Aggregate by Drying"

Performed by Supplier/ Manufacturer

Aggregates	ODOT approved aggregate test reports (Includes gradation & absorption)
Cement	Manufacturer(s) Certification
Fly Ash	Manufacturer(s) Certification

Concrete Testing Methods

Performed by Mack Industries Inc.

Slump	ASTM C-143	"Slump of Hydraulic Cement Concrete"
Air	ASTM C-231	
Temperature	ASTM C-1064	

Making and Curing Test Cylinders ASTM C-31

Yield Test	ASTM C-138
Slump flow VSI	ASTM C-1611
Absorption	ASTM C-497
J-ring	ASTM C-1621

Performed by Solar testing

Organic Impurities (Fine Aggregates)	ASTM C40-99
Absorption Test (Core Sample)	ASTM C-497

Copies of all results are kept on file in the Quality Control Office.

Sampling and Testing Frequency

All Sampling & Testing is done daily per shift and as directed per inspector and job specifications. Compression Tests are done on 1,7, and 28-day basis. Aggregate wash tests will be performed bi-weekly. Moisture tests will be done daily. Yield tests will also be done weekly. Aggregate gradation will be tested bi-weekly.

MATERIALS INFORMATION

Fine Aggregate (Natural Concrete Sand – ODOT Certified)

Source of Supply

Baker Sand, Inc.	**American Sand and Gravel**	**Lafarge**
7800 White Road	8188 Wales Avenue NW	9206 Price Road
Burbank, OH 44214	North Canton, Ohio 44720	Shalersville, Ohio 44266

Method of Transfer and Handling from Pit to Mixer

Fine Aggregate received by truck unloaded on a concrete pad ground storage. Transferred by loader to ground hopper then conveyed into storage bin, gravity fed to weigh hopper, weighed and discharged into mixer.

Fine Aggregate Sampling & Testing

Sampling location from the ground stock pile from three (3) different areas.

Sampling and testing frequency twice (2) per month. Certification on file from material supplier.

Deleterious material is tested monthly by wash test method ASTM C117.

Control Tolerance Percent Passing

SIEVE SIZE	ASTM LIMITS	CONTROL LIMITS
3/8	100	100
#4	95-100	97-100
#8	80-100	82-100
#16	50-85	53- 88
#30	25- 60	30- 55
#50	5- 30	8- 27
#100	0- 10	0- 8
F.M.	+/- .20	+/- .18

When graduation or fineness modules test result deviates from control limits of +/- 0.18 supplier will be notified by phone. Action taken will be recorded.

Testing frequency will be increased to one (1) sample per shipment until test results are within the control limits for three (3) consecutive tests.

Should test results deviate from ODOT limits, rejected material will not be used on ODOT projects.

Coarse Aggregate

Type and Source of Supply

Coarse Aggregate ODOT #8 & #57

American Sand and Gravel
8188 Wales Avenue NW
North Canton, Ohio 44720

Light Weight Gradations and Unit Weights are Maintained if Applicable.
This product is only used in MSE Walls.
Di Geronimo Aggregates LLC
8900 Hemlock Road.
Independence, Ohio 44131

Method of Transfer and Handling from Pit to Mixer

Coarse aggregate received by truck unloaded on a concrete pad ground storage with sprinkler system to maintain moisture. Transferred by front end loader to ground hopper then conveyed into storage bin, gravity fed into weigh hopper, weighed and discharged into mixer.

Course Aggregate Sampling & Testing
Sampling location from the above ground stockpile from three (3) different areas. Sample and testing frequency are twice (2) per month. certification on file from the material supplier. Deleterious material is tested monthly by wash test method.

When gradation tests reading deviates from control limits, supplier will be notified by phone. Action taken will be recorded.

Testing frequency will be increased to one (1) sample per shipment until test results are within the control limits for three (3) consecutive tests.

Test results that deviate from ODOT limits material will be rejected from use on ODOT projects and used on private commercial.

Control Tolerance Percent Passing

Sieve Size	ASTM Limits ODOT #8	Control Limits
1/2"	100	100
3/8"	85-100	87-100
#4	10-30	12-28
#8	0-10	0-8
#16	0-5	0-3

Method of Transfer and Handling from Pit to Mixer
Coarse aggregate received by truck unloaded on a concrete pad ground storage with sprinkler system to maintain moisture. Transferred by front end loader to ground hopper then conveyed into storage bin, gravity fed into weigh hopper, weighed and discharged into mixer.

Course Aggregate Sampling & Testing
Sampling location from the above ground stockpile from three (3) different areas. Sample and testing frequency is twice (2) per month. certification on file from the material supplier. Deleterious material is tested monthly by wash test method.

When gradation tests reading deviates from control limits, supplier will be notified by phone. Action taken will be recorded.

Testing frequency will be increased to one (1) sample per shipment until test results are within the control limits for three (3) consecutive tests.

Test results that deviate from ODOT limits material will be rejected from use on ODOT projects and used on private commercial.

Control Tolerance Percent Passing

Sieve Size	ASTM Limits ODOT #8	Control Limits
1 1/2"	100	100
1"	95-100	97-100
½"	25-60	29-56
#4	0-10	0-8
#8	0-5	0-3

Cement and Fly Ash

Cement Type I/II & III
All Cement and Flyash are ODOT Certified.

All Material meet specifications for their intended use.

Source & Type
Portland Type-I Cement (ASTM C-150 & AASHTO M-85)
Portland Type II Cement (ASTM C-150 & AASHTO M-85)
Portland Type-III Cement (ASTM C-150 & AASHTO M-85)
Class F & C Fly Ash (ASTM C-618 & AASHTO M-295)

Lehigh
301 Highway 31
Speed, IN 47172-1300
Pick up at Leetsdale, PA Terminal

Lafarge Corporation
Cleveland Terminal
2500 Elm Street
Cleveland, Ohio 44113

Holcim
15215 Day Road
Dundee, MI 48131

Headwaters Resources
4043 North Euclid
Bay City, Michigan 48706

FlyAsh Direct
4228 Airport Rd
Cincinnati, OH 45226

A certified mill analysis will accompany every shipment.

Method of Transport, Storage, Handling & Introduction into Mixer

Cement and Fly Ash will be delivered by truck tanker and pneumatically loaded into silo. Cement and Fly Ash are gravity fed into the weigh hopper, weighed, and discharged into the mixer. Cement is the first to be batched. Fly Ash is second. Water will not be discharged during the time cementitious material is added to the mixer. Water cement ratio is .45

Admixtures

Source and Type – Euclid Chemical
All Admixture's are ODOT Certified.

Eucon Air Mac12 (Air-Entraining ASTM C-260)
Air Mac12 is formulated for use as an air entraining admixture for concrete of all types and is manufactured under rigid control which assures uniform and precise performance. Air Mac12 adds microscopic air bubbles in concrete and is acceptable to use in all types of concrete. Air Mac12 does not contain added chlorides and will not promote the corrosion of steel.

Euclid Accelguard NCA (Accelerator ASTM C-494, TYPE C)
Accelguard NCA is a non-chloride, water reducing and accelerating admixture. Accelguard NCA contains no calcium chloride or any other intentionally added chlorides and will not initiate or promote the corrosion of steel members present

in the concrete. Accelguard NCA meets the interim requirements of ASTM C-494 types C and E, and AASHTO M194 types C and E.

Plastol 6400 (ASTM C-494, TYPES A&F)
Is a polycarboxylate based high range water-reducing admixture which enables concrete to be produced with very low water to cement ratios. Plastol 6400 produces flowable and self-consolidating concrete at low doses.

Self-compacting concrete (SCC) is a high-performance concrete characterized by its mobility, and ease at which it flows into place and self-consolidates under in its own weight. Concrete with these properties exhibits greater in place density, mechanical strength and durability. In addition to exhibiting high mobility, SCC is resistant to segregation of its constituent ingredients. Our initial mix qualification for SCC was developed according to ODOT S1073.

CNI (Corrosion Inhibitor ASTM C-494, TYPE C)
A liquid added to concrete during the batching process. It chemically inhibits the corrosive action of chlorides on reinforcing steel in concrete.

Eucon Retarder (Concrete Retarder ASTM C494, Type B&D)
Is a synthetically produced liquid water-reducing and set retarding admixture for concrete.

Method of Transport, Storage, Handling & Introduction into mixer

The admixtures are supplied and shipped by Euclid Chemical. The admixtures are transported to the plant in bulk liquid tanker trucks. The admixture is pumped to storage tanks.

During the batching operation, the admixtures are computer measured and discharged separately by a pressurized system into the mixer.

Euclid Chemical certifies admixtures measuring dispensers annually.
All admixtures are compatible with other component materials and will not be changed without retesting to total mix.

Water Source – City

We utilize our City water for batch water.

PROCESS CONTROL

Equipment Calibration

The batch plant scale, digital scales, admixture dispensers, air meters, and compression tester will all be calibrated annually or when results vary from expected values. All calibrations will be performed according to applicable ASTM standards.

Aggregate Moisture Testing

Location

Coarse and fine aggregate sampling shall be obtained for moisture test sampling from the storage locations.

Coarse Aggregate Method of Testing

Free moisture will be calculated based on the total dry method. Moisture will be checked daily.

Fine Aggregate Method Testing

Moisture shall be determined using a moisture probe, located before the weigh hopper. The accuracy of the probe and moisture tester will be checked weekly by the total dry method. Moisture will be checked daily.

Control Tolerance & Corrective Action

Whenever the results of additional test for free moisture vary more than ½ of one (1) percent, adjustments shall be made to attain the appropriate batch weights on the following batch. Maximum water/cement ratio is not exceeded and is .45 and is posted in the batch plant. The following are the batching tolerances.

Cement- -0,+4% for less than 1 yard. +/- 1% for over 1 yard. –0,+4% PENN DOT

Water- +- 1%. PENN DOT +2%

Fine aggr.- +-2%

Coarse aggr.- +-2%

Admixtures- +-3%

Slump Testing/ Slump Flow VSI Testing

Location

Slump, Slump flow, and VSI test specimen shall be made at the plant from samples obtained from the placement bucket at the batch plant staging area.

Frequency

Testing will be done daily in accordance with ASTM C-143. When pouring SCC, a slump flow and VSI test will be performed, in accordance with ASTM C-1611, on the first batch and then each batch after that until two consecutive batches fall within the tolerances. After that, a slump flow and VSI test will be performed every 50 yards or (4) hrs. whichever is greater. Slump flow tests will be performed with the cone inverted so that the smaller side is down.

Control Tolerance and Corrective Action

In the event the slump varies from the target value an immediate adjustment to the concrete mix shall be made to correct the slump/flow for succeeding the batches. The target value for this is between five (5”) and ten inches (10”) for regular concrete and between twenty-two (22”) and twenty-seven (27”) inches for SCC. PENN DOT SCC target is 25”, with an acceptable range of 22-28 inches, with j-ring concrete will be within 2” of initial spread test. Any batches above the target value will be rejected for use on ODOT & PENN DOT projects. Any batches below the target value will be vibrated as needed.

Air Test

Location and Frequency

Air test shall be made at the plant from samples obtained from the placement bucket at the batch plant staging area according to ASTM C-231. Air content is tested every 50 cubic yards or every 4 hrs. whichever requires the greater number of tests. The target value for this is between six and nine percent. For PENN DOT work only- air is 7%+-2 (Do not apply the aggregate correction factor).

Control Tolerances & Corrective Action

In the event the air varies from the target value an immediate adjustment to the concrete mix shall be made to correct the succeeding the batches. Concrete with air content less than six percent after the aggregate correction factor will be rejected for use on ODOT projects.

Compressive Strength Testing

Location

Compressive strength specimens shall be made at the plant from samples obtained at batch plant staging area. These specimens are then stored outside in the same environment as the product until they are ready for testing compressive strength. Mack uses the standard deviation of 5215 (pending ODOT's approval).

Frequency

Sampling will be in accordance with ASTM C-31. Six (6) cylinders will be made for each 50 yards. Two tests will be taken on 1st shift and one will be performed on night shift. The test specimens will be broken as follows: 2 cylinders @ 24 hours, 2 cylinders @ 7 days, and 2 cylinders @ 28 days. PENN DOT requires 4 cylinders for 28-day break. Target strength will be 4000 psi. Test cylinders will follow representative products to match climate conditions. Cylinders will be made a minimum of once per day. Neoprene pads used for compressive testing are turned over every 50 breaks and are replaced every 100 breaks. A log of flip dates and replacement dates is located beside the compression machine. Load rate will be 35 PSI per second. Cylinders will only be broken by a certified strength testing tech. Our minimum PSI to strip forms is 1400psi for 4000psi mix and 1800psi for a 5000psi mix. Minimum PSI to ship product for ODOT is 4000 for catch basins and manholes, 5000 for post's and boxes, and 2500 for private. PENN DOT requires 85% of design strength to strip (5000 psi mix would be 4250).

Temperature Testing

Location

Concrete temperature will be tested at the plant from a sample obtained from the placement bucket at the batch plant staging area.

Frequency

Testing will be done daily in accordance with ASTM 1064. Concrete with temperature over the maximum or under the minimum limit will be rejected from use on DOT and/ or high spec projects. The maximum concrete temperature is 90 degrees Fahrenheit and the minimum temperature is 50 degrees Fahrenheit.

Yield Testing

Location

Unit Weight and yield tests will be made for each 150 yards at the plant from Samples obtained from the placement bucket at the batch plant staging area.

Gasket Quality Control

Certificates of conformance will be received with each shipment of gaskets. The certificates will include test information on the durometer, length, volume, diameter, and splice strength.

SCC Mix Qualification

The initial mix qualification for SCC mixes used daily. 4 cylinders were made with the SCC mix. The aggregates used in the mix were tested for gradation and moisture. The concrete temperature was tested and a yield test was performed. The test specimens were tested for 7-day compressive strength and also 28-day compressive strength. The SCC mix was also tested by ODOT and a letter of certification from ODOT are on file. Daily Q.C. operations for SCC are spelled out in this manual. Concrete testing procedures will be the same for SCC as for regular concrete except that slump testing will be replaced by slump flow testing. Also, rodding and vibrating will be omitted from any test performed on fresh SCC, unless the slump flow is below the acceptable range of 22-27 inches. PENNDOT we will target 25", with an acceptable range is 22-28 inches, when using j-ring spread will be within 2" of initial spread.

Product Performance Testing

One absorption test will be performed on the mix design with the lowest amount of cementitious material. Step horizontal and vertical load testing will be performed annually. These tests will be performed according to ASTM C497. Vacuum testing of all septic tanks will be performed annually per ASTM C1227. Water tightness testing will be performed annually for each septic tank form. Water tightness tests will be performed according to ASTM C1227.

RECORDS

Compressive Strength Records

Results of all compressive strength test results will be maintained and kept at the plant.

Quality Control Training Records

All training records are current and kept in QC office.

Certificates of Conformance

Records are maintained and current in QC office.

Additional Records

All records outlined in NPCA Certification shall be kept in Q.C. for five (5) years and shall be available to ODOT upon request.

The following records are kept for at least (5) years in the following locations.
All Material test records- QC office
All product specifications- Engineering
All equipment Calibration records-QC office
All concrete test records-QC office
Neoprene pad counts-QC lab
All concrete batch reports-QC office
All inspection records-QC office

All certs are maintained for miscellaneous materials

All coating Requirements are met and recorded for miscellaneous materials.

ASTM Test Methods

Copy of 2015 ASTM Test Methods on file

All certifications are maintained for miscellaneous materials.

All products are marked with their production date to be able to associate the product with the records. In addition, we write down date of production on delivery ticket and keep on file in the QC office.

PRODUCTION PRACTICES

QC Responsibilities

Quality Control Manager is only one responsible for plant QC operations. There will be one NPCA certified inspector for each shift, and at least one qualified back up on each shift. Quality Control will use a Pre- and post-pour check list that is on the back of the production print on a daily basis. QC will verbally inform when a mold is ready to pour. Quality control Associates records by date of production and writing date of production for the pieces being shipped. They are also responsible for the following items daily. Testing of concrete for air, flow, and temperature. Crushing cylinders and performing a moisture test daily are done daily. Unit weight records will be performed on a weekly basis. Sieve tests are performed on a by-monthly basis. Quality Control also performs yard walks and fills out product repair sheets when needed. When steam curing Quality Control will Record initial set once per month. Ambient Temperature records shall be maintained one per week. And temperature recorders will be used daily.

Shop Drawings

Shop Drawings stamped by a professional engineer will be kept on file in the QC office

Training

Quality control technicians will have the following training
NPCA PQS-1
ACI-field testing technician
ACI-strength testing technician (if breaking cylinders)

Production staff and forklift operators will have the following training
Production employees will watch (4) hours of safety videos
Once safety videos are over the will follow around a designated trainer for two weeks.
Once employee shows the ability to do work on their own, they will perform tasks by themselves.

Drivers will have the following training
Drivers must have CDL
Drivers will go on ride along with trained drivers until they can perform tasks by themselves

Reinforcement

Reinforcement steel shall be fabricated so as to conform to the tolerances and specifications established for the precast concrete product being produced.

Cages of reinforcing shall be fabricated by either tying the bars, wires, or welded wire fabric into rigid assemblies. In all cases care and discretion must be used to assure that the integrity of precast product is maintained.

Reinforcement steel shall be positioned as specified by design so that the concrete cover conforms to requirements. Concrete cover shall not be less than ½ inch after pour.

Embedded items shall be positioned at locations specified in the design and shall be held in place so that they do not move significantly during casting.

We work from shop drawings; the reinforcing assembly is built to project specifications. The QC coordinator will check product reinforcing to make sure the size and its location is correct.

Mill certifications for all rebar, wire, and cable are kept on file, and are cross-checked with heat numbers. Epoxy coated rebar and black steel is kept up off the ground and the epoxy is covered to protect the coating prior to casting. Certificates are crosschecked with heat numbers of products being used and stored. Reinforcing specifications for different products are on file to ensure proper materials are in the correct products.

Box Culvert(Reinforcing)

We will maintain documentation of every Box Culvert reinforcing steel cage with this information of required cage versus actual cage used, steel areas, WWR style, cage length, and tied wire laps. These dimensional checks will also be linked to the Mill certification for the wire. Joint design for these products will also be kept on file in the Quality Control Office.

Manhole(Reinforcing)

We will maintain documentation of every manhole reinforcing steel cage with this information of required cage versus actual cage used, steel area, WWR style, wire diameter, cage diameter, cage height, tied wire laps. These dimensional checks will also be linked to the Mill certification for that roll of wire used. Joint design will also be kept on file in the Quality Control Office. Structural design calculations will be kept on file for all the stock manhole flat slab top designs.

Pre-Pour Operations

Forms shall be cleaned after each use. Concrete tape and other materials adhering to the forms shall be removed. Thorough cleaning is to be performed before applying form release agent. We currently use Hill and Griffith, Grifcote R-VOC.

The key consideration of the application for our form release agent is to strive for a uniform coating of the form. Our release agent will be sprayed on to the form. Excess appreciation will be blotted and drained. The primary purpose for release agents are to aid in the stripping process, assist in the producing a defect free concrete surface, assist in keeping he form surface clean and increase the working life of the form surfaces.

Reinforcement is placed in the form after form oil application.

Prior to casting concrete, an inspection shall be made to determine if the form with the reinforcement, embedded items, and block-outs conforms to the design. Deviation from the design shall be corrected before concrete is cast. Upon approval, the drawing is initialed and dated by the shift coordinator checking the set-up.

Form is inspected for buildup and worn parts. Also, dimensions are checked and adjustments will be made prior to casting. Forms with worn parts or inaccurate dimensions will be taken out of service until maintenance can be performed.

Dry-Cast Products shall have dimensional checks done daily. Checks shall be made on (3) reinforcing cages or 3% whichever is greater. A0lso dimensional checks shall be performed on (3) of each production run or 3% whichever is greater, all chosen on random basis by QC personnel.

Casting Concrete

Concrete is mixed in a (two) 2-yard stationary pan mixer. Concrete is dispersed into (two) 2-yard placement bucket (Transport equipment is checked and recorded daily). Concrete test samples are taken form the placement bucket at this location. This placement bucket is taken by an overhead crane or forklift. Placement bucket is raised by overhead crane and taken to position over mold.

Concrete shall be deposited into forms as near to its final location as practical or no more than 12 inches above the top of the forms. The free fall of the concrete shall be kept to a minimum. Acceptable time to complete placement of concrete is about 30 minutes and re-plasticizing is allowed if necessary. Length of concrete flow in formwork is limited to 20 feet and no vibration should be used to enhance movement. Standard set times will be between 45 minutes and 375 minutes in accordance with ASTM C-150.

Consolidating Concrete

Concrete is placed in the forms and consolidated in such a manner that segregation does not take place and honeycombed areas are kept to a minimum. Concrete is placed in the mold and vibrated with internal or external vibration.

Internal vibrators shall be lowered vertically into the concrete without being forced downward until the tip of the vibrator reaches the bottom of the form or until it penetrates into a previously consolidated lift. Vibration continues until all voids and entrapped air pockets within the vibrators field of action are released. Full consolidation is judged by the formation of a mortar rich appearance on the concrete surface and the escaping air bubbles cease.

The vibrator shall be lifted from the concrete at about the same rate at which it was lowered. The vibrator is then moved into a location so that the fields of action overlap and the process is repeated until all the concrete in the mold has been consolidated. Re-vibration of concrete after initial consolidation is accepted as necessary to weld successive lifts together.

External vibrators are mounted on forms to best distribute their impact. External vibrators shall be turned on after concrete is 6” above bracket. Multiple brackets are used on larger molds. External vibrators operate until air bubbles essentially stop coming to the surface.

Vibration should not continue for a prolonged period that would cause segregation of aggregates.

Consolidating SCC Concrete

Vibration of concrete when using a self-compacting concrete admix is not necessary unless the spread is not sufficient to allow the concrete to flow properly. If the spread is less than 22 inches the concrete can be vibrated as discussed in the **Consolidating Concrete** section.

Finishing Concrete

Finishing is achieved by hand trowel or float to grade lines on the mold. Proper finishing and coverage of form is ensured at the schedule completion check. It is at this time the worker's schedules and time cards are approved as complete and initialed by the shift coordinator or QC Manager.

Curing Concrete

Effective curing should begin as soon as casting is completed. Curing is accomplished by moisture retention method. The mold acts as a protector from harsh elements.

There is an open area where concrete is placed into the mold. Products are covered with visqueen to hold in moisture.

Buildings are heated with forced air or infrared heaters. Air circulators are used to keep buildings at a uniform temperature to aid in curing.

Concrete will not be stripped from the forms until it has reached a minimum stripping strength of 1400 psi for 4000 mixes and 1800 psi for 5000 mixes.

Steam Curing

Effective curing should begin as soon as casting is completed. The concrete shall not be subjected to steam until after the concrete has attained initial set. Initial set will be tested a minimum of once per month and will be obtained using a penetrometer (Initial set=500psi) per ASTM C-403. The product station will be covered with visqueen after casting is completed and the last product poured will be tested for initial set. Steam will then be applied to the product station ½ hour after initial set is obtained. The product station ambient temperature is then monitored and documented by use of a chart recorder. This will ensure that the ambient curing temperature does not exceed 150 degrees. The chart recorder will also monitor that the rise in ambient curing temperature does not exceed a maximum of 40 degrees per hour. The ambient curing temperature of the product station will be monitored and documented a minimum of once per week. The steam curing process will be shut down manually if the ambient temperature exceeds 150 degrees or there is a rise in temperature of more than 40 degrees per hour and the steam process will be resumed once the temperature subsides below the maximum levels.

Hot and Cold Weather Concreting

During hot weather, aggregates will be sprinkled with water to cool them. This helps keep the concrete temperature under 90 degrees Fahrenheit.
During cold weather, hot water will be used to heat the concrete mix, and we will steam the aggregates when they are frozen so no frozen aggregates are being used. These will be used to keep the concrete temperature over 50 degrees Fahrenheit. PENN DOT requires concrete temp over 40 degrees. Water will not be heated above 150 degrees Fahrenheit.

Post Pour Operations

Our quality control checks are placed throughout the production process. We use pre- pour checklists and post pour checklist to document everything (see attached checklists).

Our post pour inspection is made after the concrete has been stripped from the mold. This check makes certain that no movement occurred during the pour and measures to the exact tolerance according to ASTM C478 and C1227. If the piece needs any rework it is noted on the print. The piece must receive this attention and be approved by the QC Manager before it can leave the production area.

At final inspection, any customer requested or regulatory labeling requirements are marked on the concrete product. Type of label information could be job#, piece#, contractor, job name, date of production, manufacturer stencil, QC approved initials. Usually this is done with spray paint or black marking crayons.

A daily yard walk through is performed by the QC Manager to check on quality of product that is deemed ready to ship. Yard storage problems are noted and corrections made. QC Manager will use a green, yellow and red system in the yard. Green= good to go. Yellow= needs repair. Red= scrap. A sheet will be made of all repairs needed in the yard, and given to yard repairperson. Once repair is made the sheet is then given back to QC Manager. He will then look at it and if it is good he will then give it a green tag.

Housekeeping

Housekeeping will be checked at the end of each shift. There is a place on the schedule for the supervisor to sign off on housekeeping. In addition, each employee is assigned an area that he/she is responsible for.

REPAIR METHODS

Patching & Repair Procedures

Qualified plant personnel to determine if repairs are necessary, and if so, what repair is required before shipping evaluate products damaged during stripping.

Chips and/or surface defects, fractures, and spalls that do not expose reinforcement are cosmetic defects. The depth range is less than 2" with a surface area of less than 100 square inches.

Defects not impairing the functional use or expected life of a precast concrete product are considered minor defects. Minor defects are repaired by methods that do not impair the product.

Defects that impair the functional use or the expected life of a product are considered major defects. Major defects are evaluated by qualified personnel to determine if repairs are feasible and if so, establish a repair procedure. Proper repairing procedures and curing are inspected. Records of major repairs are kept on file. Pieces are marked to indicate their use. ODOT and Penn Dot will be notified before any major repairs will be made on their products.

Patch and repair techniques vary to adequately correct each type of defect. Our most common materials are Dayton/Superior Re-crete 5, Chemseal and Waterstop. When brand-name materials are specified, we follow the manufacturer's instructions.

Field repairs require specially trained personnel. They must be qualified in confined space training and properly equipped. Field conditions and troubleshooting may require use of expensive epoxy injections to stop active leaks in an underground structure.

Cosmetic Repair

The area to be repaired shall be clean of dirt, grease, or loose concrete. The area is moistened to ensure a good bond. Message HiCap into the concrete as a slurry coat. Immediately place HiCap onto the repair location, leaving extra material on the surface. Allow to set. Then carve and shape to match the surrounding concrete. Cure as per manufactures instructions.

Minor Repair

The area to be repaired shall be clean of dirt, grease, or loose concrete. The area is moistened to ensure a good bond. Chips or voids are to be filled with Recrete-5and allowed to cure. Excess Recrete-5 is removed and area is shaved to a smooth surface. Very shallow repairs are coated with Recrete-5 by brushing mixture over area and allowed to cure. Honeycomb will be chipped away into good material then patched and allowed to cure.

Major Repair
Large pieces that break off can be re-attached with the use of HY-150 concrete epoxy, which is manufactured by Hilti Inc. Pieces to be attached must be clean and free of grease, oil, and loose concrete. This method can only be done if the broken piece is in tacked and in good condition. Major repairs that do not have the piece to attach will be built up with water-stop. Quick bolts will be used to hold large patch repairs on, when possible a steel or wooden mold will be used to shape the repair to conform to the original product. After final application, the area will be coated with a thin layer of Recrete-5 to fill any small voids or marks. The area will then be allowed to cure before final inspection.

Unless specified by the customer, all repairs are to be done in accordance with the NPCA Quality Control Manual, Section 4.7.1 Repairing Minor Defects.

NOTE: the QC Program defines the quality requirements for the precast plant. Product design specifications always supersede. If certain requirements are not specified in the design or in this QC Program, please refer to the NPCA QC Manual.

Plant Requirements

All molds and forms have serial numbers on them to track maintenance and repairs. Our maintenance department inspects and adjusts all molds and forms at least annually or anytime that the mold or form is worked on. Records of all repairs and checks are kept on file in the maintenance office.

ODOT will be notified by e-mail three days prior to the beginning of production of a ODOT job.

TE-24

Any products being shipped to ODOT will be done using the TE-24 system.

PENN DOT

Addendum

The following testing procedures will only be run this frequent only when doing Penn Dot work. All other work will fall under the main body for testing.

Aggregate Testing

Gradations of fine aggregates and course aggregates will be run every time the bin is restocked. Wash tests will be run every five gradations. Moisture test will be run daily at the beginning of work.

Straight-Line Charts

Straight-Line charts will be used for aggregate gradations, slump and air.

Batch Scale Checks

The following will be performed monthly. Aggregate scale, cement scale and water meter.

Calibration of Equipment

Admixture dispensers and cylinder compression machine will be done yearly by outside source. Air meter will be calibrated every two weeks. 50-pound weights will be calibrated every three years by private calibration service.

Concrete Tests

Air test will be done on first batch of day and two thereafter at increments of 10 yards to establish consistency. Spread test and j-ring test will be done first batch of day and two thereafter at increments of 10 yards to establish consistency. VSI will be recorded after each spread test. Concrete temperature will also be done on first batch and two thereafter at increments of 10 yards to establish consistency.

Prepour Checks

The frequency in which the form dimensions and steel placement shall be checked is 100%.

Identification of Compression Test Specimen Molds and Compression tests Specimens

Test cylinders will be made using steel cylinders. Each mold will be permanently marked with its own ID. The following will be marked on all cylinders.

-Date molded
-Mix identification
-Piece or pieces the cylinders represent
-Series number that is on steel cylinders
-Name of plants QC technician who molded the specimens
-Name of Penn Dot representative who witnessed molding of specimens

In addition, the above following will be recorded on a form and will be kept on file in the quality control office.

Post Pour Checks

Post pour checks will be done on at least 10% per type of product.

Repair and Patching

Only bulletin 15 approved repair material will be used on Penn Dot products and the manufactures recommendations will be followed. In addition, all repairs will be evaluated against the pub 145, and anything outside the limits will have to be sent to Penn Dot for approval to repair.

Documentation

The following will be documented and kept on file

1. Batch reports
2. Gradations
3. Moisture
4. Certification shipping form (CS-4171)
5. Pre-pour and post-pour checklists

Water Cement Ratio

We will be using a water cement ratio of .47 for Penn Dot work only.

Coating Procedures

Addendum

The following coating procedures will only be done when coating ODOT posts.

Cure

Product will be cured for a minimum of three days.

Surface Preparation

Thoroughly clean all concrete surfaces removing dust, dirt, oil and loose concrete. Pieces will be water blasted using a 7000 PSI pressure washer exposing the sand matrix portion of the concrete. Coating will not be applied until concrete is dry with no standing water. Before paint is applied pieces will be air blasted and/or wiped down with a rag to make sure dust is removed from piece.

Mixing Procedure

Check the shelf life of paint to make sure it is not expired. Mix paint thoroughly for at least 15 minutes and periodically through out the day using a mechanical drill and paddle to properly disperse aggregate and pigment.

Application

Ambient temperature shall be between 45 degrees' f and 100 degrees' f when painting. Paint will be applied by brush, roller or spray. The temperature should be a minimum of 5 degrees above the dew point prior to application. We will meet the minimum requirements of 15 dry mils. This will be monitored by applying the calculation below.

Wet film mils= 1604/sqft/gallon application rate
Dry film mils= wet film thickness X (% solids in coating)

Shipping and handling

There will be a 24-hour cure time before we transport posts to our storage area. Due to shipping and handling they may require additional field application before final acceptance.

APPLICATION

Ohlin & Reed
STRUCTURAL DESIGN CONSULTANTS

October 16, 2020 JOHN P. REED, P.E.

Christopher Merklin
Office of Geotechnical Engineering
Attn: Dorothy Adams
Ohio Department of Transportation
Mail Stop 5090
1980 West Broad Street 3rd Floor
Columbus, OH 43223

Subject: Precast "T" Wingwall

Dear Ms. Adams,

This is a letter of intent requesting approval of the subject Prefabricated Retaining Wall System (PRWS) and inclusion on the Ohio Department of Transportation (ODOT) Approved Product List (APL). Ohlin & Reed, Structural Design Consultants will be the engineering firm performing the design calculations and preparing the structural drawings for the PRWS as a representative of Mack Industries, the ODOT certified precast concrete fabricator that will be supplying the PRWS.

The design wherein is for a semigravity retaining wall consisting of a conventionally reinforced precast stem and spread footing placed on a well-compacted granular base. Figure 1 illustrates the PRWS for this submittal. The following design cases will be considered for this PRWS:

1. Level backfill with and without a live load surcharge
2. Backfill with an infinite 2:1 slope
3. Backfill with a 2:1 slope that breaks to a level backfill at a distance equal to the design height of the wall

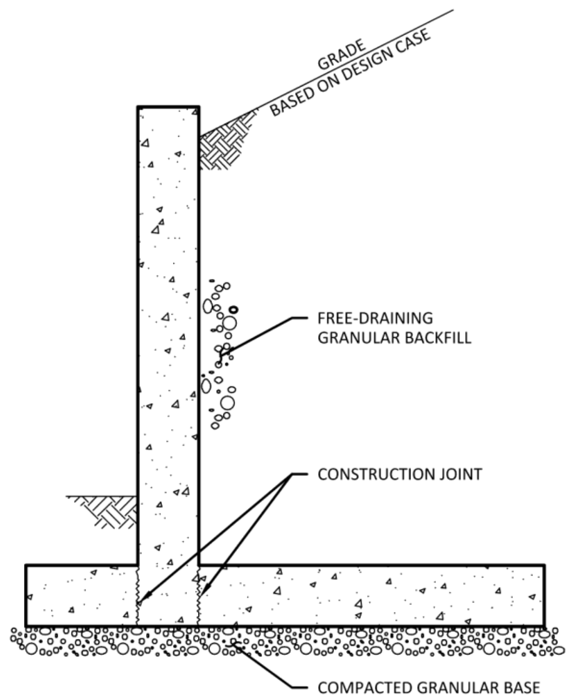


Figure 1: Geometry of prefabricated retaining wall system

Design of the PRWS will be such to ensure stability against bearing capacity failure, overturning, and sliding. Strength and stability design of the PRWS will be in accordance with AASHTO LRFD and the ODOT BDM.

Coulomb Theory will be used to calculate the active earth pressure on the PRWS. For the case of a breaking back-fill, Coulomb's active earth pressure will be calculated by using

Coulomb trial wedge analysis. Any passive earth pressure used to resist sliding will be calculated using Rankine Theory with a neglected height equal to the frost depth.

The sequence of construction for the PRWS is as follows:

A. Construction at Precast Fabricator
    1. Setup mold and reinforcing steel for stem wall
    2. Pour concrete for stem wall
    3. Finish and strip stem wall
    4. Tilt stem wall to vertical orientation
    5. Roughen construction joints to ¼” amplitude and clean
    6. Setup mold and reinforcing steel for heel
    7. Pour concrete for heel
    8. Setup mold and reinforcing steel for toe
    9. Pour concrete for toe
    10. Finish and strip heel and toe
    11. Ship to construction site
B. Construction at Site
    1. Prepare site and subgrade in accordance with the specifications and contract documents
    2. Place Precast Wingwalls in final locations
    3. Bring backfill up evenly on both sides of the wingwalls with maximum unbalanced fill of 2’-0” until fill over toe has reached the design height
    4. Continue backfilling over heel until fill has reached the design height

Attachments A through H have been attached to this letter for your use.

Please call if you have any questions or need further information.

Submitted by:

John P. Reed, P.E.
Ohlin & Reed, Inc.

OHIO DEPARTMENT OF TRANSPORTATION

Attachment A: Declaration of Proprietorship and Point of Contact

Prefabricated Retaining Wall System	Precast "T" Wingwall *Name of Prefabricated Wall System* Mack Industries, Inc. *Name of Wall Supplier*
Contact person for the prefabricated retaining wall system	Al Mong *Name* 201 Columbia Road *Address (line 1)* *Address (line 2)* Valley City — *City*; Ohio — *State or Province*; 44280 — *Zip code or Postal Code* United States *Country* (800) 482-3111 ext 6302 — *Phone number*; (330) 617-8391 — *Fax number* among@mackconcrete.com *e-mail address*
Signature and title of authorized wall supplier representative	Al Mong *Signature* Al Mong *Typed or printed name* Engineering Manager — *Title*; 10/14/20 — *Date*

Attachment B: Declaration of Design Responsibility

We, the Wall Supplier of the prefabricated retaining wall system affirm that we are responsible for the internal stability and the sliding and eccentricity external design of the retaining wall system and will either perform the design with our own employees or contract with an Ohio Registered Professional Engineer to perform the design for us.

Precast "T" Wingwall
Prefabricated Retaining Wall System

Al Mong
Signature

Al Mong
Typed or printed name

Engineering Manager	10/14/20
Title	*Date*

Attachment C: Implied and Proffered Warranties

Prefabricated Retaining Wall System: Precast "T" Wingwall

☐Yes ☒No Does an implied or explicit warranty apply to the wall system or any part thereof?

If yes, please describe in detail the provisions of the warranty:

Description of warranty

Attachment D: Declaration of Understanding of ODOT's Design and Construction Specifications

We, the Wall Supplier of the prefabricated retaining wall system affirm that we are aware of all Ohio Department of Transportation publications and directives, including but not limited to the Bridge Design Manual, Location and Design Manual, Manual of Procedures, and Construction and Materials Specifications as they pertain to retaining walls.

Precast "T" Wingwall
Prefabricated Retaining Wall System

Al Mong
Signature

Al Mong
Typed or printed name

Engineering Manager	10/14/20
Title	*Date*

Attachment E: Declaration of Patents and Proprietary Technology

Prefabricated Retaining Wall System: Precast "T" Wingwall

☐Yes ☒No Is the prefabricated retaining wall system as a whole covered by a patent?

If Yes

Patent Number	*Date of Patent Application*

☐Yes ☒No Is any part of the prefabricated retaining wall system covered by a patent, copyrighted or otherwise protected?

If Yes

Description of part covered by patent

Patent Number	*Date of Patent Application*

1. ☐Yes ☒No If there is any specific information regarding your firm, the system or components, your application for approval, or any other matter that you wish to be treated as confidential, describe by categories or subject of confidential data how you would like the ODOT to treat this information. Also, where appropriate, describe any measures or safeguards that have been applied (or could be applied) to protect the confidentiality of the information.

If Yes

Description of component covered by patent

Patent Number	*Date of Patent Application*

Description of confidential material

Attachment F: Declaration of Fabricators or Precast Concrete Manufacturers

Prefabricated Retaining Wall System: Precast "T" Wingwall

List all precast concrete producers certified according to ODOT Supplemental Specification 1073 that will be manufacturing concrete components of the prefabricated retaining wall system. If the wall system is a metallic bin wall, list all fabricators of the bin components.

List of certified precast concrete producers or fabricators and contact information

Mack Industries
507 Derby St
Bowling Green, OH 43402
419-353-7081
PS Code 09725-01

Mack Industries
201 Columbia Rd
PO Box 335
Valley City, OH 44280
330-483-3111
PS Code 09724-01

Mack Industries
2207 Sodom-Hutchings Rd
PO Box 456
Vienna, OH 44473
330-638-7680
PS Code 09726-01

Mack Industries (formerly United Precast Industries)
400 Howard St
Mt Vernon, OH 43050
PS Code 09559-01

Attachment G: Affirmation of Notification Responsibility

We, the Wall Supplier of the prefabricated retaining wall system affirm that after the system is approved, we will notify the Ohio Department of Transportation of any changes to the prefabricated retaining wall system which will affect the design, construction, inspection, and performance requirements of the wall system. The Department will then determine if the change will require a reevaluation of the prefabricated retaining wall system.

Precast "T" Wingwall
Prefabricated Retaining Wall System

Al Mong
Signature

Al Mong
Typed or printed name

Engineering Manager
Title

10/14/20
Date

Attachment H: Authorization for Duplication and Reproduction

We, the Wall Supplier of the prefabricated retaining wall system hereby grant the Ohio Department of Transportation authorization to duplicate and reproduce all documents contained within this submittal package. We acknowledge that any and all documents submitted become a public record upon receipt by the Department and are subject to a public records request, with the exception of information clearly identified as trade secrets and which meets the definition of a trade secret as described in Ohio Revised Code 1333.61(D).

Precast "T" Wingwall

Prefabricated Retaining Wall System

Al Mong

Signature

Al Mong

Typed or printed name

Engineering Manager — 10/14/20

Title — *Date*

SAMPLE CALCULATIONS

APPENDIX 5: EXAMPLE CALCULATIONS

Precast "T" Wingwall

Design Criteria

Code

- AASHTO LRFD Bridge Design Specifications, latest edition with interims
- ODOT Bridge Design Manual, latest edition
- Building Code Requirements for Structural Concrete, ACI 318-14

STATE OF OHIO JOHN P. REED E-050588 REGISTERED PROFESSIONAL ENGINEER

Design Data

Soil Conditions:

Internal Angle of Friction of Backfill Soil	$\phi_f = 30$ *deg*
Total Unit Weight of Backfill Soil	$\gamma_f = 120$ *pcf*
Total Unit Weight of Soil Over Toe, Including Rip Rap	$\gamma_t = 120$ *pcf*
Buoyant Weight of Cover Over Toe	$\gamma_t - \gamma_w = 57.6$ *pcf*
Batter Angle of Back Face of Wall	$\alpha = 0$ *deg*
Slope of Backfill	2:1 Breaking to Level

Foundation Design Criteria:

External Angle of Friction For Foundation Soil	$\delta_{fd} = 22$ *deg*
Coefficient of Friction (Precast Concrete-on-Soil)	$\mu = \tan\left(\delta_{fd}\right) = 0.4$
Nominal Bearing Capacity of Foundation Soil	$q_n = 7500$ *psf*
Subgrade Reaction Modulus	$k_s = 100$ *pci*

Lateral Loading:

Angle of Friction At Heel For External Stability (Soil-on-Soil)	$\delta_{ext} = 20$ *deg*
Angle of Friction At Stem Wall (Soil-on-Precast Concrete)	$\delta_{int} = 15$ *deg*
Equivalent Fluid Pressure Acting At Heel	$EFP_{a.ext} = 35.7$ *pcf*
Equivalent Fluid Pressure Acting At Stem Wall	$EFP_{a.int} = 58.6$ *pcf*
Equivalent Fluid Pressure of Passive Soil	$EFP_p = 173$ *pcf*

Precast Concrete:

Compressive Strength of Concrete At 28 Days	$f'_c = 5000$ *psi*
Unit Weight of Concrete	$\gamma_c = 150$ *pcf*
Yield Strength of Reinforcing Steel	$f_y = 60$ *ksi*

NOTE: Engineer of Record To Verify The Design Assumptions Stated Above

Precast "T" Wingwall

Description

The following design calculations are for a pre-cast concrete wingwall conforming to the latest editions of the LRFD Bridge Design Specifications and ODOT Bridge Design Manual.

These design calculations include bearing resistance and stability checks at the strength limit state. Overall stability is not included in these calculations are are the responsibility of the engineer of record.

Assumptions

1. Live load surcharge stabilizing loads (if applicable) are ignored in overturning and sliding analyses.
2. The buoyant weight of the soil in front of the toe will be used to calculate passive pressure resistance used in sliding analysis.
3. Footing depth and toe cover are based on contract documents and is assumed to be sufficient to negate the effects of scour potential.

Precast "T" Wingwall

1.0 Parameters

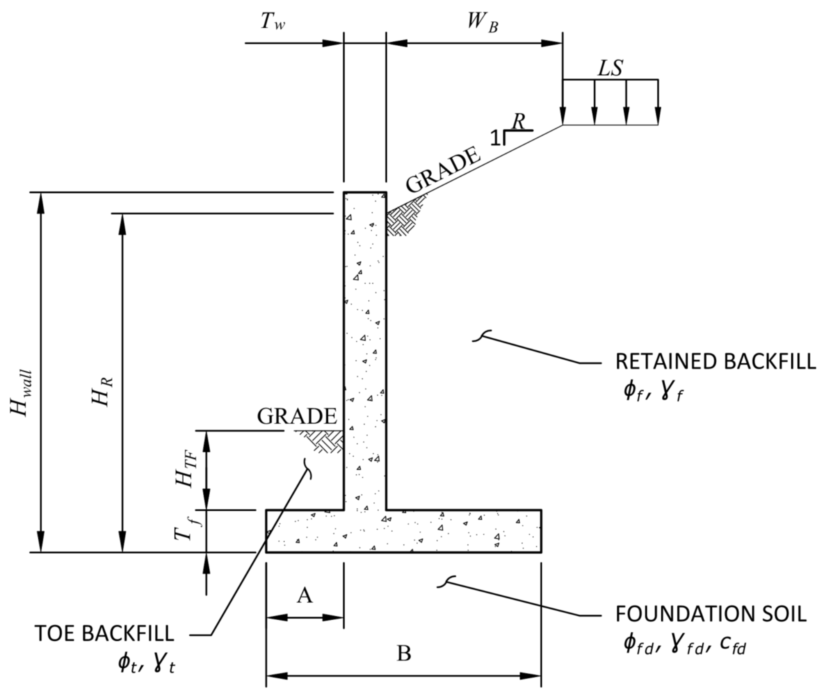


Figure 1.0-1: Wingwall Parameters

Wall Geometry

$H_{wall} := 8\ ft + 0\ in$	*(Overall Height)*
$H_R := H_{wall} - 6\ in$	*(Retained Soil Height)*
$H_{TF} := 30\ in$	*(Height of Fill Over Toe)*
$T_w := 12\ in$	*(Wall Thickness)*
$B := 10\ ft + 0\ in$	*(Width of Footing)*
$T_f := 12\ in$	*(Thickness of Footing)*
$A := 1\ ft + 6\ in$	*(Toe Distance)*
$W_B := H_R$	*(Distance to Breaking Point: Set = NaN For Infinite Backfill)*
$R := 2$	*(Run Factor For Sloping Backfill: Set = 0 For Flat)*

Precast "T" Wingwall

Soil: Backfill

$\gamma_f := 120\ pcf$ (Soil Unit Weight)

$\phi_f := 30\ deg$ (Angle of Internal Friction)

$\delta_f := \frac{2}{3} \cdot \phi_f = 20\ deg$ (Angle of External Friction)

$EFP_{min} := 35\ pcf$ (Minimum Equivalent Fluid Pressure: Refer to Spec)

Soil: Toe

$\gamma_t := 120\ pcf$ (Soil Unit Weight)

$\phi_t := 30\ deg$ (Angle of Internal Friction)

Soil: Foundation

$\gamma_{fd} := 120\ pcf$ (Soil Unit Weight)

$c_{fd} := 0\ psf$ (Cohesion of Soil)

$\delta_{fd} := 22\ deg$ (Angle of External Friction: AASHTO Table C3.11.5.3-1)

$k_s := 100\ pci$ (Subgrade Reaction Modulus)

Subgrade: For Bearing and Sliding

$q_n := 7500\ psf$ (Nominal Soil Bearing Resistance)

Reinforced Concrete Properties

$f'_c := 5000\ psi$ (Concrete Compressive Strength)

$\gamma_c := 150\ pcf$ (Concrete Unit Weight)

$f_y := 60\ ksi$ (Yield Strength of Reinforcing Bars)

$E_s := 29000\ ksi$ (Modulus of Elasticity of Reinforcing Bars)

Precast "T" Wingwall

Resistance Factors

$\phi_b := 0.55$ *(Bearing: AASHTO Table 11.5.7-1)*

$\phi_T := 1.0$ *(Sliding: AASHTO Table 11.5.7-1)*

$\phi_{ep} := 0.5$ *(Passive Pressure: AASHTO Table 10.5.5.2.2-1)*

Surcharge Load

$L_{traffic} := \text{“Break”}$ *(Distance From Wall Back-Face to Edge of Traffic: Set = "Break" To Equal Break Point)*

$LS := 250\ psf$ *(Surcharge Load)*

$LS_{min} := 40\ psf$ *(Minimum Surcharge Load)*

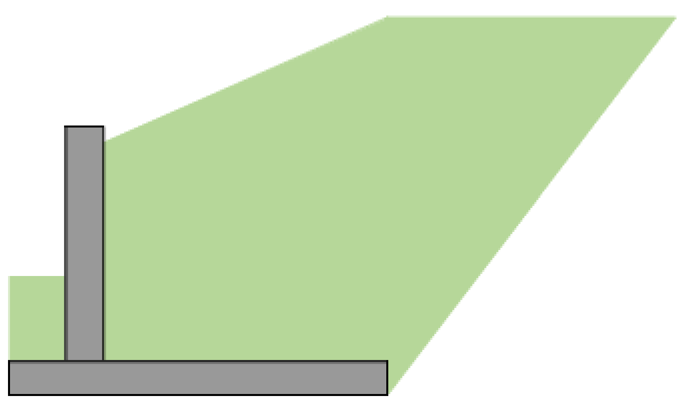


Figure 1.0-2: Wingwall Geometry Including Active Soil Wedge

Precast "T" Wingwall

2. Loads

2.1 Active Earth Pressure Coefficient

Active earth pressure is calculated using the Coulomb trial wedge analysis. The analysis starts at the top of the wall and proceeds at depth intervals to the bottom of the wall. The critical planar failure surface that produces the maximum active force is identified and analyzed at each depth interval. Earth pressure is determined by using the difference in calculated active force at each step.

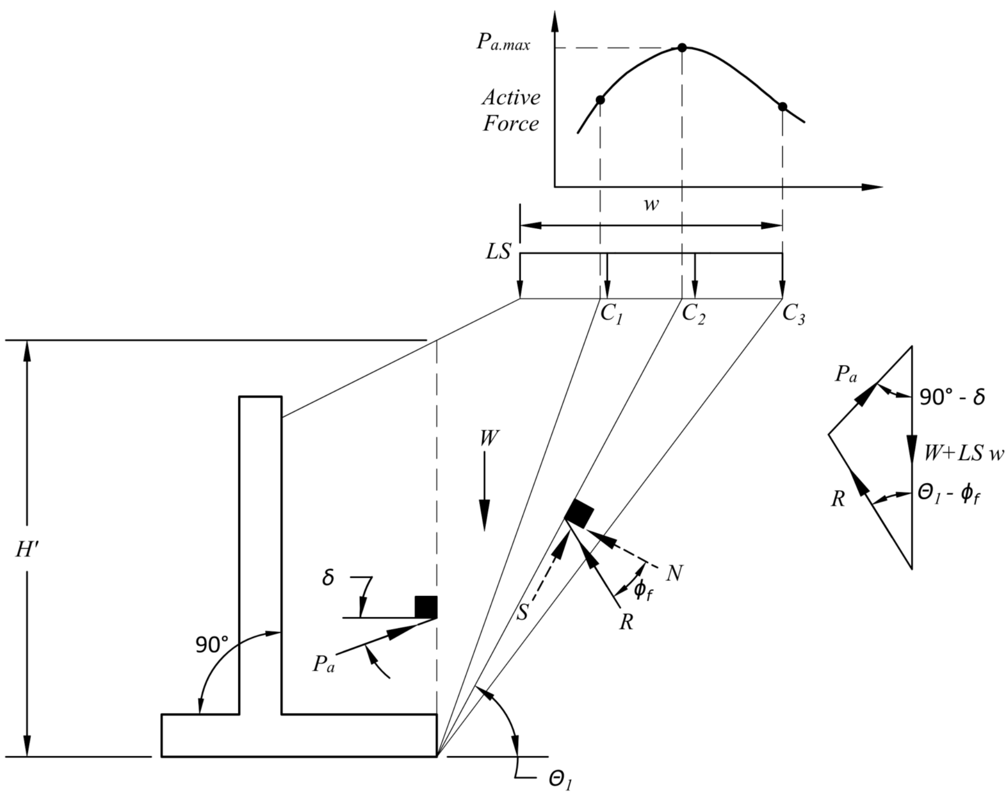


Figure 1.0-3: Active Pressure

Precast "T" Wingwall

2.1.1 Earth Pressure At Heel For External Stability

$\theta_{max.ext} = 56.0\ deg$ — *Angle of Soil Wedge For Maximum Active Earth Pressure*

$P_{a.ext} = 3.09\ \frac{kip}{ft}$ — *Maximum Resultant Active Force*

$P_{LS.ext} = 0.84\ \frac{kip}{ft}$ — *Active Force From Surcharge*

$\delta_{ext} = 20\ deg$ — *Incline of Active Force*

$k_{a.ext} = 0.297$ — *Coefficient of Active Earth Pressure*

$EFP_{a.ext} := \max\left(k_{a.ext} \cdot \gamma_f, EFP_{min}\right) = 35.68\ pcf$ — *Active Equivalent Earth Pressure*

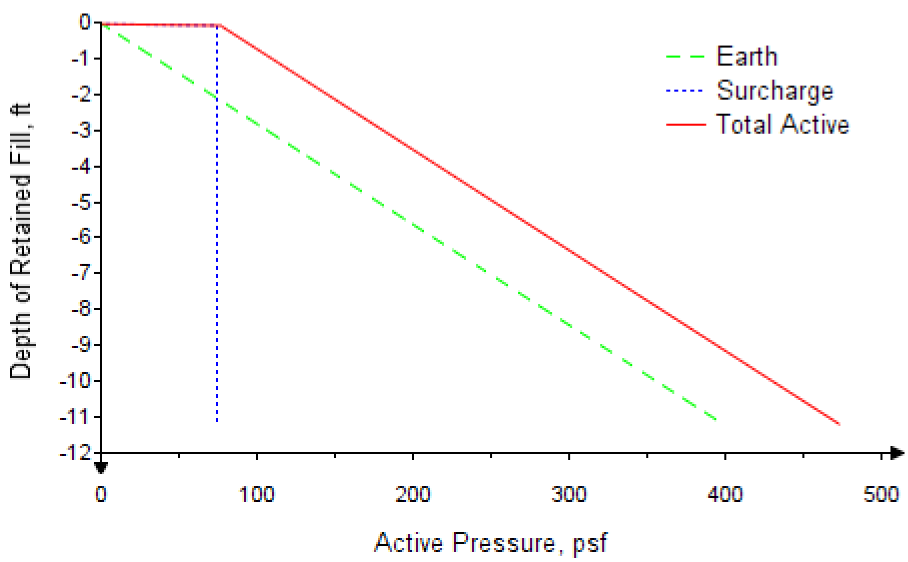


Figure 2.1.1-1: Active Pressure At End Of Heel For External Stability

Precast "T" Wingwall

2.1.2 Earth Pressure At Stem Wall For Structural Design

$\theta_{max.int} = 47.0\ deg$ — *Angle of Soil Wedge For Maximum Active Earth Pressure*

$P_{a.int} = 1.46\ \frac{kip}{ft}$ — *Maximum Resultant Active Force*

$P_{LS.int} = 0.23\ \frac{kip}{ft}$ — *Active Force From Surcharge*

$\delta_{int} := \frac{1}{2}\ \phi_f = 15.0\ deg$ — *Incline of Active Force*

$k_{a.int} = 0.488$ — *Coefficient of Active Earth Pressure*

$EFP_{a.int} := \max\left(k_{a.int} \cdot \gamma_f, EFP_{min}\right) = 58.59\ pcf$ — *Active Equivalent Earth Pressure*

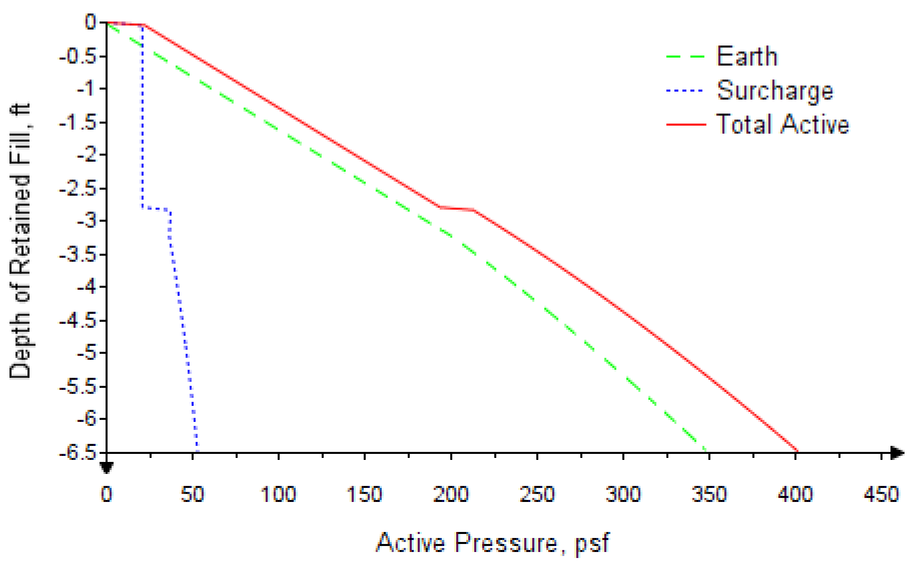


Figure 2.1.2-1: Active Pressure At Stem Wall

Precast "T" Wingwall

2.2 Passive Earth Pressure Coefficient

The coefficient of passive earth pressure is calculated using Rankine Theory, which aligns well with AASHTO Figure 3.11.5.4-1 when conservatively neglecting friction between soil and wall $\delta = 0°$. The buoyant weight of the soil in front of the toe will be used in determining the passive pressure resistance for sliding stability checks.

$$k_p := \tan\left(45° + \frac{\phi_t}{2}\right)^2 = 3.00$$ *Coefficient of Passive Earth Pressure*

$$EFP_p := k_p \cdot (\gamma_t - \gamma_w) = 172.8\ pcf$$ *Passive Equivalent Earth Pressure*

2.3 Unfactored Loads

Forces and moments are computed using Figures 1.0-1 and Figure 2.3-1. Overturning moments are taken about point 'O'

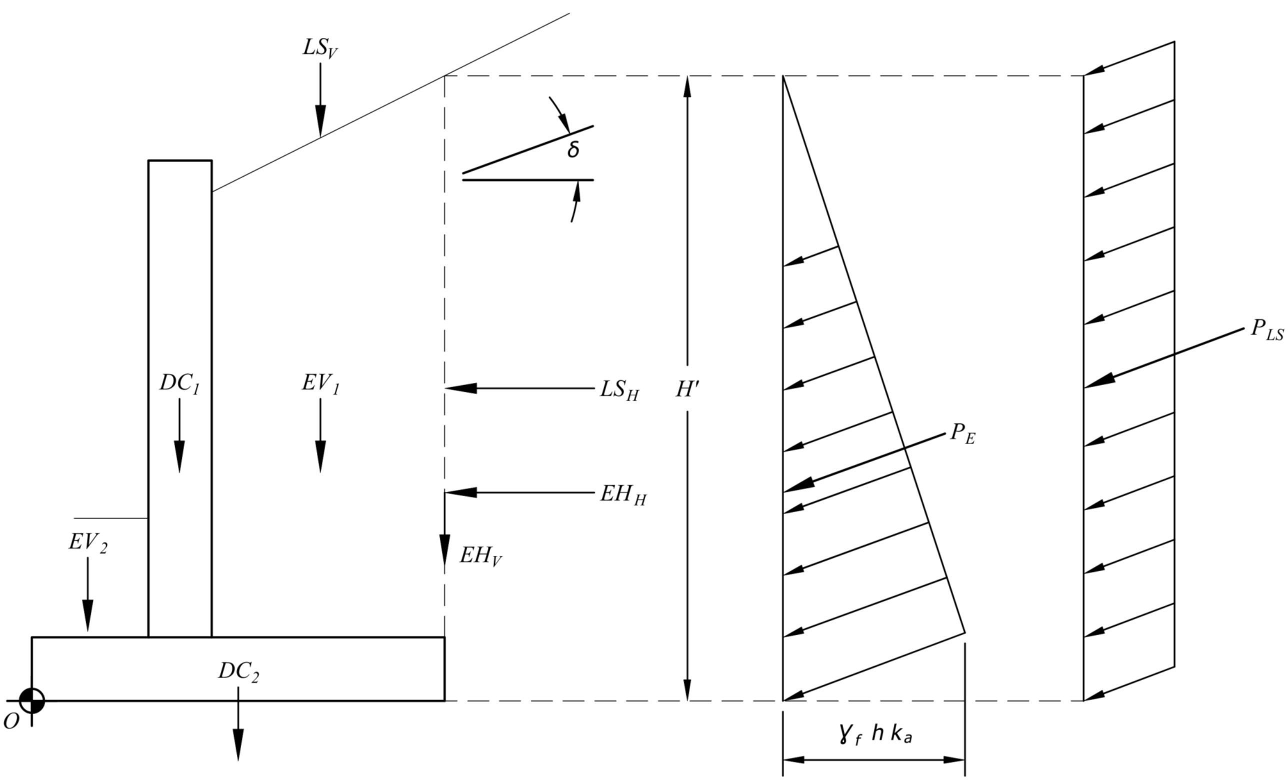


Figure 2.3-1: Loads on Wingwall

Precast "T" Wingwall

Table 2.3-1 — Vertical Loads & Moments				
Load Type	Description	V (kip/ft)	Moment Arm (ft)	MV (kip-ft)/ft
DC_1	Stem Dead Load	1.05	2.00	2.10
DC_2	Footing Dead Load	1.50	5.00	7.50
EV_1	Vertical Pressure From Dead Load Of Fill On Heel	7.54	6.53	49.22
EV_2	Vertical Pressure From Dead Load Of Fill On Toe	0.45	0.75	0.34
EH_V	Vertical Component of Horizontal Earth Pressure	0.77	10.00	7.72
LS_V	Vertical Component of Live Load Surcharge	0.00	10.00	0.00

Table 2.3-2 — Horizontal Loads & Moments				
Load Type	Description	H (kip/ft)	Moment Arm (ft)	MH (kip-ft)/ft
EH_H	Horizontal Component of Earth Pressure	2.12	3.75	7.96
LS_H	Horizontal Component of Live Load Surcharge	0.79	5.63	4.42

Precast "T" Wingwall

2.4 Factored Loads

Maximum and minimum load factors are used to determine extreme load effects on the wingwall. Factored loads and moments for each limit state are calculated by applying the appropriate load factors per AASHTO Tables 3.4.1-1 and 3.4.1-2.

The vertical component of the live load surcharge, LS_V, is not used in the analysis of sliding and overturning but is used to analyze bearing as shown in AASHTO 11.5.6 Figure C11.5.6-3a. The service limit state is used for crack control calculations.

Total Factored Force Effect:

$$Q = \sum n_i \cdot \gamma_i \cdot Q_i$$

AASHTO 3.4.1-1

where,

Q_i = force effects from loads calculated in 2.3

γ_i = load factors as shown in Table 2.4-1

$n_i = n_D \cdot n_R \cdot n_I \geq 0.95$ for loads which a maximum value of γ_i is appropriate

$= \dfrac{1}{n_D \cdot n_R \cdot n_I} \leq 1.0$ for loads which a minimum value of γ_i is appropriate

Load Modifiers:

$n_D := 1.0$ ductility *AASHTO 1.3.3*

$n_R := 1.0$ redundancy *AASHTO 1.3.4*

$n_I := 1.0$ operational classification *AASHTO 1.3.5*

Table 2.4-1 — Load Factors

Load Combination	γ_{DC}	γ_{EV}	γ_{EH}	γ_{LS_V}	γ_{LS_H}	Application
Strength Ia	0.90	1.00	1.50	-	1.75	Sliding, Eccentricity
Strength Ib	1.25	1.35	1.50	1.75	1.75	Bearing, Strength Design
Service	1.00	1.00	1.00	1.00	1.00	Wall Crack Control

Precast "T" Wingwall

Table 2.4-2 —Summary of Loads				
Load Combination	Vertical Load & Moment		Horizontal Load & Moment	
	V (kip/ft)	MV (kip-ft)/ft	H (kip/ft)	MH (kip-ft)/ft
Strength Ia	11.44	69.78	4.56	19.67
Strength Ib	15.13	90.48	4.56	19.67
Service	11.31	66.88	2.91	12.38

3. Stability Checks

The proportions of the wingwall are checked in this section to ensure stability against bearing capacity failure, overturning, and sliding in accordance with AASHTO 11.6.3.

3.1 Eccentricity Limits

AASHTO 11.6.3.3

$$e_{max} := \frac{B}{3} = 3.33\ ft$$ *AASHTO 11.6.3.3*

$$e_i := \frac{B}{2} - \frac{MV_i - MH_i}{V_i}$$

Strength Ia:

$$\frac{e_{Ia}}{e_{max}} = 0.19 \le 1.0$$ **OK**

Precast "T" Wingwall

3.2 Bearing Resistance Check
AASHTO 11.6.3.2

$q_R := \phi_b \cdot q_n = 4125\ psf$ *Factored Bearing Resistance On Soil*

$\sigma_{v_i} := \dfrac{V_i}{B - 2 \cdot \left| e_i \right|}$ *AASHTO 11.6.3.2-1*

Strength Ib:

$\sigma_{v_{Ib}} = 1616.07\ psf$

$\dfrac{\sigma_{v_{Ib}}}{q_R} = 0.39 \le 1.0$ **OK**

3.3 Limit Settlement
AASHTO 10.6.2.4

$\Delta_s := \dfrac{\sigma_{v_{service}}}{k_s} = 0.08\ in$ *Differential Settlement*

$\Delta_{max} := \dfrac{B}{500} = 0.24\ in$ *Limiting Differential Settlement*

$\theta_s := \operatorname{atan}\left(\dfrac{\Delta_s}{B}\right) = 0.04\ deg$ *Rotation Due to Settlement*

$\Delta_w := H_{wall} \cdot \sin\left(\theta_s\right) = 0.07\ in$ *Tilt Due to Settlement*

$\dfrac{\Delta_s}{\Delta_{max}} = 0.34 \le 1.0$ **OK**

Precast "T" Wingwall

3.4 Sliding Check
AASHTO 11.6.3.6

$R_u := H_{Ia} = 4.56 \ \frac{kip}{ft}$ *Maximum Total Horizontal Force*

$V_{Ia} = 11.44 \ \frac{kip}{ft}$ *Maximum Total Vertical Force*

$h := T_f + H_{TF} = 42 \ in$ *Height of Soil For Passive Resistance*

$h_{neglect} := 42 \ in$ *Neglected Height of Soil For Passive Resistance*

$R_{ep} := \max\left(0 \cdot plf, \frac{1}{2} \cdot EFP_p \cdot \left(h^2 - h_{neglect}{}^2\right)\right) = 0 \ \frac{kip}{ft}$ *Nominal Passive Resistance*

$R_\tau := V_{Ia} \cdot \tan\left(\delta_{fd}\right) = 4.62 \ \frac{kip}{ft}$ *Nominal Sliding Resistance (AASHTO Eq. 10.6.3.4-2)*

$R_R := \phi_T \cdot R_\tau + \phi_{ep} \cdot R_{ep} = 4.62 \ \frac{kip}{ft}$ *Factored Sliding Resistance (AASHTO Eq. 10.6.3.4-1)*

$\frac{R_u}{R_R} = 0.99 \ \le \ 1.0$ **OK**

Precast "T" Wingwall

4.0 STRENGTH DESIGN

The wingwall design is based on flexure at critical sections taken at the front, back and bottom of the stem wall. Shear design will be based on the same critical section used for flexure. Calculations for crack control, temperature and shrinkage, and shear friction (if applicable) for the stem, heel, and toe are also included in this section.

$f'_c = 5000\ psi$ — *Concrete Compressive Strength*

$f_y = 60\ ksi$ — *Yield Strength of Reinforcement*

$\gamma_c = 150\ pcf$ — *Concrete Unit Weight*

$K_1 := 1.0$ — *Correction Factor For Aggregate (AASHTO 5.4.2.4)*

$E_s = 29000\ ksi$ — *Modulus of Elasticity of Reinforcement (AASHTO 5.4.3.2)*

$$E_c := 120000\ ksi \cdot K_1 \cdot \left(\frac{\gamma_c}{1000\ pcf}\right)^{2.0} \cdot \left(\frac{f'_c}{ksi}\right)^{0.33} = 4592.2\ ksi$$
Modulus of Elasticity of Concrete (AASHTO 5.4.2.4)

$$n := \frac{E_s}{E_c} = 6.32$$
Modular Ratio (AASHTO 5.6.1)

$$\beta_1 := 0.85 - \left(\frac{f'_c}{ksi} - 4.0\right) \cdot 0.05 = 0.8$$
Compression Zone Factor (AASHTO 5.6.2.2)

Precast "T" Wingwall

4.1 Stem Wall Design

$d_b := 0.625\ in$ — *Diameter of Reinforcement*

$A_b := \frac{\pi}{4} \cdot d_b^{\ 2} = 0.31\ in^2$ — *Area of Reinforcement*

$s := 8\ in$ — *Spacing of Reinforcement*

$d_{cover} := 2\ in$ — *Concrete Clear Cover*

$d_s := T_w - d_{cover} - \frac{d_b}{2} = 9.69\ in$ — *Effective Depth*

Table 4.1-1 — Horizontal Loads & Moments At Base of Stem

Load Type	Description	H (kip/ft)	Moment Arm (ft)	MH (kip-ft)/ft
EH_H	Horizontal Component of Earth Pressure	1.20	2.17	2.59
LS_H	Horizontal Component of Live Load Surcharge	0.22	2.63	0.58

Table 4.1-2 — Summary of Loads

Load Combination	Horizontal Load & Moment	
	V_u (kip/ft)	M_u (kip-ft)/ft
Strength Ia	2.18	4.89
Strength Ib	2.18	4.89
Service	1.41	3.17

Precast "T" Wingwall

4.1.1 Flexure Design
AASHTO Section 5.6.3.1

$A_s := \frac{A_b}{s} = 0.46\ \frac{in^2}{ft}$ — *Design Steel Area*

$\alpha_1 := 0.85$ — *Stress Block Factor (AASHTO 5.6.2.2)*

$c := \frac{A_s \cdot f_y}{\alpha_1 \cdot f'_c \cdot \beta_1} = 0.68\ in$ — *Distance From The Extreme Compression Fiber to the Neutral Axis (AASHTO Eq. 5.6.3.1.1-4)*

$a := \beta_1 \cdot c = 0.54\ in$ — *Equivalent Stress Block (AASHTO 5.6.2.2)*

$\varepsilon_{cl} := 0.0020$ — *Compression-Controlled Strain Limit (AASHTO 5.6.2.1)*

$\varepsilon_{tl} := 0.0050$ — *Tension-Controlled Strain Limit (AASHTO 5.6.2.1)*

$\varepsilon_t := 0.003 \cdot \left(\frac{d_s - c}{c}\right) = 0.04$ — *Net Tensile Strain In The Extreme Tension Steel At Nominal Resistance*

$\phi := min\left(0.75 + 0.15 \cdot \frac{\varepsilon_t - \varepsilon_{cl}}{\varepsilon_{tl} - \varepsilon_{cl}}, 0.90\right) = 0.90$ — *Resistance Factor (AASHTO 5.5.4.2)*

$M_n := A_s \cdot f_y \cdot \left(d_s - \frac{a}{2}\right) = 21.67\ \frac{kip \cdot ft}{ft}$ — *Nominal Flexural Strength (AASHTO 5.6.3.2.2-1)*

$M_r := \phi \cdot M_n = 19.5\ \frac{kip \cdot ft}{ft}$ — *Flexural Resistance (AASHTO Eq. 5.6.3.2.1-1)*

$\frac{\max\left(M_u\right)}{M_r} = 0.25 \ \leq\ 1.0$ **OK**

Precast "T" Wingwall

4.1.2 Check Minimum Reinforcement Requirements
AASHTO Section 5.6.3.3

$\lambda := 1.0$ — *Concrete Density Modification Factor For Normal Weight Concrete (AASHTO 5.4.2.8)*

$\gamma_1 := 1.6$ — *Flexural Cracking Variability Factor (AASHTO 5.6.3.3)*

$\gamma_3 := 0.67$ — *Ratio of Specified Minimum Yield Strength to Ultimate Tensile Strength (AASHTO 5.6.3.3)*

$f_r := 0.24 \cdot \lambda \cdot \sqrt{f'_c \cdot ksi} = 536.66\ psi$ — *Modulus of Rupture of Concrete (AASHTO 5.4.2.6)*

$S_c := \frac{T_w^{\ 2}}{6} = 288\ \frac{in^3}{ft}$ — *Section Modulus*

$M_{cr} := \gamma_3 \cdot \gamma_1 \cdot f_r \cdot S_c = 13.81\ \frac{kip \cdot ft}{ft}$ — *Cracking Moment (AASHTO Eq. 5.6.3.3-1)*

$M_{req} := min\left(M_{cr}, 1.33 \cdot \max\left(M_u\right)\right) = 6.51\ \frac{kip \cdot ft}{ft}$ — *Required Moment For Minimum Reinforcement*

$\frac{M_{req}}{M_r} = 0.33\ \le\ 1.0$ **OK**

4.1.3 Standard Hook Development Length
AASHTO Section 5.10.8.2.4a

$\lambda_{rc} := 0.8$ — *Reinforcement Confinement Factor*

$\lambda_{cw} := 1.2$ — *Coating Factor (Epoxy Coated)*

$\lambda_{er} := \frac{\max\left(M_u\right)}{\phi \cdot A_s \cdot f_y \cdot \left(d_s - \frac{a}{2}\right)} = 0.25$ — *Excess Reinforcement Factor*

$$l_{hb} := \frac{38.0 \cdot d_b}{60} \cdot \left(\frac{f_y}{\sqrt{f'_c \cdot ksi}}\right) = 10.62\ in$$

$l_{dh} := \max\left(l_{hb} \cdot \left(\frac{\lambda_{rc} \cdot \lambda_{cw} \cdot \lambda_{er}}{\lambda}\right), 6\ in, 8 \cdot d_b\right) = 6\ in$ — *Development Length of Standard Hook (AASHTO Eq. 5.10.8.2.4a-1)*

$\frac{l_{dh}}{T_f - d_{cover}} = 0.6\ \le\ 1.0$ **OK**

4.1.4 Control of Cracking By Distribution of Reinforcement
AASHTO Section 5.6.7

$\gamma_e := 0.75$ — *Exposure Factor*

$h := T_w$ — *Overall Thickness*

$d_c := d_{cover} + \frac{1}{2} \cdot d_b = 2.31\ in$ — *Concrete Cover*

$d_e := h - d_c = 9.69\ in$ — *Effective Depth*

$\rho := \frac{A_s}{d_e} = 0.004$ — *Reinforcement Ratio*

$n = 6.32$ — *Modular Ratio*

$k := \sqrt{2 \cdot n \cdot \rho + (n \cdot \rho)^2} - n \cdot \rho = 0.2$

$j := 1 - \frac{k}{3} = 0.93$

$f_{ss} := \frac{M_{u_{service}}}{A_s \cdot j \cdot d_e} = 9.13\ ksi$ — *Tensile Stress in Reinforcement*

$\beta_s := 1 + \frac{d_c}{0.7 \cdot (h - d_c)} = 1.34$ — *Ratio of Flexural Strain At the Extreme Tension Face to the Strain of the Reinforcement (AASHTO Eq. 5.6.7-2)*

$s_{max} := \frac{700 \cdot \gamma_e}{\beta_s \cdot f_{ss}} \cdot \frac{kip}{in} - 2 \cdot d_c = 38.25\ in$ — *Maximum Spacing (AASHTO Eq. 5.6.7-1)*

$\frac{s}{s_{max}} = 0.21 \leq 1.0$ **OK**

Precast "T" Wingwall

4.1.5 Shear Design

AASHTO Section 5.7.3.3

$$d_v := \max\left(\frac{\max(M_n)}{A_s \cdot f_y}, 0.9 \cdot d_e, 0.72 \cdot T_w\right) = 9.42\ in$$

Effective Shear Depth (AASHTO 5.7.2.8)

$$M_U := \max(M_u, V_u \cdot d_v) = 4.89\ \frac{kip \cdot ft}{ft}$$

Factored Moment

$$V_U := \max(V_u) = 2.18\ \frac{kip}{ft}$$

Factored Shear

$$N_U := -0.9 \cdot DC_1 = -0.95\ \frac{kip}{ft}$$

Factored Axial Force

$$\varepsilon_s := \frac{\frac{|M_U|}{d_v} + 0.5 \cdot N_U + |V_U|}{E_s \cdot A_s} = 0.0006$$

Longitudinal Tensile Strain (AASHTO Eq. 5.7.3.4.2-4)

$$s_x := \text{if } A_s \geq 0.003 \cdot s \;\; \| \; min(d_v, s) \;\; \text{else} \;\; \| \; d_v \;\; = 8\ in$$

Crack Spacing Parameter (AASHTO 5.7.3.4.2)

$$a_g := 0.75\ in$$

Maximum Aggregate Size

$$s_{xe} := min\left(\max\left(12\ in, s_x \cdot \frac{1.38\ in}{a_g + 0.63\ in}\right), 80\ in\right) = 12\ in$$

Crack Spacing Parameter (AASHTO Eq. 5.7.3.4.2-7)

$$\beta := \frac{4.8}{(1 + 750 \cdot \varepsilon_s)} \cdot \frac{51\ in}{(39\ in + s_{xe})} = 3.32$$

Shear Resistance Parameter (AASHTO Eq. 5.7.3.4.2-2)

$$V_c := 0.0316 \cdot \beta \cdot \lambda \cdot \sqrt{f'_c \cdot ksi} \cdot d_v = 26.5\ \frac{kip}{ft}$$

Nominal Shear Resistance of Concrete (AASHTO Eq. 5.7.3.3-3)

$$V_n := min(V_c, 0.25 \cdot f'_c \cdot d_v) = 26.5\ \frac{kip}{ft}$$

Nominal Shear Resistance

$$\frac{V_U}{0.9\ V_n} = 0.09 \;\; \leq \; 1.0$$ **OK**

Shear Strength Check For Unreinforced Section (AASHTO 5.7.2.3)

Precast "T" Wingwall

4.1.6 Check Deflection of Stem

AASHTO Section 5.6.3.5

$$\rho_s := \frac{A_s}{T_w} = 0.0032$$ *Steel Ratio*

$$\xi := 2.0$$ *Time Dependent Factor For Sustained Loads*

$$\lambda_\Delta := \frac{\xi}{1 + 50 \cdot \rho_s} = 1.72$$ *Deflection Amplification For Sustained Loads*

$$M_a := M_{u_{service}} = 3.17\ \frac{kip \cdot ft}{ft}$$ *Maximum Total Service Level Moment*

$$M_{cr} := f_r \cdot S_c = 12.88\ \frac{kip \cdot ft}{ft}$$ *Cracking Moment*

$$I_g := \frac{{T_w}^3}{12} = 1728\ \frac{in^4}{ft}$$ *Moment of Inertia of Gross Section*

$$c_s := n \cdot A_s \cdot \left(\sqrt{1 + \frac{2 \cdot d_s}{n \cdot A_s}} - 1\right) = 0.16\ ft$$

$$I_{cr} := \frac{{c_s}^3}{3} + n \cdot A_s \cdot \left(d_s - c_s\right)^2 = 203.64\ \frac{in^4}{ft}$$ *Moment of Inertia of Cracked Section*

$$I_e := min\left(\left(\frac{M_{cr}}{M_a}\right)^3 \cdot I_g + \left(1 - \left(\frac{M_{cr}}{M_a}\right)^3\right) \cdot I_{cr}, I_g\right) = 1728\ \frac{in^4}{ft}$$ *Effective Moment of Inertia*

$$\Delta_p := k_{a.int} \cdot LS = 122.07\ psf$$ *Maximum Horizontal Pressure Due To Surcharge*

$$\Delta := \Delta_w + \frac{\lambda_\Delta \cdot 2 \cdot EH_h \cdot \left(H_R - T_f\right)^3}{15 \cdot E_c \cdot I_e} + \frac{\Delta_p \cdot \left(H_R - T_f\right)^4}{8 \cdot E_c \cdot I_e} = 0.09\ in$$ *Total Deflection At Service Load*

$$\Delta_{max} := \frac{H_R}{120} = 0.75\ in$$ *Maximum Overall Deflection*

$$\frac{\Delta}{\Delta_{max}} = 0.12 \le 1.0$$ **OK**

Precast "T" Wingwall

4.1.7 Shrinkage and Temperature Reinforcement - Stem

AASHTO Section 5.10.6

$d_b := 0.625\ in$ — *Diameter of Reinforcement*

$s_{TS} := 12\ in$ — *Spacing of Reinforcement*

$A_b := \frac{\pi}{4} \cdot d_b^{\ 2} = 0.31\ in^2$ — *Area of Reinforcement*

$A_s := \frac{A_b}{s_{TS}} = 0.31\ \frac{in^2}{ft}$ — *Design Steel Area*

$b := H_{wall} - T_f = 84\ in$

$h := T_w = 12\ in$ — *Thickness of Section*

$$A_{s.min} := min\left(\max\left(0.11\ \frac{in^2}{ft}, \frac{1.30 \cdot b \cdot h}{2 \cdot (b+h) \cdot f_y} \cdot \frac{ksi}{12}\right), 0.60\ \frac{in^2}{ft}\right) = 0.114\ \frac{in^2}{ft}$$

Minimum Steel Area (AASHTO 5.10.6-2)

$\frac{A_{s.min}}{A_s} = 0.37 \ \le\ 1.0$ **OK**

4.2 Footing Heel Design

$d_{b.top} := 0.625\ in$ *Diameter of Top Reinforcement*

$d_{b.bot} := 0.625\ in$ *Diameter of Bottom Reinforcement*

$A_{b.top} := \frac{\pi}{4} \cdot d_{b.top}^{\ 2} = 0.31\ in^2$ *Area of Top Reinforcement*

$A_{b.bot} := \frac{\pi}{4} \cdot d_{b.bot}^{\ 2} = 0.31\ in^2$ *Area of Bottom Reinforcement*

$s = 8\ in$ *Spacing of Reinforcement*

$d_{cover} := 2\ in$ *Concrete Clear Cover*

$d_s := T_f - d_{cover} - \frac{d_{b.top}}{2} = 9.69\ in$ *Effective Depth*

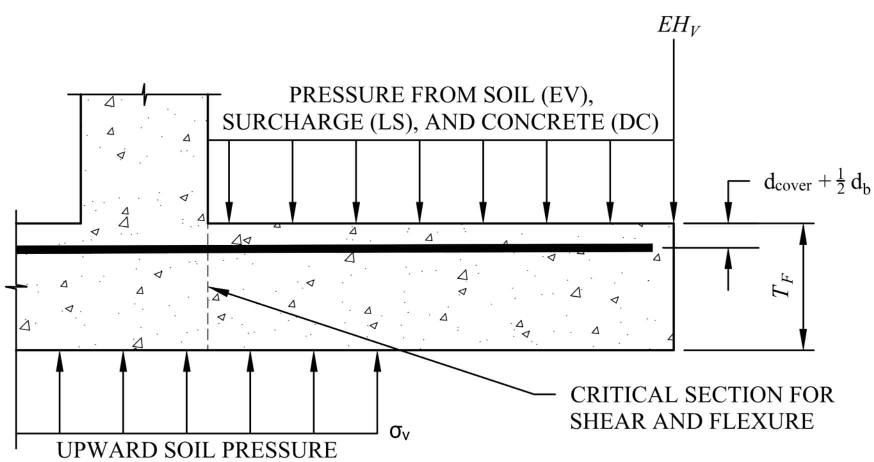


Figure 4.2-1: Heel Design Details

Table 4.2-1 — Vertical Loads & Moments				
Load Type	Description	V (kip/ft)	Moment Arm (ft)	MV (kip-ft)/ft
DC	Footing Dead Load	1.13	3.75	4.22
EV	Vertical Pressure From Dead Load Of Fill On Heel	7.54	4.03	30.38
EH_V	Vertical Component of Horizontal Earth Pressure	0.77	7.50	5.79
LS_V	Vertical Component of Live Load Surcharge	0.00	7.50	0.00

Precast "T" Wingwall

Table 4.2-2 — Summary of Forces		
Load Combination	Vertical Load & Moment	
	V_u (kip/ft)	M_u (kip-ft)/ft
Strength Ia	1.53	17.27
Strength Ib	1.65	16.92
Service	1.06	10.49

4.2.1 Tension Design of Heel

AASHTO Section 5.6.6.1

$\phi := 0.90$ — *Resistance Factor For Tension*

$A_s := \frac{A_{b.top} + A_{b.bot}}{s} = 0.92 \ \frac{in^2}{ft}$ — *Design Steel Area*

$P_n := f_y \cdot A_s = 55.22 \ \frac{kip}{ft}$ — *Nominal Tensile Resistance (AASHTO 5.8.2.4.1-1)*

$P_r := f_y \cdot A_s = 55.22 \ \frac{kip}{ft}$ — *Factored Tensile Resistance (AASHTO 5.6.6.1-1)*

$P_{req} := \max\left(V_{u.stem}\right) = 2.18 \ \frac{kip}{ft}$ — *Required Tensile Strength*

$\frac{P_{req}}{P_r} = 0.04 \ \leq \ 1.0$ **OK**

4.2.2 Lap Splice in Tension

AASHTO Section 5.10.8.4.3a

$\lambda_{rl} := 1.0$ — *Reinforcement Location Factor*

$\lambda_{cf} := 1.2$ — *Coating Factor (Epoxy Coated)*

$\lambda_{rc} := 1.0$ — *Reinforcement Confinement Factor*

$\lambda_{er} := \frac{P_{req}}{P_r} = 0.04$ — *Excess Reinforcement Factor*

Precast "T" Wingwall

$$l_{db} := 2.4 \cdot d_b \cdot \frac{f_y}{\sqrt{f'_c \cdot ksi}} = 40.25\ in$$

$$l_d := \max\left(12\ in, l_{db} \cdot \left(\frac{\lambda_{rl} \cdot \lambda_{cf} \cdot \lambda_{rc} \cdot \lambda_{er}}{\lambda}\right)\right) = 12\ in$$

Development Length of Reinforcement
(AASHTO Eq. 5.10.8.2.1a-1)

$$l := 1.3 \cdot l_d = 15.6\ in$$

Require Lap Splice in Tension
(Class B Splice)

4.2.3 Flexure Design of Heel
AASHTO Section 5.6.3.1

$$A_s := \frac{A_{b.top}}{s} = 0.46\ \frac{in^2}{ft}$$

Design Steel Area

$$\alpha_1 := 0.85$$

Stress Block Factor
(AASHTO 5.6.2.2)

$$c := \frac{A_s \cdot f_y}{\alpha_1 \cdot f'_c \cdot \beta_1} = 0.68\ in$$

Distance From The Extreme Compression Fiber to the Neutral Axis
(AASHTO Eq. 5.6.3.1.1-4)

$$a := \beta_1 \cdot c = 0.54\ in$$

Equivalent Stress Block
(AASHTO 5.6.2.2)

$$\varepsilon_{cl} := 0.0020$$

Compression-Controlled Strain Limit
(AASHTO 5.6.2.1)

$$\varepsilon_{tl} := 0.0050$$

Tension-Controlled Strain Limit
(AASHTO 5.6.2.1)

$$\varepsilon_t := 0.003 \cdot \left(\frac{d_s - c}{c}\right) = 0.04$$

Net Tensile Strain In The Extreme Tension Steel At Nominal Resistance

$$\phi := min\left(0.75 + 0.15 \cdot \frac{\varepsilon_t - \varepsilon_{cl}}{\varepsilon_{tl} - \varepsilon_{cl}}, 0.90\right) = 0.90$$

Resistance Factor
(AASHTO 5.5.4.2)

$$M_n := A_s \cdot f_y \cdot \left(d_s - \frac{a}{2}\right) = 21.67\ \frac{kip \cdot ft}{ft}$$

Nominal Flexural Strength
(AASHTO 5.6.3.2.2-1)

$$M_r := \phi \cdot M_n = 19.5\ \frac{kip \cdot ft}{ft}$$

Flexural Resistance
(AASHTO Eq. 5.6.3.2.1-1)

$$\frac{\max(M_u)}{M_r} = 0.89 \le 1.0$$ **OK**

4.2.4 Combined Tension and Flexure

$$\frac{\max\left(M_u\right)}{M_r}+\frac{P_{req}}{P_r}=0.92 \quad \le 1.0 \quad \textbf{OK}$$

4.2.5 Check Minimum Reinforcement Requirements

AASHTO Section 5.6.3.3

$\lambda := 1.0$ — *Concrete Density Modification Factor For Normal Weight Concrete (AASHTO 5.4.2.8)*

$\gamma_1 := 1.6$ — *Flexural Cracking Variability Factor (AASHTO 5.6.3.3)*

$\gamma_3 := 0.67$ — *Ratio of Specified Minimum Yield Strength to Ultimate Tensile Strength (AASHTO 5.6.3.3)*

$f_r := 0.24 \cdot \lambda \cdot \sqrt{f'_c \cdot ksi} = 536.66\ psi$ — *Modulus of Rupture of Concrete (AASHTO 5.4.2.6)*

$S_c := \frac{{T_f}^2}{6} = 288\ \frac{in^3}{ft}$ — *Section Modulus*

$M_{cr} := \gamma_3 \cdot \gamma_1 \cdot f_r \cdot S_c = 13.81\ \frac{kip \cdot ft}{ft}$ — *Cracking Moment (AASHTO Eq. 5.6.3.3-1)*

$M_{req} := min\left(M_{cr}, 1.33 \cdot \max\left(M_u\right)\right) = 13.81\ \frac{kip \cdot ft}{ft}$ — *Required Moment For Minimum Reinforcement*

$$\frac{M_{req}}{M_r}=0.71 \quad \le 1.0 \quad \textbf{OK}$$

4.2.6 Tension Development Length of Standard Hook

AASHTO Section 5.10.8.2.4a

$\lambda_{rc} := 0.8$ — *Reinforcement Confinement Factor*

$\lambda_{cw} := 1.2$ — *Coating Factor (Epoxy Coated)*

$\lambda_{er} := \frac{\max\left(M_u\right)}{\phi \cdot A_s \cdot f_y \cdot \left(d_s - \frac{a}{2}\right)} + \frac{P_{req}}{P_r} = 0.92$ — *Excess Reinforcement Factor*

$$l_{hb} := \frac{38.0 \cdot d_{b.top}}{60} \cdot \left(\frac{f_y}{\sqrt{f'_c \cdot ksi}}\right) = 10.62\ in$$

Precast "T" Wingwall

$$l_{dh} := \max\left(l_{hb} \cdot \left(\frac{\lambda_{rc} \cdot \lambda_{cw} \cdot \lambda_{er}}{\lambda}\right), 6\ in, 8 \cdot d_{b.top}\right) = 9.43\ in$$

Development Length of Standard Hook
(AASHTO Eq. 5.10.8.2.4a-1)

$$\frac{l_{dh}}{A - d_{cover}} = 0.59 \le 1.0$$ **OK**

4.2.7 Control of Cracking By Distribution of Reinforcement

AASHTO Section 5.6.7

$\gamma_e := 1.00$ — *Exposure Factor*

$h := T_f$ — *Overall Thickness*

$d_c := d_{cover} + \frac{1}{2} \cdot d_{b.top} = 2.31\ in$ — *Concrete Cover*

$d_e := h - d_c = 9.69\ in$ — *Effective Depth*

$\rho := \frac{A_s}{d_e} = 0.004$ — *Reinforcement Ratio*

$n = 6.32$ — *Modular Ratio*

$$k := \sqrt{2 \cdot n \cdot \rho + (n \cdot \rho)^2} - n \cdot \rho = 0.2$$

$$j := 1 - \frac{k}{3} = 0.93$$

$f_{ss} := \frac{M_{u_{service}}}{A_s \cdot j \cdot d_e} = 30.25\ ksi$ — *Tensile Stress in Reinforcement*

$\beta_s := 1 + \frac{d_c}{0.7 \cdot (h - d_c)} = 1.34$ — *Ratio of Flexural Strain At the Extreme Tension Face to the Strain of the Reinforcement*
(AASHTO Eq. 5.6.7-2)

$s_{max} := \frac{700 \cdot \gamma_e}{\beta_s \cdot f_{ss}} \cdot \frac{kip}{in} - 2 \cdot d_c = 12.63\ in$ — *Maximum Spacing*
(AASHTO Eq. 5.6.7-1)

$$\frac{s}{s_{max}} = 0.63 \le 1.0$$ **OK**

Precast "T" Wingwall

4.2.8 Shear Design
AASHTO Section 5.7.3.3

$$d_v := \max\left(\frac{\max(M_n)}{A_s \cdot f_y}, 0.9 \cdot d_e, 0.72 \cdot T_f\right) = 9.42 \; in$$

Effective Shear Depth (AASHTO 5.7.2.8)

$$M_U := \max(M_u, V_u \cdot d_v) = 17.27 \; \frac{kip \cdot ft}{ft}$$

Factored Moment

$$V_U := \max(V_u) = 1.65 \; \frac{kip}{ft}$$

Factored Shear

$$N_U := 0 \; \frac{kip}{ft}$$

Factored Axial Force

$$\varepsilon_s := \frac{\frac{|M_U|}{d_v} + 0.5 \cdot N_U + |V_U|}{E_s \cdot A_s} = 0.0018$$

Longitudinal Tensile Strain (AASHTO Eq. 5.7.3.4.2-4)

$$s_x := \text{if } A_s \ge 0.003 \cdot s \;\; \| \; min(d_v, s) \;\; \text{else} \;\; \| \; d_v \; = 8 \; in$$

Crack Spacing Parameter (AASHTO 5.7.3.4.2)

$$a_g := 0.75 \; in$$

Maximum Aggregate Size

$$s_{xe} := min\left(\max\left(12 \; in, s_x \cdot \frac{1.38 \; in}{a_g + 0.63 \; in}\right), 80 \; in\right) = 12 \; in$$

Crack Spacing Parameter (AASHTO Eq. 5.7.3.4.2-7)

$$\beta := \frac{4.8}{(1 + 750 \cdot \varepsilon_s)} \cdot \frac{51 \; in}{(39 \; in + s_{xe})} = 2.06$$

Shear Resistance Parameter (AASHTO Eq. 5.7.3.4.2-2)

$$V_c := 0.0316 \cdot \beta \cdot \lambda \cdot \sqrt{f'_c \cdot ksi} \cdot d_v = 16.45 \; \frac{kip}{ft}$$

Nominal Shear Resistance of Concrete (AASHTO Eq. 5.7.3.3-3)

$$V_n := min(V_c, 0.25 \cdot f'_c \cdot d_v) = 16.45 \; \frac{kip}{ft}$$

Nominal Shear Resistance

$$\frac{V_U}{0.9 \; V_n} = 0.11 \;\; \le \; 1.0$$ **OK**

Shear Strength Check For Unreinforced Section (AASHTO 5.7.2.3)

Precast "T" Wingwall

4.2.9 Shear Friction At Construction Joint

AASHTO Section 5.7.4

Normal weight concrete placed against a clean concrete surface, free of laitance, with surface intentionally roughened to an amplitude of 0.25in.

$\phi := 0.9$

$c := 0.24\ ksi$ — *Cohesion Factor (AASHTO 5.7.4.4)*

$\mu := 1.0$ — *Friction Factor (AASHTO 5.7.4.4)*

$K_1 := 0.25$ — *Fraction of Concrete Strength Available to Resist Interface Shear (AASHTO 5.7.4.4)*

$K_2 := 1.5\ ksi$ — *Limiting Interface Shear Resistance (AASHTO 5.7.4.4)*

$A_{vf} := A_s = 0.46\ \frac{in^2}{ft}$ — *Area of Interface Shear Reinforcement*

$V_{ui} := \max\left(V_u\right) = 1.65\ \frac{kip}{ft}$ — *Maximum Factored Interface Shear Force*

$P_c := 0\ \frac{kip}{ft}$ — *Permanent Net Compressive Force*

$f_y = 60\ ksi$ — *Yield Strength of Steel*

$A_{cv} := T_f = 144\ \frac{in^2}{ft}$ — *Area of Concrete Engaged In Shear Transfer*

$$A_{vf.min} := min\left(\frac{0.05\ ksi \cdot A_{cv}}{f_y}, \frac{1.33 \cdot V_{ui}}{\phi \cdot \mu \cdot f_y}\right) = 0.04\ \frac{in^2}{ft}$$

Minimum Steel Area (AASHTO Eq. 5.7.4.2-1)

$$V_{ni} := min\left(c \cdot A_{cv} + \mu \cdot \left(A_{vf} \cdot f_y + P_c\right), K_1 \cdot f'_c \cdot A_{cv}, K_2 \cdot A_{cv}\right) = 62.17\ \frac{kip}{ft}$$

Nominal Interface Shear Resistance (AASHTO Eq. 5.7.4.3-3)

$$V_{ri} := \phi \cdot V_{ni} = 55.95\ \frac{kip}{ft}$$

Factored Interface Shear Resistance (AASHTO Eq. 5.7.4.3-1)

$\frac{V_{ui}}{V_{ri}} = 0.03\ \le\ 1.0$ **OK**

Precast "T" Wingwall

4.2.10 Shrinkage and Temperature Reinforcement

AASHTO Section 5.10.6

$d_b := 0.625\ in$ — *Diameter of Reinforcement*

$s_{TS} := 12\ in$ — *Spacing of Reinforcement*

$A_b := \frac{\pi}{4} \cdot d_b^{\ 2} = 0.31\ in^2$ — *Area of Reinforcement*

$A_s := \frac{A_b}{s_{TS}} = 0.31\ \frac{in^2}{ft}$ — *Design Steel Area*

$b := B = 120\ in$

$h := T_w = 12\ in$ — *Thickness of Section*

$A_{s.min} := min\left(\max\left(0.11\ \frac{in^2}{ft}, \frac{1.30 \cdot b \cdot h}{2 \cdot (b+h) \cdot f_y} \cdot \frac{ksi}{12}\right), 0.60\ \frac{in^2}{ft}\right) = 0.118\ \frac{in^2}{ft}$ — *Minimum Steel Area (AASHTO 5.10.6-2)*

$\frac{A_{s.min}}{A_s} = 0.39 \ \leq\ 1.0$ **OK**

4.3 Footing Toe Design

$d_b := d_{b.bot} = 0.63\ in$ *Diameter of Reinforcement*

$A_b := \frac{\pi}{4} \cdot d_b^{\ 2} = 0.31\ in^2$ *Area of Reinforcement*

$s = 8\ in$ *Spacing of Reinforcement*

$d_{cover} := 2\ in$ *Concrete Clear Cover*

$d_s := T_f - d_{cover} - \frac{d_b}{2} = 9.69\ in$ *Effective Depth*

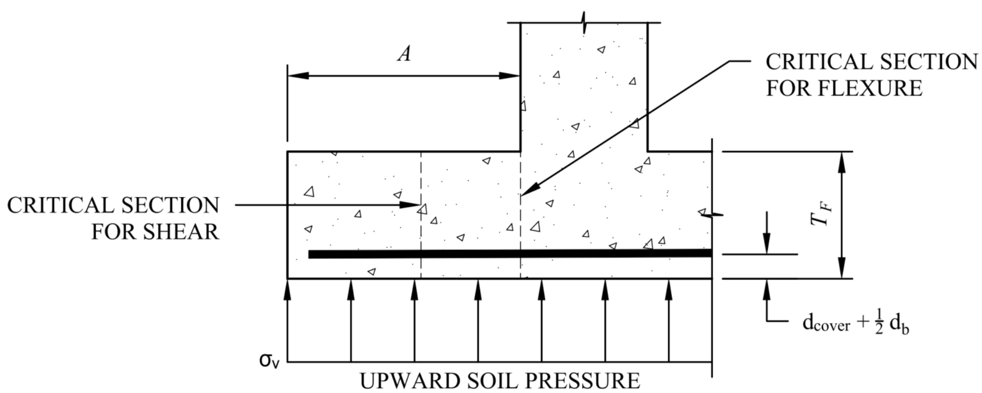


Table 4.3-1 — Summary of Forces		
Load Combination	Vertical Load & Moment	
	V_u (kip/ft)	M_u (kip-ft)/ft
Strength Ia	0.90	1.47
Strength Ib	1.12	1.82
Service	0.81	1.32

Precast "T" Wingwall

4.3.1 Flexure Design of Toe

AASHTO Section 5.6.3.1

$A_s := \frac{A_b}{s} = 0.46\ \frac{in^2}{ft}$ *Design Steel Area*

$\alpha_1 := 0.85$ *Stress Block Factor (AASHTO 5.6.2.2)*

$c := \frac{A_s \cdot f_y}{\alpha_1 \cdot f'_c \cdot \beta_1} = 0.68\ in$ *Distance From The Extreme Compression Fiber to the Neutral Axis (AASHTO Eq. 5.6.3.1.1-4)*

$a := \beta_1 \cdot c = 0.54\ in$ *Equivalent Stress Block (AASHTO 5.6.2.2)*

$\varepsilon_{cl} := 0.0020$ *Compression-Controlled Strain Limit (AASHTO 5.6.2.1)*

$\varepsilon_{tl} := 0.0050$ *Tension-Controlled Strain Limit (AASHTO 5.6.2.1)*

$\varepsilon_t := 0.003 \cdot \left(\frac{d_s - c}{c}\right) = 0.04$ *Net Tensile Strain In The Extreme Tension Steel At Nominal Resistance*

$\phi := min\left(0.75 + 0.15 \cdot \frac{\varepsilon_t - \varepsilon_{cl}}{\varepsilon_{tl} - \varepsilon_{cl}}, 0.90\right) = 0.90$ *Resistance Factor (AASHTO 5.5.4.2)*

$M_n := A_s \cdot f_y \cdot \left(d_s - \frac{a}{2}\right) = 21.67\ \frac{kip \cdot ft}{ft}$ *Nominal Flexural Strength (AASHTO 5.6.3.2.2-1)*

$M_r := \phi \cdot M_n = 19.5\ \frac{kip \cdot ft}{ft}$ *Flexural Resistance (AASHTO Eq. 5.6.3.2.1-1)*

$\frac{\max\left(M_u\right)}{M_r} = 0.09 \ \le\ 1.0$ **OK**

Precast "T" Wingwall

4.3.2 Check Minimum Reinforcement Requirements

AASHTO Section 5.6.3.3

$\lambda := 1.0$ — *Concrete Density Modification Factor For Normal Weight Concrete (AASHTO 5.4.2.8)*

$\gamma_1 := 1.6$ — *Flexural Cracking Variability Factor (AASHTO 5.6.3.3)*

$\gamma_3 := 0.67$ — *Ratio of Specified Minimum Yield Strength to Ultimate Tensile Strength (AASHTO 5.6.3.3)*

$f_r := 0.24 \cdot \lambda \cdot \sqrt{f'_c \cdot ksi} = 536.66\ psi$ — *Modulus of Rupture of Concrete (AASHTO 5.4.2.6)*

$S_c := \frac{{T_f}^2}{6} = 288\ \frac{in^3}{ft}$ — *Section Modulus*

$M_{cr} := \gamma_3 \cdot \gamma_1 \cdot f_r \cdot S_c = 13.81\ \frac{kip \cdot ft}{ft}$ — *Cracking Moment (AASHTO Eq. 5.6.3.3-1)*

$M_{req} := min\left(M_{cr}, 1.33 \cdot \max\left(M_u\right)\right)$ — *Required Moment For Minimum Reinforcement*

$\frac{M_{req}}{M_r} = 0.12\ \le\ 1.0$ **OK**

4.3.3 Tension Development Length

AASHTO Section 5.10.8.2.1a

$\lambda_{rl} := 1.0$ — *Reinforcement Location Factor*

$\lambda_{cf} := 1.2$ — *Coating Factor (Epoxy Coated)*

$\lambda_{rc} := 1.0$ — *Reinforcement Confinement Factor*

$\lambda_{er} := \frac{\max\left(M_u\right)}{M_r} = 0.09$ — *Excess Reinforcement Factor*

$l_{db} := 2.4 \cdot d_b \cdot \frac{f_y}{\sqrt{f'_c \cdot ksi}} = 40.25\ in$

$l_d := l_{db} \cdot \left(\frac{\lambda_{rl} \cdot \lambda_{cf} \cdot \lambda_{rc} \cdot \lambda_{er}}{\lambda}\right) = 4.5\ in$ — *Development Length of Reinforcement (AASHTO Eq. 5.10.8.2.1a-1)*

$\frac{l_d}{A} = 0.25\ \le\ 1.0$ **OK**

Precast "T" Wingwall

4.3.4 Control of Cracking By Distribution of Reinforcement
AASHTO Section 5.6.7

$\gamma_e := 1.00$ — *Exposure Factor*

$h := T_f$ — *Overall Thickness*

$d_c := d_{cover} + \frac{1}{2} \cdot d_b = 2.31\ in$ — *Concrete Cover*

$d_e := h - d_c = 9.69\ in$ — *Effective Depth*

$\rho := \frac{A_s}{d_e} = 0.004$ — *Reinforcement Ratio*

$n = 6.32$ — *Modular Ratio*

$k := \sqrt{2 \cdot n \cdot \rho + (n \cdot \rho)^2} - n \cdot \rho = 0.2$

$j := 1 - \frac{k}{3} = 0.93$

$f_{ss} := \frac{M_{u_{service}}}{A_s \cdot j \cdot d_e} = 3.81\ ksi$ — *Tensile Stress in Reinforcement*

$\beta_s := 1 + \frac{d_c}{0.7 \cdot (h - d_c)} = 1.34$ — *Ratio of Flexural Strain At the Extreme Tension Face to the Strain of the Reinforcement (AASHTO Eq. 5.6.7-2)*

$s_{max} := \frac{700 \cdot \gamma_e}{\beta_s \cdot f_{ss}} \cdot \frac{kip}{in} - 2 \cdot d_c = 132.48\ in$ — *Maximum Spacing (AASHTO Eq. 5.6.7-1)*

$\frac{s}{s_{max}} = 0.06 \ \le 1.0$ **OK**

Precast "T" Wingwall

4.3.5 Shear Design

AASHTO Section 5.7.3.3

$$d_v := \max\left(\frac{\max(M_n)}{A_s \cdot f_y}, 0.9 \cdot d_e, 0.72 \cdot T_f\right) = 9.42\ in$$

Effective Shear Depth (AASHTO 5.7.2.8)

$$M_U := \max(M_u, V_u \cdot d_v) = 1.82\ \frac{kip \cdot ft}{ft}$$

Factored Moment

$$V_U := \max(V_u) = 1.12\ \frac{kip}{ft}$$

Factored Shear

$$N_U := 0\ \frac{kip}{ft}$$

Factored Axial Force

$$\varepsilon_s := \frac{\frac{|M_U|}{d_v} + 0.5 \cdot N_U + |V_U|}{E_s \cdot A_s} = 0.0003$$

Longitudinal Tensile Strain (AASHTO Eq. 5.7.3.4.2-4)

$$s_x := \text{if } A_s \geq 0.003 \cdot s \;\; \| \; min(d_v, s) \;\; \text{else} \;\; \| \; d_v \quad = 8\ in$$

Crack Spacing Parameter (AASHTO 5.7.3.4.2)

$$a_g := 0.75\ in$$

Maximum Aggregate Size

$$s_{xe} := min\left(\max\left(12\ in, s_x \cdot \frac{1.38\ in}{a_g + 0.63\ in}\right), 80\ in\right) = 12\ in$$

Crack Spacing Parameter (AASHTO Eq. 5.7.3.4.2-7)

$$\beta := \frac{4.8}{(1 + 750 \cdot \varepsilon_s)} \cdot \frac{51\ in}{(39\ in + s_{xe})} = 4.02$$

Shear Resistance Parameter (AASHTO Eq. 5.7.3.4.2-2)

$$V_c := 0.0316 \cdot \beta \cdot \lambda \cdot \sqrt{f'_c \cdot ksi} \cdot d_v = 32.12\ \frac{kip}{ft}$$

Nominal Shear Resistance of Concrete (AASHTO Eq. 5.7.3.3-3)

$$V_n := min(V_c, 0.25 \cdot f'_c \cdot d_v) = 32.12\ \frac{kip}{ft}$$

Nominal Shear Resistance

$$\frac{V_U}{0.9\ V_n} = 0.04 \leq 1.0$$ **OK**

Shear Strength Check For Unreinforced Section (AASHTO 5.7.2.3)

4.3.6 Shear Friction At Construction Joint

AASHTO Section 5.7.4

Normal weight concrete placed against a clean concrete surface, free of laitance, with surface intentionally roughened to an amplitude of 0.25in.

$\phi := 0.9$

$c := 0.24\ ksi$ — *Cohesion Factor (AASHTO 5.7.4.4)*

$\mu := 1.0$ — *Friction Factor (AASHTO 5.7.4.4)*

$K_1 := 0.25$ — *Fraction of Concrete Strength Available to Resist Interface Shear (AASHTO 5.7.4.4)*

$K_2 := 1.5\ ksi$ — *Limiting Interface Shear Resistance (AASHTO 5.7.4.4)*

$A_{vf} := A_s = 0.46\ \frac{in^2}{ft}$ — *Area of Interface Shear Reinforcement*

$V_{ui} := \max\left(V_u\right) = 1.12\ \frac{kip}{ft}$ — *Maximum Factored Interface Shear Force*

$P_c := 0\ \frac{kip}{ft}$ — *Permanent Net Compressive Force*

$f_y = 60\ ksi$ — *Yield Strength of Steel*

$A_{cv} := T_f = 144\ \frac{in^2}{ft}$ — *Area of Concrete Engaged In Shear Transfer*

$$A_{vf.min} := min\left(\frac{0.05\ ksi \cdot A_{cv}}{f_y}, \frac{1.33 \cdot V_{ui}}{\phi \cdot \mu \cdot f_y}\right) = 0.03\ \frac{in^2}{ft}$$

Minimum Steel Area (AASHTO Eq. 5.7.4.2-1)

$$V_{ni} := min\left(c \cdot A_{cv} + \mu \cdot \left(A_{vf} \cdot f_y + P_c\right), K_1 \cdot f'_c \cdot A_{cv}, K_2 \cdot A_{cv}\right) = 62.17\ \frac{kip}{ft}$$

Nominal Interface Shear Resistance (AASHTO Eq. 5.7.4.3-3)

$$V_{ri} := \phi \cdot V_{ni} = 55.95\ \frac{kip}{ft}$$

Factored Interface Shear Resistance (AASHTO Eq. 5.7.4.3-1)

$\frac{V_{ui}}{V_{ri}} = 0.02\ \le\ 1.0$ **OK**

5.0 Summary of Calculations

The following is a summary of the external stability and strength design checks for the wingwall:

Table 5.0-1 — Summary of Calculations		
External Stability		
Demand-To-Capacity Ratio		
Eccentricity	0.19	
Bearing	0.39	
Sliding	0.99	
Serviceability		
Demand-To-Capacity Ratio		
Settlement	0.34	*Differential Settlement (3.3)*
Stem Deflection	0.12	*Overall Stem Deflection(4.1.6)*
Stem Wall		
Reinforcement		
Flexural	#5 @ 8" o.c.	
Temp. & Shrinkage	#5 @ 12" o.c.	
Demand-To-Capacity Ratio		
Flexure	0.60	*Development of Reinforcement (4.1.3)*
Shear	0.16	*Concrete Shear Strength (4.1.5)*
Heel		
Reinforcement		
Flexural	#5 @ 8" o.c.	
Temp. & Shrinkage	#5 @ 12" o.c.	
Demand-To-Capacity Ratio		
Flexure	0.92	*Combined Tension and Flexure (4.2.4)*
Shear	0.11	*Concrete Shear Strength (4.2.8)*
Toe		
Reinforcement		
Flexural	#5 @ 8" o.c.	
Temp. & Shrinkage	#5 @ 12" o.c.	
Demand-To-Capacity Ratio		
Flexure	0.25	*Development of Reinforcement (4.3.3)*
Shear	0.04	*Concrete Shear Strength (4.3.5)*

NOTES

1. WINGWALLS ARE DESIGNED AS FREE-STANDING STRUCTURES. MECHANICAL CONNECTIONS TO BOX-CULVERT ARE NOT REQUIRED.
2. THE CONCRETE COMPRESSIVE STRENGTH SHALL BE A MINIMUM OF 5,000 PSI AT 28 DAYS
3. ALL REINFORCING SHALL BE EPOXY COATED, HAVE A MINIMUM YIELD STRENGTH OF 60,000PSI, AND CONFORM TO THE REQUIREMENTS OF ASTM A615 U.N.O.
4. ROUGHEN CONCRETE SURFACE AT CONSTRUCTION JOINTS TO 1/4" AMPLITUDE. REMOVE LOOSE DEBRIS AND CLEAN THOROUGHLY. MOISTEN SURFACE PRIOR TO PLACING CONCRETE.
5. 2020 SPECIFICATIONS:

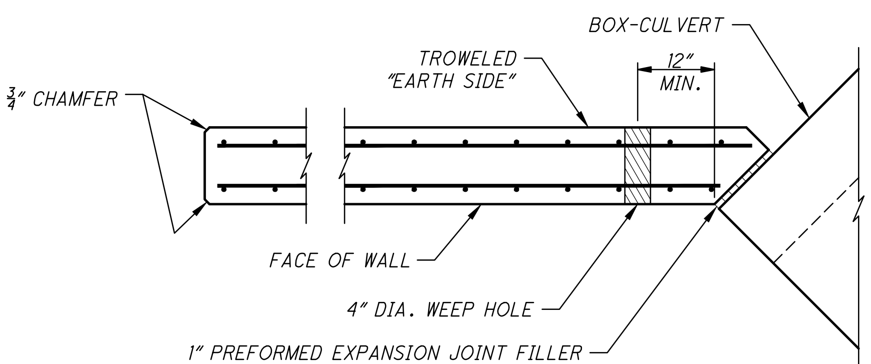
   THE STANDARD SPECIFICATIONS OF THE STATE OF OHIO, DEPARTMENT OF TRANSPORTATION, INCLUDING SUPPLEMENTAL SPECIFICATIONS LISTED IN THE PLANS AND CHANGES LISTED IN THE PROPOSAL SHALL GOVERN THIS DESIGN.

6. DESIGN DATA:

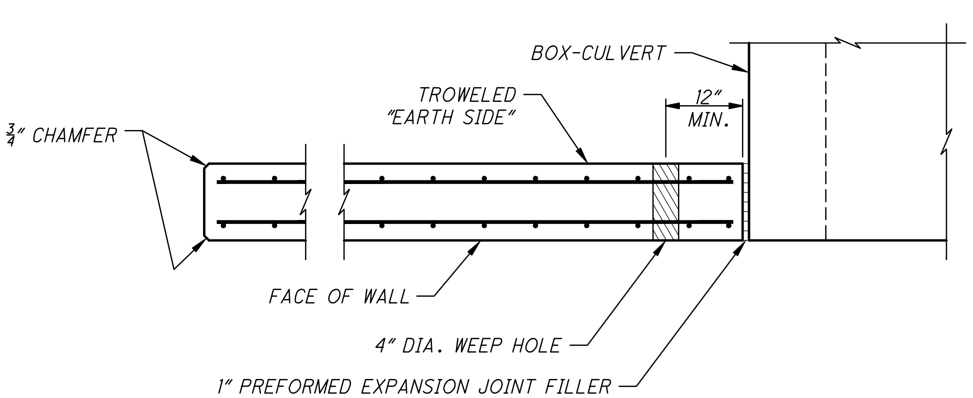
   INTERNAL ANGLE OF FRICTION OF BACKFILL SOIL, ϕ_f = 30°
   TOTAL UNIT WEIGHT OF BACKFILL SOIL = 120 PCF
   EXTERNAL ANGLE OF FRICTION FOR FOUNDATION SOIL, ϕ_{fd} = 22°
   NOMINAL BEARING CAPACITY OF FOUNDATION SOIL, q_n = 7,500 PSF
   UNIT WEIGHT OF CONCRETE = 150 PCF
   SLOPE OF BACKFILL = 2:1 BREAKING TO LEVEL

FIELD CONSTRCTION

1. PREPARE SITE AND SUBGRADE IN ACCORDANCE WITH THE SPECIFICATIONS AND CONTRACT DOCUMENTS
2. WINGWALLS SHALL BE SUPPORTED BY A MINIMUM 12" GRANULAR BASE COMPACTED TO 98% OF THE STANDARD PROCTOR (ASTM D698) MAXIMUM DRY LABORATORY DENSITY.
3. BRING BACKFILL UP EVENLY ON BOTH SIDES OF WINGWALL WITH NO MORE THAN A 1'-0" DIFFERENTIAL IN ELEVATION UNTIL THE DESIGN TOE BACKFILL ELEVATION IS REACHED.
4. THE MINIMUM DISTANCE FROM THE TOP OF THE STREAM BED TO THE BOTTOM OF THE WINGWALL FOOTING SHALL MEET LOCAL FROST DEPTH OF 3'-6".

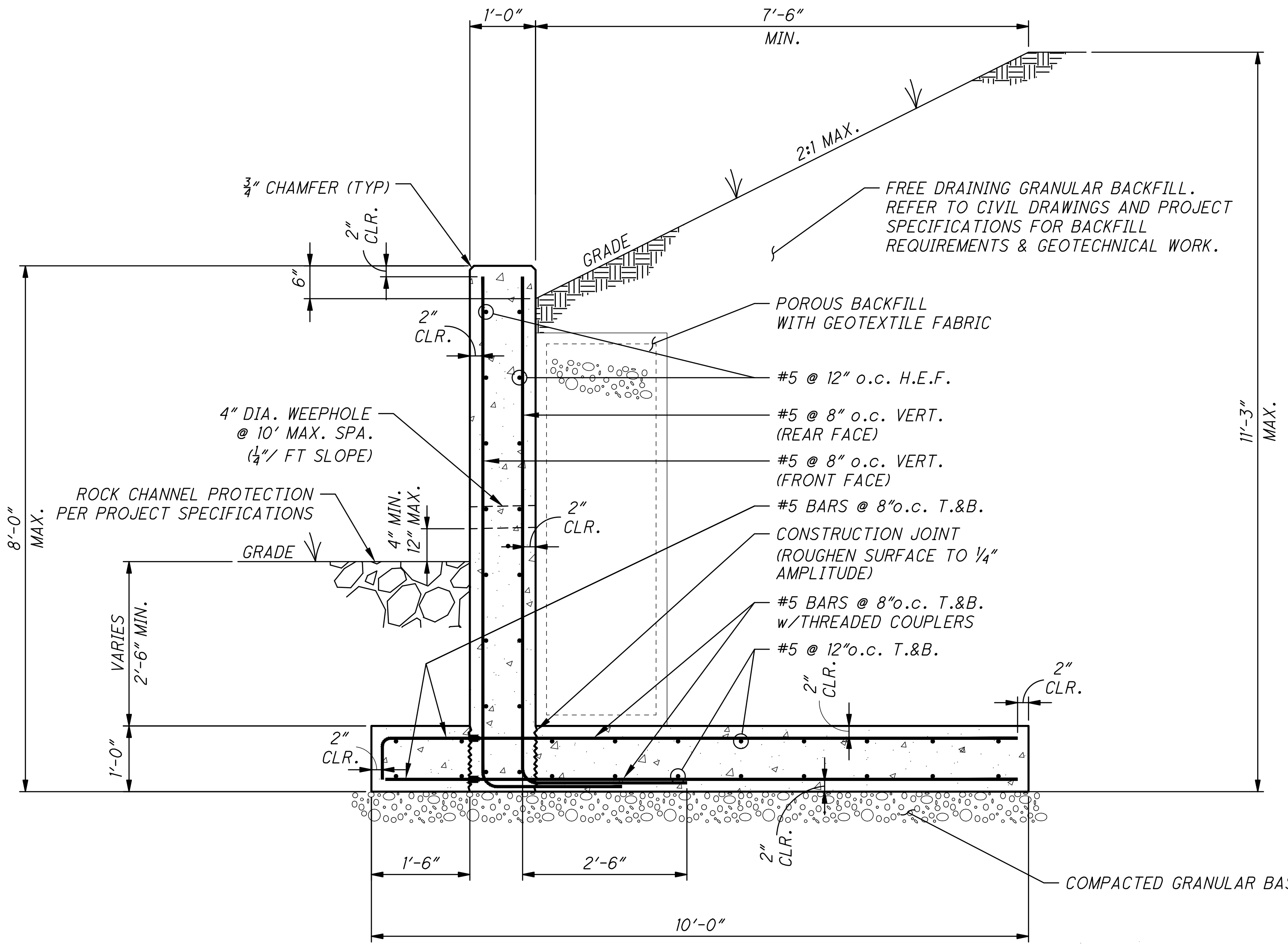


SKEWED WINGWALL



PARALLEL WINGWALL

END OF WALL DETAIL



WINGWALL SECTION

STATE OF OHIO
JOHN P. REED
E-050588
REGISTERED PROFESSIONAL ENGINEER

DESIGN AGENCY
OHLIN & REED, INC.
STRUCTURAL DESIGN CONSULTANTS

REVIEWED	DATE
JJS	11/12/20
STRUCTURE FILE NUMBER	
XXX	

DESIGNED	DRAWN
JMW	JMW
CHECKED	REVISED
JJS	XXX

STRUCTURAL DETAILS
ODOT PREFABRICATED RETAINING WALL SYSTEMS
APPROVAL PROCESS

PID No. #####
####

1 / 1

TEST DATA

AMERICAN SAND & GRAVEL

ODOT / Penn DOT

Aggregate Gradation

Product Bottom Sand **Date Tested** 12/15/2020

Date Sampled 12/14/2020

Sampled By DH

Plant 4

Wash Loss

Tare	**1.**	0.0
Sample Before	**2.**	498.30
Sample After	**3.**	493.70
Weight Loss (2-3)	**4.**	
% Finer than the #200 sieve	**5.**	0.90

Gradation Sieve Size	Accum. Weight	Percent Retained	Percent Passing	ODOT Spec	PennDOT Spec
2-1/2"					
2"					
1-1/2"					
1"					
3/4"					
1/2"					
3/8"	0.00	0.00	100.0	100%	100%
#4	0.00	0.00	100.0	95-100%	95-100%
#8	42.90	8.69	91.3	70-100%	70-100%
#16	158.90	23.50	67.8	38-80%	45-85%
#30	289.20	26.39	41.4	18-60%	25-65%
#50	421.00	26.70	14.7	5-30%	10-30%
#100	482.20	12.40	2.3	1-10%	0-10%
#200	491.80	1.94	0.4	0-5%	
Pan	493.70				

Remarks F/M = 2.83

Lab Tech JMJ

AMERICAN SAND & GRAVEL
ODOT / Penn DOT
Aggregate Gradation

Product #57 Gravel

Date Tested 12/10/2020

Date Sampled 12/10/2020

Sampled By DH

Plant 4

	Wash Loss
Tare 1.	0.0
Sample Before 2.	8347.7
Sample After 3.	8299.3
Weight Loss (2-3) 4.	
% Finer than the #200 sieve 5.	0.6

Gradation Sieve Size	Accum. Weight	Percent Retained	Percent Passing	ODOT/PennDOT Spec
2-1/2"				
2"				
1-1/2"	0.0	0.0	100.0	100%
1"	551.1	6.6	93.4	95-100%
3/4"	2053.4	18.1	75.3	
1/2"	5981.6	47.4	27.9	25-60%
3/8"	7812.0	22.0	5.9	
#4	8212.9	4.9	1.0	0-10%
#8	8224.5	0.1	0.9	0-5%
#16	8238.9	0.2	0.7	0-5%
#30				
#50				
#100				
#200				
Pan	8398.0			

Remarks

Lab Tech JMJ

AMERICAN SAND & GRAVEL
ODOT / Penn DOT
Aggregate Gradation

Product #8 Gravel

Date Tested 12/10/2020

Date Sampled 12/10/2020

Sampled By DH

Plant 4

Wash Loss

Tare	**1.**	0.0
Sample Before	**2.**	4321.6
Sample After	**3.**	4297.6
Weight Loss (2-3)	**4.**	
% Finer than the #200 sieve	**5.**	0.6

Gradation Sieve Size	Accum. Weight	Percent Retained	Percent Passing	ODOT/PennDOT Spec
2-1/2"				
2"				
1-1/2"				
1"				
3/4"				
1/2"	0.0	0.0	100.0	**100%**
3/8"	285.7	6.6	93.4	**85-100%**
#4	3332.9	71.0	22.4	**10-30%**
#8	4250.4	21.3	1.1	**0-10%**
#16	4266.4	0.4	0.7	**0-5%**
#30				
#50				
#100				
#200				
Pan	4296.2			

Remarks

Lab Tech JMJ

LEHIGH
HEIDELBERGCEMENTGroup

Mill Test Certificate Report

Type: III ASTM

Grind Number: November-20

Test Period: 11/01/20 **to:** 11/30/20

Certification

Lehigh Cement Company, LLC certifies that at time of shipment, the portland cement designated as Type III manufactured at the Speed, Indiana plant conforms to the standard composition and physical requirements of the current Standard Specification for Portland Cement of ASTM C 150 for Type III portland cement. This certification carries no other express or implied warranties and Lehigh Cement Company LLC, is not responsible for improper use or workmanship of the described cement.

General Information

Supplier: Lehigh Cement Company LLC
Address: Highway 31
Speed, IN 47172
Telephone: (800) 437-7762

Source Location: Speed Plant

Contact: Customer Service

Test Data on ASTM "Standard" Requirements

Chemical Requirements (ASTM C-150, Table 1)

Item	Limit	Results
SiO_2	A	20.20
Al_2O_3	6.0 Max	4.81
Fe_2O_3	6.0 Max	3.58
CaO	A	64.26
MgO	6.0 max	2.37
SO_3	D	3.15
Loss on Ignition	3.5 max	2.21
Na_2O	A	0.11
K_2O	A	0.62
Insoluble Residue	1.5 max	0.35
CO_2	A	1.53
Limestone %	5.0 max	3.73
$CaCO_3$ in Limestone	70% Min	93
Potential Compounds:		Adjusted
C_3S	A	52.79
C_2S	A	17.19
C_3A	8 max	6.67
C_4AF	A	10.86
$C_3S+4.75*C_3A$	<100	84

Physical Requirements (ASTM C-150, Table 3)

Item	Limit	Results
Fineness:		
% Passing 45μm (No. 325)	A	0.72
Blaine Fineness (m^2/Kg)	260 min	602
Autoclave Expansion (%)	0.8 max	0.003
Vicat Setting Time:		
Initial Set (minutes)	45 min	79
Air Content (%)	12 max	6.06
Compressive Strengths Mpa:		
1-Day	A	26.76
3-Day	12.0 min	40.23
7-Day	19.0 min	46.24
28-Day	A	60.00
Compressive Strengths, PSI:		
1-Day	A	3881
3-Day	1450 min	5833
7-Day	2470 min	6704
28-Day	A	8700
Mortar Bar Expansion, C-1038, %	Max 0.020	0.006

Test Data on ASTM Optional Requirement

Chemical Requirements (ASTM C-150, Table 2)

Item	Limit	Results
Equivalent Alkalies	0.60 max	0.52

Physical Requirements (ASTM C-150, Table 4)

Item	Limit	Result
False Set	Min 50	
Heat of Hydration, 3-day C-1702, cal/g		

Additional Data

Item	Limestone	Inorganic Processing Addition
Amount	3.73	-
SiO_2	5.60	-
Al_2O_3	0.48	-
Fe_2O_3	0.41	-
CaO	89.26	-
SO_3	0.46	-

Base Cement Phase Compostion	Result
C_3S	54.55
C_2S	17.79
C_3A	6.89
C_4AF	11.22

Notes

Footnotes:
A: no limit applicable
D: if SO3 exceeds 3.0%, C-1038 shall not be more than 0.020%

December 14, 2020
Date

Rebecca L Corder
Quality Control Manager:

BORAL RESOURCES

Materials Testing & Research Facility
2650 Old State Hwy 113
Taylorsville, GA 30178
770-684-0102

ASTM C618 / AASHTO M295 Testing of W.H. Sammis Station Fly Ash

Sample Date: 10/1 - 10/30/20
Sample Type: Monthly
Sample ID:

Report Date: 12/9/2020
MTRF ID: 2204SM

Chemical Analysis	**Results**	**ASTM Limit Class F / C**	**AASHTO Limit Class F / C**
Silicon Dioxide (SiO2)	40.77 %		
Aluminum Oxide (Al2O3)	19.94 %		
Iron Oxide (Fe2O3)	29.42 %		
Sum (SiO2+Al2O3+Fe2O3)	90.13 %	50.0 min	50.0 min
Sulfur Trioxide (SO3)	1.13 %	5.0 max	5.0 max
Calcium Oxide (CaO)	3.86 %	18.0 max / >18.0	18.0 max / >18.0
Magnesium Oxide (MgO)	0.66 %		
Sodium Oxide (Na2O)	0.46 %		
Potassium Oxide (K2O)	1.65 %		
Sodium Oxide Equivalent (Na2O+0.658K2O)	1.55 %		
Moisture	0.13 %	3.0 max	3.0 max
Loss on Ignition	2.48 %	6.0 max	5.0 max
Available Alkalies, as Na2Oe	0.66 %	Not Required	1.5 max*

*when required by purchaser

Physical Analysis			
Fineness, % retained on 45-µm sieve	15.02 %	34 max	34 max
Strength Activity Index - 7 or 28 day requirement			
7 day, % of control	78 %	75 min	75 min
28 day, % of control	84 %	75 min	75 min
Water Requirement, % control	99 %	105 max	105 max
Autoclave Soundness	-0.02 %	0.8 max	0.8 max
Density	2.79 g/cm3		

The test data listed herein was generated by applicable ASTM methods. The reported results pertain only to the sample(s) or lot(s) tested. This report cannot be reproduced without permission from Boral Resources.

Christy Sieg
Christy Sieg
Lab Manager

AASHTO ACCREDITED

EUCON AIR MAC12

AIR ENTRAINING AGENT FOR CONCRETE

EUCLID CHEMICAL

DESCRIPTION

EUCON AIR MAC12 is formulated for use as an air entraining admixture for concrete of all types and is manufactured under rigid control which assures uniform and precise performance. EUCON AIR MAC12 adds microscopic air bubbles in concrete and is acceptable to use in all types of concrete, including mixtures that have been traditionally difficult to entrain air. EUCON AIR MAC12 contains no added chlorides or chemicals known to promote the corrosion of steel.

PRIMARY APPLICATIONS

- Ready mix concrete
- Structural concrete
- Mass concrete
- Paving concrete
- All exterior concrete subjected to freeze/thaw cycles

FEATURES/BENEFITS

- Provides a stable air void system with proper bubble size and spacing.
- Improved air void system protects concrete against damage caused by repetitive freeze/thaw cycles.
- Concrete is made more resistant to de-icing salts, sulfate attack and corrosive water.
- Reduces bleeding and segregation of concrete.
- Less mixing water can be used per yard (meter) of concrete with improved placeability.

TECHNICAL INFORMATION

Typical Engineering Data

Specific Gravity.................................. 1.01
% of solids by weight.......................... 15.0
pH..11.0

EUCON AIR MAC12 is an aqueous solution compound of synthetic chemicals. It is compatible with the full range of Euclid admixtures and concrete mixes containing accelerators, water reducing admixtures, retarding admixtures and high range water reducers.

PACKAGING

EUCON AIR MAC12 is packaged in bulk, 275 gal (1041 L) totes, 55 gal (208 L) drums and 5 gal (18.9 L) pails.

SHELF LIFE

2 years in original, unopened package.

SPECIFICATIONS/COMPLIANCES

EUCON AIR MAC12 meets or exceeds the requirements of the following specifications:

- ASTM Specification C 260
- AASHTO Specification M 154
- ANSI/NSF STD 61

Directions for Use

EUCON AIR MAC12 typically is dosed at a rate of 0.1 to 4.0 oz per 100 lbs (6 to 260 mL per 100 kg) of total cementitious material. The amount of EUCON AIR MAC12, to achieve a desired air content, will vary depending on type of cement, fineness of sand, ambient air and concrete temperature, design of the mix, other admixtures, type of mixing equipment, etc. Concrete mixes must be tested regularly to confirm that proper air content is achieved. EUCON AIR MAC12 should be added with the initial batch water or directly to the sand to achieve maximum efficiency.

Precautions/Limitations

- Consult your local Euclid Chemical representative for proper dosage rate adjustments when using fly ash, slag or high range water reducers.
- Add to the mix independent of other admixtures.
- Protect EUCON AIR MAC12 from freezing.
- Do not agitate using air or an air lance.
- Excessive air entrainment will lower flexural and compressive strengths so frequent testing is recommended.
- In all cases, consult the Safety Data Sheet before use.

Rev. 01.19

PLASTOL 6400

HIGH RANGE WATER REDUCER - SUPERPLASTICIZER

EUCLID CHEMICAL

DESCRIPTION

PLASTOL 6400 is a polycarboxylate based high range water reducing admixture which enables concrete to be produced with very low water to cement ratios. Plastol 6400 produces flowable and self-consolidating concrete at low doses and can obtain up to 45% water reduction. Plastol 6400 contains no added chlorides or chemicals known to promote the corrosion of steel.

PRIMARY APPLICATIONS

- High performance concrete
- Negative slump concrete
- Heavily reinforced concrete
- Flatwork and mass concrete
- High early strength concrete
- Precast / prestressed concrete
- High slump, flowable concrete

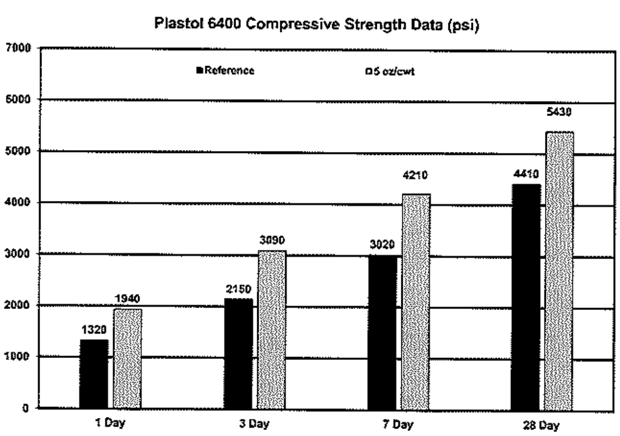
FEATURES/BENEFITS

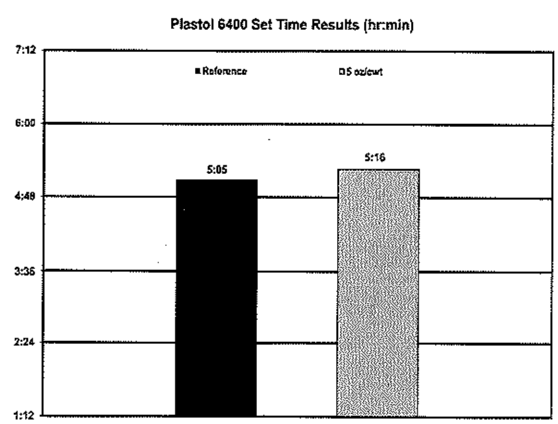
- Produces low water content and low water/cement ratio concrete allowing higher strengths
- Produces flowing concrete with quicker stripping strengths
- Aids in concrete placement and reduces labor cost
- When used in precast work with Type I and Type III cements, Plastol 6400 will produce very high early strengths
- Improved air stability characteristics

TECHNICAL INFORMATION

Performance Data:

The following test results were achieved using typical ASTM C 494 mix design requirements, 517 lb/yd^3 (307 kg/m^3) cement content and similar (± 0.5)% air content. These results were obtained under laboratory conditions with materials and mix designs meeting the specifications of ASTM C 494. Changes in materials and mix designs can affect the dosage response of PLASTOL 6400.





Packaging

PLASTOL 6400 is packaged in bulk, 275 gal (1041 L) totes, 55 gal (208 L) drums and 5 gal (18.9 L) pails.

Shelf Life

1 year in original, unopened container

Specifications/Compliances

- Complies with the requirements of ASTM C 494, Types A & F admixtures
- Complies with ASTM C 1017 as a Type I admixture
- Complies with the requirements of AASHTO M 194
- ANSI/NSF STD 61 registered

Directions for Use

PLASTOL 6400 has a recommended dosage range of 3 to 12 oz per 100 lbs (200 to 780 mL per 100 kg) of cementitious material.

Dosage recommendations depend on the characteristics of the materials being used in the mix design. Higher dosages are acceptable with prior testing and confirmation of the desired performance with specific materials used.

For any concrete application including Self-Consolidating Concrete (SCC), the dosage of PLASTOL 6400 will vary depending on the mix design, local materials, and individual needs of the concrete producer. Trial mixes should be run to verify plastic and hardened performance with local materials. If the material gradations are not optimum for SCC, a viscosity modifier may be used to improve the quality of the mix. Please consult a local Euclid Chemical Sales Professional for trial mixtures and dosage recommendations.

PLASTOL 6400 can be added to the initial batch water or directly on the freshly batched concrete and mixed for approximately 5 minutes or 70 revolutions. However, better results have been observed batching directly on the freshly batched concrete.

It should not come into contact with dry cement or other admixtures until mixed thoroughly with the concrete batch. PLASTOL 6400 is compatible with other Euclid Chemical admixtures including air-entraining agents, accelerators, most water reducers, retarders, shrinkage reducers, corrosion inhibitors, viscosity modifiers, and microsilica; however, each material should be added to the concrete separately.

Precautions / Limitations

- Care should be taken to maintain PLASTOL 6400 above freezing; however, freezing and subsequent thawing will not harm the material if thoroughly agitated. Never agitate with air or an air lance, use a circulation pump or small paddle mixer instead.
- If re-dosing PLASTOL 6400 at the job site, it is recommended that the air content of the concrete mix is checked to conform to job specifications.
- In all cases, consult the Safety Data Sheet before use.

ACCELGUARD® NCA

NON-CHLORIDE, ACCELERATING & WATER REDUCING ADMIXTURE

EUCLID CHEMICAL

DESCRIPTION

ACCELGUARD NCA is an accelerating and water reducing admixture for concrete. It improves properties of plastic and hardened concrete, provides a significant improvement in early stiffening and setting characteristics, improved workability and decreased bleeding and segregation. ACCELGUARD NCA contains no added chlorides or chemicals known to promote the corrosion of steel, is compatible with air-entraining admixtures, HRWR admixtures (super plasticizers), and conventional water reducing admixtures. ACCELGUARD NCA works well at all temperatures but has shown to be most effective in the 35°F to 50°F (2°C to 10°C).

PRIMARY APPLICATIONS

- Cold weather concreting
- Structural and plain concrete
- Precast and post tensioned concrete

FEATURES/BENEFITS

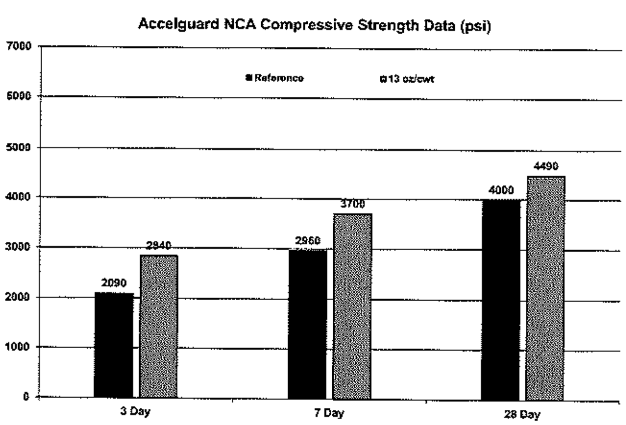
- Reduces initial set 1 to 4 hours depending on concrete temperatures
- Improves workability and provides denser concrete
- Minimizes bleeding and segregation
- Improves compressive strength development at early ages
- Decreases overtime allowing earlier finishing
- Increases protection for reinforcement in concrete
- Decreases concrete form stripping times

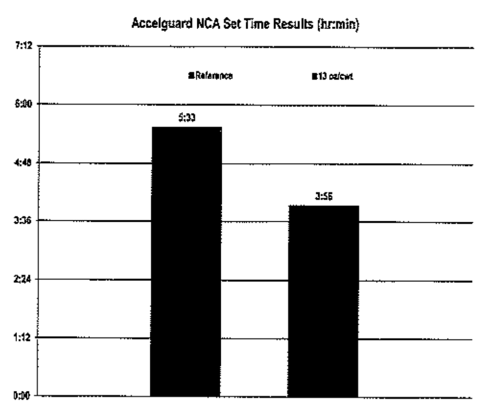
TECHNICAL INFORMATION

Performance Data

The following test results were achieved using typical ASTM C 494 mix design requirements, 517 lb/yd³ (307 kg/m³) cement content and similar (± 0.5)% air content.

These results were obtained under laboratory conditions with materials and mix designs meeting the specifications of ASTM C 494. Changes in materials and mix designs can affect the dosage response of ACCELGUARD NCA.





ACCELERATORS

ACCELGUARD® NCA

MASTER FORMAT: 03 30 00 03 40 00

19215 Redwood Road • Cleveland, OH 44110
800-321-7628 t • 216-531-9596 f

Shelf Life

2 years in original, unopened container.

Packaging

ACCELGUARD NCA is packaged in bulk, 275 gal (1041 L) totes, 55 gal (208 L) drums and 5 gal (18.9 L) pails.

Specifications/Compliances

- Fully complies with ASTM C 494, Type C and E admixture specifications.
- Fully complies with AASHTO M 194.
- ACI 201, Guide for Durable Concrete and ACI 302 Guide for Concrete Floor and Slab Construction prohibit the use of chlorides in many types of concrete. ACCELGUARD NCA may be used in these types of concrete. Examples of which are: floors over prestressed concrete or galvanized decking, floors containing two kinds of embedded metal, reinforced concrete in moist environments and/or exposed to chloride deicing salts.

Directions for Use

The typical dosage range for ACCELGUARD NCA is 12 - 75 oz per 100 lbs (780 - 4890 mL/100kg) of cementitious material. Higher dosages are acceptable with prior testing and confirmation of the desired performance with specific materials being used.

ACCELGUARD NCA should be added to the initial batch water of the concrete mixture. Do not dispense onto dry cement. For ambient temperatures below 50°F (10°C) follow ACI 306 Cold Weather Requirements.

Precautions/Limitations

- ACCELGUARD NCA will freeze at temperatures of approximately -15°F (-26°C). Freezing and thawing will not harm the material if thoroughly agitated.
- Do not use air for agitation.
- Keep concrete from freezing until a minimum of 500 psi (3.5 MPa) is achieved.
- In all cases, consult the Safety Data Sheet before use.

Rev. 08.19

EUCON RETARDER 75

WATER REDUCING AND SET CONTROLLING ADMIXTURE

EUCLID CHEMICAL

DESCRIPTION

EUCON RETARDER 75 is a synthetically produced liquid water reducing and set retarding admixture for concrete. It will improve the plastic and hardened properties when added to a concrete mix. EUCON RETARDER 75 contains no added chlorides or chemicals known to promote the corrosion of steel.

PRIMARY APPLICATIONS

- Prestressed concrete
- Concrete requiring water reduction and set time control
- Architectural concrete
- Hot weather concrete placement

FEATURES/BENEFITS

Plastic Concrete

- Retards setting characteristics
- Improves finishability
- Improves workability
- Reduces water requirements
- Reduces segregation

Hardened Concrete

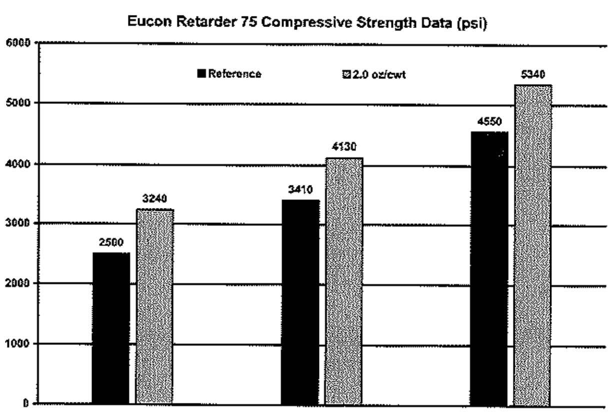
- Increases strengths
- Improves finished appearance
- Reduces cracking
- Reduces permeability
- Non staining

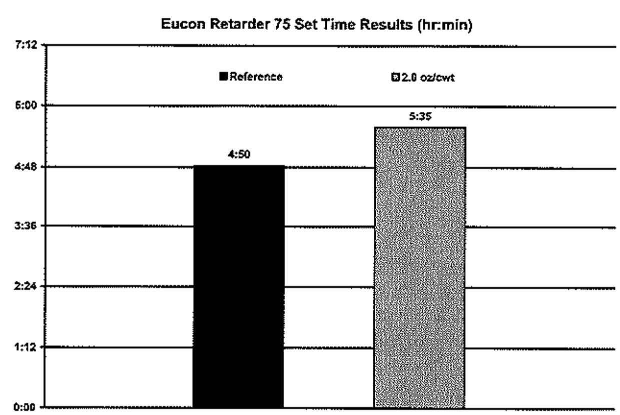
TECHNICAL INFORMATION

Performance Data

The following test results were achieved using typical ASTM C 494 mix design requirements, 517 lb/yd³ (307 kg/m³) cement content and similar (± 0.5)% air content.

These results were obtained under laboratory conditions with materials and mix designs meeting the specifications of ASTM C494. Changes in materials and mix designs can affect the dosage response of EUCON RETARDER 75.





Packaging

EUCON RETARDER 75 is packaged in bulk, 275 gal (1041 L) totes, 55 gal (208 L) drums and 5 gal (18.9 L) pails.

Shelf Life

1 year in original, unopened container.

Specifications/Compliances

- ASTM C 494, Types B & D
- AASHTO M 194
- ANSI/NSF STD 61

Directions for Use

EUCON RETARDER 75 is normally used at dosages of 2 to 5 oz per 100 lb (130 to 330 ml per 100 kg) of cementitious material. Depending on the application, higher dosages are acceptable with prior testing and confirmation of the desired performance with specific materials being used.

EUCON RETARDER 75 should be added to the initial batch water of the concrete mixture. Do not dispense onto dry cement. Because of variations in job conditions and concrete materials, dosages other than the recommended amounts may be required. In such cases, contact your local Euclid sales representative.

Precautions/Limitations

- Care should be taken to maintain EUCON RETARDER 75 above freezing; however, freezing and subsequent thawing will not harm the material if thoroughly agitated.
- Add to mix independent of other admixtures.
- In all cases, consult the Safety Data Sheet before sue.

Rev. 01.19

SIMCOTE, INC.

CERTIFICATE OF COMPLIANCE

NAME: Mack Industries

ATTENTION:

REFERENCE: 64463 XHY

PROJECT: PO #PV49761

COUNTY:

CONTRACTOR:

To Whom It May Concern,

The representative samples of the cleaned and coated bars have been tested and they conform to the requirements of ASTM A615 and A775 specifications.

SIMCOTE, INC.

William A. Maniaci
General Manager

ALL STEEL MADE AND COATED IN THE U.S.A.

1645 Red Rock Rd. • St. Paul MN 55119
Phone (651) 735-9660 • Fax # (651) 735-9664

250 N. Greenwood St. • Marion, OH 43302
Phone (740) 382-5000 • Fax # (740) 383-1167

SUMMARY SHEET

CUSTOMER NAME: Mack Industries, Inc.

JOB / ORDER NUMBER: 64463 XHY

CONTRACTOR:

DATE: December 30, 2020

SIZE	HEAT NUMBER	COATING DATE	POWDER NUMBER
5	4400007890	12-02-20	0K26B

SIMCOTE, INC.
250 North Greenwood Street
Marion, OH 43302-
Phone: (740) 382-5000 FAX: (740) 383-1167

JOB NUMBER	RELEASE NUMBER	REQ. DELIVERY DATE	PAGE
64463	26		1 of 1

JOB NAME: 2020 Stock File
CC: XHY
CUSTOMER: MACK INDUSTRIES
BY: JF

MATERIAL TYPE	REFERENCE	DRAWING ID	DESCRIPTION
Rebar, Grade 60, Epoxy	PO# PV49761		#5 x 20' EPOXY REBAR

Itm	Qty	Size	Length	Mark	Shape	Lbs	A	B	C	D	E	F/R	G	H	J	K	O	BC
1	2302	5	20-00	STOCK		48020												0
	2302					48020												

MILL CERTS REQUIRED PO# PV49761 DEL 1-5-21

MACK INDUSTRIES INC 330-483-3111
201 COLUMBIA RD
VALLEY CITY, OH 44280

Total Weight: 48,020 Lbs

Longest Length: 20-00

INSPECT EPOXY COATING FOR DAMAGE, TOUCH UP, PADDING, & PLACING OF DUNNAGE

INITIALS: ____________ DATE: ____/____/____

WEIGHT SUMMARY

Rebar, Grade 60, Epoxy

	TOTAL			STRAIGHT			LIGHT BENDING			HEAVY BENDING		
SIZE	ITEMS	PIECES	LBS	ITEMS	PIECES	LBS	ITEMS	PIECES	LBS	ITEMS	PIECES	LBS
5	1	2302	48,020	1	2302	48,020	0	0	0	0	0	0
	1	2302	48,020	1	2302	48,020	0	0	0	0	0	0

4400007890 10-01-20

NUCOR®

Mill Certification

10/01/2020

MTR#:497952-4
Lot #:440000789023
912 Cheney Avenue
Marion, OH 43302 US
800 333-4011
Fax: 740 383-6429

Sold To: SIMCOTE INC
250 N GREENWOOD ST
MARION, OH 43302 US

Ship To: SIMCOTE INC - MARION
250 N GREENWOOD ST
MARION, OH 43302 US

Customer PO	OH-2189	Sales Order #	44005184 - 1.12
Product Group	Rebar	Product #	1059656
Grade	A615 Gr 60/M31 C	Lot #	440000789023
Size	#5	Heat #	4400007890
BOL #	BOL-588422	Load #	497952
Description	Rebar #5/16mm A615 Gr 60/M31 C 60' 0" [720"] 6001-10000 lbs	Customer Part #	
Production Date	09/17/2020	Qty Shipped LBS	9012
Product Country Of Origin	United States	Qty Shipped EA	144
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States

Melting Date: 09/15/2020

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Sn (%)
0.40	1.03	0.015	0.037	0.209	0.13	0.18	0.06	0.26	0.005	0.010

Other Test Results

Yield (PSI) : 64000

Elongation in 8" (%) : 13.0

Tensile (PSI) : 107000

Bend Test : Pass

Average Deformation Height (IN) : 0.042

Weight Percent Variance (%) : -4.12

Comments:

All manufacturing processes of the steel materials in this product, including melting, have occurred within the United States.
All products produced are weld free. Mercury, in any form, has not been used in the production or testing of this material.

4400007890 10-01-20

Ignatius Okafor, Division Metallurgist

Simcote, Inc.
Daily Quality Report
Epoxy Coated Reinforcing Steel

Date: DECEMBER 2, 2020

250 N. Greenwood St.
Marion, OH 43302

Phone: (740) 382-5000

Heat #: 4400007853 4400005437
4400007854 4400008593
4400007855 4400008403
4400007890

Powder Lot #: 0K26C
0K26B

Type: 3M

Inspector: R. TREADWAY
*Bend: OK
Temp: 425 Fahrenheit
Cure Time: 33 Seconds

Bar Size	Heat #	Hldy.	1	2	3	4	5	6	7	8	9	10	Avg.
5X60'	4400007853	*1	10.9	11.5	11.3	10.9	9.9	9.9	10.4	11.1	9.9	11.2	10.7
		5	11.1	10.7	9.8	9.8	9.9	8.9	9.4	9.8	11.1	11.8	10.2
		8	11.1	10.3	9.9	10.9	12.0	10.8	10.6	10.7	11.2	11.3	10.9
		6	11.8	11.3	10.8	10.3	9.8	9.9	9.5	9.4	9.3	9.7	10.2
		4	10.0	11.0	10.7	10.6	10.4	9.9	10.0	8.8	9.4	10.9	10.2
		7	9.9	10.3	9.5	9.5	9.0	9.3	9.8	11.2	11.1	11.0	10.1
	4400007854	2	9.8	9.7	9.0	10.5	11.0	10.9	10.8	9.8	10.1	9.1	10.1
		8	11.1	10.3	10.3	9.8	9.9	10.5	11.9	11.0	10.7	10.9	10.6
		5	10.1	10.0	9.7	8.9	10.0	9.8	9.8	9.8	9.8	9.1	9.7
		7	8.7	9.9	10.9	10.2	9.6	10.4	11.0	9.9	9.8	10.9	10.1
		1	10.0	9.5	10.8	9.8	10.3	11.1	10.5	9.8	9.8	10.1	10.2
		4	10.3	11.2	10.3	10.1	9.0	9.1	9.5	9.7	10.2	10.4	10.0
	4400007854	9	10.3	10.1	9.7	9.5	9.1	9.6	10.9	9.4	10.0	10.9	9.9
		7	9.9	11.0	10.4	9.8	9.4	9.2	9.8	10.8	10.3	9.9	10.0
		5	10.0	10.3	10.0	8.8	9.6	9.5	8.9	9.4	9.6	8.1	9.4
		13	8.5	8.9	10.5	10.5	10.3	8.8	9.3	9.9	10.9	9.7	9.7
		2	9.4	10.2	9.4	9.0	9.0	9.6	9.6	9.6	9.7	11.0	9.7
		4	11.0	9.9	10.0	9.6	9.0	9.6	9.9	10.9	10.2	10.3	10.0
	4400007854	1	10.1	10.3	9.8	10.6	10.7	10.0	9.8	9.0	9.2	10.1	10.0
		7	10.8	9.8	9.9	8.9	8.3	8.8	10.9	10.6	9.9	9.2	9.7
		6	9.4	10.3	9.5	9.6	10.5	9.8	9.6	9.1	9.9	10.0	9.8
		2	9.3	10.0	9.2	9.6	9.7	10.0	10.9	9.9	9.9	10.1	9.8
		8	10.0	10.2	10.2	10.0	9.8	10.1	9.9	9.9	9.4	10.0	10.0
		5	10.0	9.6	8.9	9.6	10.6	10.9	11.1	11.0	9.9	10.1	10.2
	4400007855	14	9.8	11.2	11.8	10.6	10.2	10.1	10.0	9.3	9.9	10.4	10.3
		7	9.9	9.5	10.0	9.9	9.8	9.8	9.6	10.3	9.9	10.0	9.9
		2	9.9	9.8	9.2	9.1	7.6	9.6	7.9	8.0	7.5	7.6	8.6
		8	8.8	8.1	8.6	8.0	8.7	8.6	9.0	10.0	9.9	10.0	9.0
		16	9.9	10.4	10.8	10.0	10.0	9.6	9.9	9.9	9.8	10.0	10.0
		4	10.1	9.5	9.8	9.9	9.4	10.3	10.6	10.8	10.7	9.9	10.1
	4400007855	7	10.3	10.6	11.1	10.4	9.4	9.9	10.4	11.2	11.5	10.8	10.6
		5	10.3	9.9	9.7	9.0	9.8	9.9	11.2	9.9	9.4	10.6	10.0
		13	9.9	10.8	11.0	11.9	11.7	11.7	9.9	11.1	10.7	10.6	10.9
		4	10.4	9.8	10.0	9.9	10.9	10.9	11.5	9.6	9.6	9.9	10.3
		8	9.8	9.9	10.2	11.0	10.3	9.6	10.3	10.8	11.2	11.0	10.4
		7	10.4	10.0	10.1	9.2	9.6	9.9	11.4	11.8	11.7	11.6	10.6
	4400007853	9	10.3	10.0	9.8	10.0	9.9	10.9	10.5	10.7	10.0	9.9	10.2
		10	9.6	9.9	10.7	10.9	10.9	10.1	10.3	11.2	10.8	10.1	10.4
		4	8.8	9.0	9.5	9.6	9.7	9.2	10.8	10.7	9.9	9.7	9.7
		5	9.6	9.5	9.5	9.3	9.7	10.5	10.7	11.9	11.0	10.4	10.2
		12	9.9	10.1	9.2	9.1	9.5	10.6	11.8	10.5	9.9	10.1	10.1
		7	9.5	11.0	10.8	11.1	11.8	10.0	9.9	9.7	9.8	9.4	10.3
	4400007853	6	8.7	8.8	10.5	9.9	8.9	9.1	11.5	9.6	11.2	9.9	9.8
		4	9.6	9.4	11.4	10.8	9.1	9.4	9.8	11.0	8.9	8.6	9.8
		2	9.9	8.5	8.4	7.5	8.9	8.9	9.7	9.2	9.9	10.6	9.2
		8	10.1	9.7	9.1	7.9	8.9	10.0	11.1	11.6	10.1	9.9	9.8
		5	10.2	9.5	8.8	9.3	10.4	11.6	10.9	10.1	9.9	11.1	10.2
		7	10.8	9.7	10.8	11.1	10.3	10.0	9.8	11.2	10.9	10.3	10.5
	4400007854	9	9.5	9.8	9.8	11.2	10.5	9.8	9.3	9.3	9.6	10.1	9.9
		4	10.7	9.9	9.8	9.6	9.5	11.2	10.8	10.9	9.8	9.8	10.2
		7	9.2	9.6	9.6	9.8	11.3	11.2	11.2	10.0	9.9	9.5	10.1
		5	9.7	9.6	9.5	7.6	8.1	9.1	9.2	9.5	9.3	9.3	9.1
		12	9.5	7.5	9.3	10.9	10.9	9.8	11.6	11.8	11.7	9.8	10.3
		4	9.5	9.9	10.0	11.2	11.4	10.6	9.8	9.9	10.9	10.1	10.3
	4400007853	2	9.5	9.0	9.1	9.1	9.8	10.4	10.8	11.3	11.8	10.6	10.1
		5	10.2	9.6	11.8	9.9	9.8	9.4	9.6	10.9	11.0	10.6	10.3
		8	10.8	9.4	9.5	10.9	11.9	10.9	9.9	9.5	10.1	9.9	10.3
		9	9.8	10.1	9.3	9.3	9.3	9.5	11.0	11.2	10.3	10.2	10.0

* - Indicates Bend Test on this Bar

Bar Size	Heat #	Hldy	1	2	3	4	5	6	7	8	9	10	Avg
5X60'	44000007853	3	9.5	9.9	10.9	11.0	10.9	10.9	10.3	9.7	10.2	9.9	10.3
		7	10.1	11.4	11.0	10.7	10.6	9.6	9.5	11.2	10.9	10.3	10.5
	4400007854	4	9.8	9.9	9.1	9.5	11.3	11.4	11.2	11.9	10.9	9.8	10.5
		2	9.8	9.2	9.4	9.3	9.5	11.2	11.5	11.2	10.3	9.8	10.1
		7	10.2	8.9	9.4	10.1	10.1	10.6	10.9	11.7	11.8	10.1	10.4
		10	9.2	9.8	10.2	11.1	11.8	10.9	9.8	9.3	9.1	8.4	10.0
		2	8.2	9.6	9.1	9.7	9.5	9.6	9.5	8.8	9.2	9.1	9.2
		5	9.4	9.9	10.3	10.5	10.4	10.6	10.5	11.9	9.8	9.3	10.3
	4400007853	14	9.6	9.8	10.3	9.8	9.7	9.8	8.9	10.5	11.2	10.8	10.0
		7	9.7	9.9	9.8	10.2	11.2	11.3	11.7	10.5	9.8	9.6	10.4
		6	8.8	9.8	10.9	10.2	9.8	9.8	9.6	9.0	11.5	10.7	10.0
		2	9.5	9.9	11.1	9.8	9.8	10.1	10.1	9.0	10.2	10.5	10.0
		8	11.7	11.6	10.6	9.8	10.1	9.8	9.9	9.9	10.0	9.8	10.3
		5	9.7	9.5	9.0	9.6	9.4	9.9	11.3	10.4	9.8	8.9	9.7
	4400007890	9	9.4	9.5	10.8	8.5	7.8	7.4	7.6	7.5	8.2	9.1	8.6
		4	9.1	10.2	10.5	10.3	10.6	10.6	9.8	9.8	9.6	10.2	10.1
		7	10.5	10.1	9.4	10.3	9.5	8.2	7.8	9.6	9.7	10.0	9.5
		5	10.4	9.8	9.8	10.0	11.7	11.8	10.6	9.8	9.9	10.2	10.4
		13	9.9	9.2	10.5	11.2	10.5	10.1	9.3	10.0	11.1	10.4	10.2
		6	10.1	10.0	10.8	11.9	10.8	9.8	9.6	9.1	9.5	9.7	10.1
	4400007854	4	10.0	10.9	10.6	9.9	9.2	9.6	11.3	11.0	10.0	9.9	10.2
		2	9.3	11.5	10.7	10.4	9.6	9.7	11.0	10.8	10.3	10.3	10.4
		8	9.2	9.5	9.3	10.3	11.0	9.6	9.7	9.4	9.6	9.9	9.7
		5	11.2	10.6	10.2	10.6	10.3	9.8	9.8	10.0	11.1	12.0	10.6
		7	10.7	10.3	10.2	9.8	9.2	10.7	12.0	11.5	10.6	9.9	10.5
		4	9.6	9.6	10.4	11.6	10.9	9.9	9.7	12.0	9.9	7.6	10.1
	4400005437	1	7.6	8.0	10.2	10.9	11.5	10.7	9.5	9.7	10.2	11.7	10.0
		6	10.6	9.7	9.8	9.6	9.7	10.4	10.6	11.6	10.3	9.9	10.2
		2	9.8	10.0	9.9	11.1	11.0	11.9	11.0	9.7	9.6	9.8	10.4
		3	11.4	12.0	10.9	10.4	10.4	10.0	10.0	10.6	10.4	9.5	10.6
		7	9.7	11.4	10.3	9.5	10.0	11.9	12.0	12.1	10.6	9.6	10.7
		6	10.0	10.1	10.6	11.7	10.4	10.0	10.0	9.0	9.8	10.4	10.2
	4400007853	4	10.7	9.8	10.1	9.2	10.0	10.3	8.7	9.1	9.6	9.7	9.7
		2	9.4	9.3	9.2	9.1	9.1	7.9	8.3	9.5	10.3	12.0	9.4
		8	11.4	10.4	9.8	9.8	9.1	9.3	9.4	9.5	9.1	8.9	9.7
		5	10.2	9.7	10.0	10.5	10.0	9.9	10.1	9.9	11.2	9.7	10.1
		7	10.0	9.0	8.8	10.0	11.0	11.9	10.4	9.9	9.7	9.4	10.0
		10	9.4	9.9	10.3	11.4	11.0	9.9	9.7	9.0	9.2	9.9	10.0
	4400007854	1	10.9	11.8	11.6	10.2	9.8	9.9	9.7	10.0	9.7	9.8	10.3
		2	9.8	9.8	10.2	10.0	9.5	9.8	9.9	10.0	10.1	11.1	10.0
		6	9.4	8.8	8.8	9.8	9.8	9.9	9.3	9.6	8.9	9.2	9.3
		4	8.1	9.1	9.2	8.5	8.9	8.4	9.1	10.4	11.4	10.7	9.4
		7	10.5	10.6	10.0	9.4	7.8	9.5	9.1	9.8	11.3	10.1	9.8
		5	10.1	8.7	10.0	9.7	9.7	9.6	10.0	9.2	9.6	9.7	9.6
6X60'	4400008393	*2	12.6	13.7	13.2	11.4	10.1	11.2	9.7	9.9	10.0	9.9	11.2
		12	13.4	14.6	9.6	12.8	13.8	11.0	10.7	10.9	10.0	9.7	11.7
		3	10.2	13.9	11.8	12.6	11.8	10.0	9.6	10.8	10.3	11.1	11.2
		4	12.9	9.6	9.9	10.2	9.8	10.1	12.8	13.4	14.8	14.3	11.8
		7	13.8	10.2	10.9	12.6	14.6	14.5	12.0	13.9	10.8	11.3	12.5
	4400008403	5	10.0	12.8	11.5	10.1	9.6	9.6	11.8	13.7	12.9	9.3	11.1
		3	10.1	11.3	13.6	14.9	13.5	13.8	11.6	10.7	10.2	10.0	12.0
		2	10.9	10.0	10.3	11.3	12.4	10.0	10.8	12.0	10.3	9.9	10.8
		15	9.6	10.6	13.8	12.6	10.6	10.5	10.0	10.3	9.8	9.7	10.7
		4	10.2	9.0	13.3	11.9	10.3	11.1	14.4	10.9	13.3	9.9	11.4
	4400008403	5	10.0	12.0	10.3	11.0	10.9	13.9	9.3	10.8	11.6	8.7	10.9
		8	9.9	10.4	11.9	12.5	11.3	10.8	8.8	10.3	9.9	11.0	10.7
		9	8.0	10.7	10.0	11.8	8.9	11.0	12.7	14.0	14.8	13.4	11.5
		3	11.3	10.9	10.8	9.9	11.8	12.9	10.9	9.6	8.8	9.6	10.7

0K26B 10-26-20

3M™ Scotchkote™ Fusion-Bonded Epoxy Rebar Coating 413/ Fusion-Bonded Epoxy Rebar Coating 413 S Certificate of Analysis

3M

Certificate of Analysis

3M Angleton

1508 East Cedar St.
Angleton, TX 77515

Customer:	SIMCOTE INC
3M Invoice Number:	BD42135
Customer PO Number:	0210151310BM
Date certificate prepared:	30-Oct-20

The 3M product listed below was produced in accordance with standard manufacturing process for the product in effect at the time of manufacture. This is to certify that the lot(s) of 3M™ Scotchkote™ Fusion-Bonded Epoxy Rebar Coating 413 manufactured by 3M at Angleton, Texas, meets the requirements of the following standards: ASTM A 775/A775 M-007b(2014), ASTM A 884/A884M-14, ASTM A 1078/A 1078M-12 Type 1, AASHTO M284-09 and AASHTO M254-06 (2010). The Lot(s) of 3M™ Scotchkote™ Fusion-Bonded Epoxy Rebar Coating 413 S is (are) equivalent to the 3M™ Scotchkote™ Fusion Bonded Epoxy Rebar Coating 413 that was tested and certified by the third party lab. This coating, when applied to steel or iron in the U.S., meets the Buy America provision as set forth in FHWA 23 CFR 635.410 Section 1041(a) of the ISTEA.

3M Stock Number:			**Quantity:**	
80-6116-1455-5 7010401049	413 S		39,600	LBS
UPC Number:				
51128611302				
Shelf Life 6 months from date of manufacture	**Storage Condition for this Product:** General Warehouse Storage (≤+27°C/80°F)			

Test Property:	Test Method Number	Min Spec.	Max Spec	Units
Gel Time Average 380°F (193°C) ± 3°	TM-001	5.0	9.0	SECONDS
Passed Through 325 Screen (45 Micron)	TM-003	32	42	%
Moisture Content-Computrac Max 4000 XL	TM-004		0.5	%

Lot Number:	Date of Manufacture:	Expiration Date:	Batch Size In Lb.	Gel Time Average 380° F (193° C)+/- 3°	Passed Through 325 Screen (45 Micron) (Avge)	Moisture Content-Computrac Max 4000 XL (Avge)
0K07C	7-Oct-20	7-Apr-21	1,800	6.1	34	0.3
0K22A	22-Oct-20	22-Apr-21	5,400	7.2	38	0.2
0K22B	22-Oct-20	22-Apr-21	9,000	7.1	36	0.2

Form 430_ver 1

0K26B 10-26-20

0K22C	22-Oct-20	22-Apr-21	3,600	6.9	39	0.3
0K23A	23-Oct-20	23-Apr-21	7,200	6.8	34	0.2
0K26B	26-Oct-20	26-Apr-21	5,400	6.9	37	0.2
0K26C	26-Oct-20	26-Apr-21	3,600	6.8	34	0.2
0K27B	27-Oct-20	27-Apr-21	3,600	6.9	35	0.3

Authorized By:	**Title :**	**Date Signed:**
Sharon Campbell	**Quality Control**	30-Oct-20
Sharon Campbell		

Please contact your 3M Customer Service Representative if you have any questions.

Warranty and Limited Remedy: Unless stated otherwise in 3M's product literature, packaging inserts or product packaging for individual products, 3M warrants that each 3M product meets the applicable 3M specifications at the time 3M ships the product. Individual products may have additional or different warranties as stated on product literature, package inserts or product packages. **3M MAKES NO OTHER WARRANTIES OR CONDITIONS, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OR CONDITION OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR ANY IMPLIED WARRANTY OR CONDITION ARISING OUT OF A COURSE OF DEALING, CUSTOM OR USAGE OF TRADE.** User is responsible for determining whether the 3M product is fit for a particular purpose and suitable for user's application. If the 3M product is shown to be nonconforming within the warranty period, your exclusive remedy and 3M's sole obligation will be, at 3M's option, to replace the nonconforming 3M product or refund the purchase price.

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