INNOVATIVE BRIDGE REPLACEMENT FOR IA 1 OVER LITTLE LICK CREEK:
LARGE-SCALE PRECAST ARCH CULVERT DELIVERED UNDER LIVE TRAFFIC CONDITIONS

IA 1 over Little Lick Creek | Van Buren County, IA

AGENDA

INTRODUCTIONS
- Matt Rasmussen (Schemmer)
- Jake Vogel (Contech)
- Travis Augustyn (Progressive Structures)

PROJECT OVERVIEW

FOUNDATION DESIGN

PRECAST ARCH CULVERT DESIGN

CONSTRUCTION

FUTURE CONSIDERATIONS

TIME-LAPSE OF CONSTRUCTION

Q&A

PROJECT OVERVIEW

EXISTING BRIDGE
- 240'-0" Long x 30'-0" Wide
  Girder-Floorbeam-Stringer Bridge

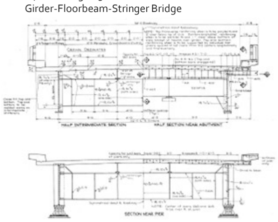
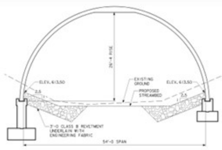


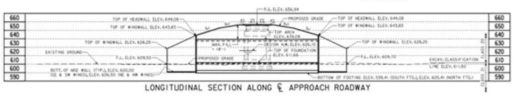
Image Courtesy of the Iowa DOT

PROJECT OVERVIEW

PROPOSED BRIDGE

- 54'-0" Span x 26'-4" Rise x 144'-0" Long Precast Concrete Arch Culvert
- Why a Precast Concrete Arch Culvert?
  - Site Topography and Geology
  - Detour Length
  - Detour Cost

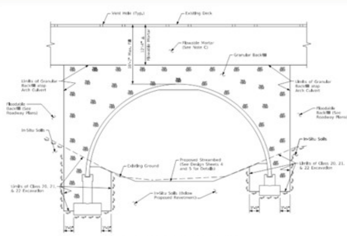




PROJECT OVERVIEW

PROJECT CHALLENGES

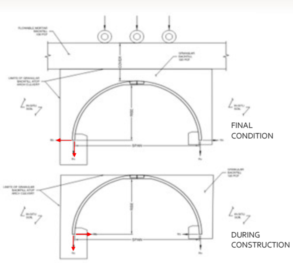
- Construction of Culvert Beneath Existing Structure While in Service
- Large Culvert Size Required MSE Wing Walls in Floodway
- Preliminary Boring Locations Coupled with Shallow Bedrock with Varying Elevation
- Long Spread Footing on Bedrock
- Construction Time (Working Days) Allotted



FOUNDATION DESIGN

SPREAD FOOTING LOADING SCENARIOS

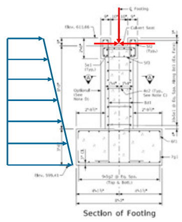
- Design for Bearing and Sliding on Bedrock
  - Long Footing
  - Stub Abutment & Retaining Wall Scenarios
- Arch Culvert Reactions During Construction vs. Final
  - Vertical Load Reduces
  - Thrust (Lateral Load) Changes Direction



FOUNDATION DESIGN

SPREAD FOOTING LOADING SCENARIOS

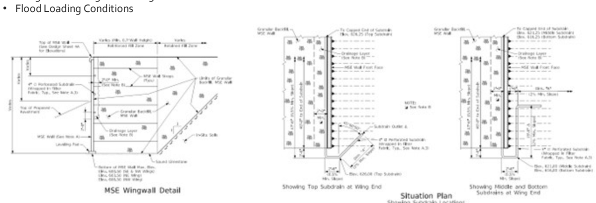
- Arch Culvert Reactions During Construction vs. Final
  - Vertical Load Reduces
  - Thrust (Lateral Load) Changes Direction
- Large Number of Analysis Model Conditions
  - South Footing
  - North Footing
  - Final Condition
  - During Construction
  - Dry Soil
  - Saturated Soil/Flooding
  - All-Soil Fill
  - Floodable Backfill for Top Section



FOUNDATION DESIGN

MSE WINGWALL LOADING SCENARIOS

- Global Design Only (Internal Design Proprietary)
- Design for Bearing and Sliding on Bedrock
- Flood Loading Conditions

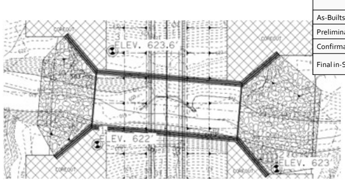


FOUNDATION DESIGN

COMPLICATIONS DURING CONSTRUCTION

- ***Preliminary Borings***
  - Locations Differed from Foundation Positions
  - Information Differed from As-Builts

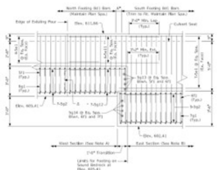
Source Data	Bottom of Footing Elevations (ft)					
	Culvert Footings		Wingwalls			
	South	North	SE	SW	NE	NW
As-Builts	603.32	607.25	-	-	-	-
Preliminary Borings	599.41	608.91	600.50	600.50	612.00	612.00
Confirmation Borings	599.41	605.41	600.50	600.50	606.50	606.50
Final in-Situ	599.41	605.41 / 602.41	600.50	600.50	603.50	606.50



FOUNDATION DESIGN

COMPLICATIONS DURING CONSTRUCTION

- Preliminary Borings
  - Locations Differed from Foundation Positions
  - Information Differed from As-Builts
- ***Variable Bedrock Elevation***
  - Differed Between Banks
  - Differed Along Banks
  - Transition Detail

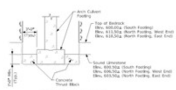


North Footing Transition Detail

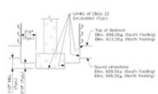
FOUNDATION DESIGN

COMPLICATIONS DURING CONSTRUCTION

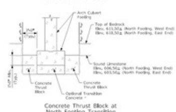
- Preliminary Borings
  - Locations Differed from Foundation Positions
  - Information Differed from As-Builts
- Variable Bedrock Elevation
  - Differed Between Banks
  - Differed Along Banks
  - Transition Detail
- ***Bedrock Did Not Allow for Neat Excavation Lines***
  - Thrust Blocks



Concrete Thrust Block



Spread Footing on Rock Detail

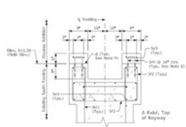


Spread Footing on Rock Detail

FOUNDATION DESIGN

COMPLICATIONS DURING CONSTRUCTION

- Preliminary Borings
  - Locations Differed from Foundation Positions
  - Information Differed from As-Builts
- Variable Bedrock Elevation
  - Differed Between Banks
  - Differed Along Banks
  - Transition Detail
- Bedrock Did Not Allow for Neat Excavation Lines
  - Thrust Blocks
- ***Keyway Wall Height Extension***
  - As-Built Elevation vs. Design Elevation



Keyway Retrofit Detail

FUTURE PROJECTS

GUIDELINES FOR FUTURE PROJECTS

- Validate Preliminary Borings vs. As-Built Data During Preliminary Design
- Provide Manufacturer with Explicit Scenarios for Reaction Estimates
- Provide Manufacturer with Estimated Soil Properties for Reaction Estimates
- Develop MSE Wall Design and Drainage Standards
- Consider Design for Bearing Elevation Tolerance
- Construction Schedule Input for Unique Projects

CONTECH ENGINEERED SOLUTIONS

IA 1 Over Little Lick Creek (Van Buren County)

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CONTECH ENGINEERED SOLUTIONS

Precast Concrete Arch Culvert Design Topics

- Multi-Leaf precast concrete arches
- Crown joint construction process
- Design process
- Backfill requirements and load cases
- Additional requirements for installation

Multi-Leaf Precast Concrete Arches

CONTECH ENGINEERED SOLUTIONS

BEBO Bridge System

- First developed in 1966 in Switzerland
- Buried Bridge precast structure
- 3-Hinged arch for self-weight
- 2-Hinge arch for construction and final loads
- C,E, and T shapes developed

Selected BEBO shape:

- C-Series: "circular shape"
  - Spans from 30' to 54' Rises from 11' to 26'
  - A twin-leaf BEBO C54T/6 was selected as the best fit structure.

Twin Leaf BEBO

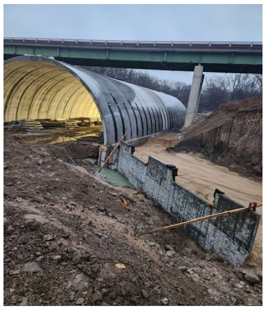
- C54'-0" span x 26'-4" rise with 18'-0" max cover

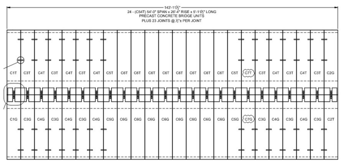
Multi-Leaf Precast Concrete Arches

CONTECH ENGINEERED SOLUTIONS

- Large-span Precast Arches are split into pieces to allow for easy transportation on a truck
  - For this project - each leaf weighed 20.8 tons (totaling in 1,000+ tons of precast arches shipped)

Multi-Leaf Precast Concrete Arches

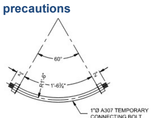




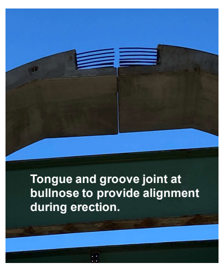
- The completed bridge consisted of 24 arch rings with an overall length of 143'-11.5"
- The 54' Span carries westbound IA 1, consisting of two, 12' lanes and two, 8' shoulders

Crown joint Construction Process

Curved "Banana" bolt installed for safety precautions



TEMPORARY CONNECTING BOLT DETAIL



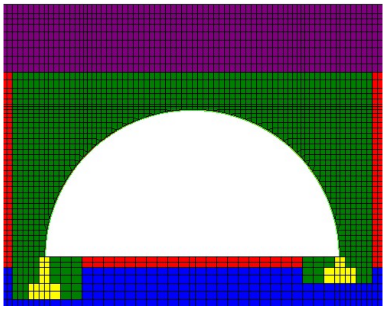
Tongue and groove joint at bullnose to provide alignment during erection.

Crown joint Construction Process

Crown joint with splice bars tied in and ready for placement of concrete

Cast-in-Place concrete placed in crown joint to make arch continuous at mid-span

Design Process – CANDE Finite Element Model



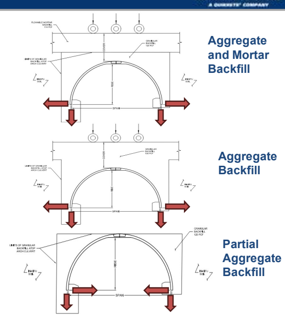
- CANDE Program uses the Finite Element method to model both the structure and the soil mass surrounding it, capturing the nonlinear behavior of the structure, the soil, and the soil-structure interface
- Maximum soil cover is 18'-0" over 54' span
- Design live load was HL-93 plus an additional 20 PSF future wearing surface

Backfill Requirements and Load Cases

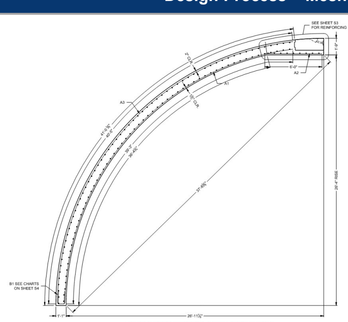
Load case 1(Under Existing Bridge):
- Partial granular backfill and lightweight flowable mortar 18'-0" max cover
- HL-93 live load with 20 PSF future wearing surface

Load case 2 (Outside Existing Bridge):
- Full granular backfill 18'-0" max cover
- HL-93 live load with 20 PSF future wearing surface
- Controlled shear design

Load case 3 (Critical Load Case during Construction):
- Backfill to top of arch with 120 PCF granular backfill
- Controlled steel moment and compression
- In addition, this load case produced inward horizontal reactions effecting design of foundations



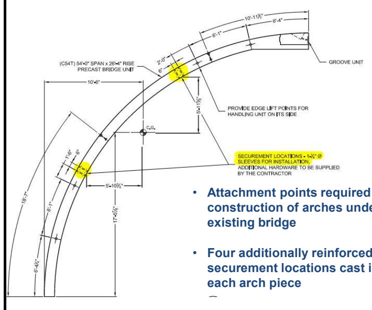
Design Process – Mesh Reinforcement



PRECAST UNIT MESH REINFORCEMENT

- Heavy Welded Wire Fabric is used as primary reinforcing to minimize labor costs and manufacturing time
- 3 layers of 2" x 7" – D16 x D14

Additional Requirements For Installation




- Attachment points required for construction of arches under existing bridge
- Four additionally reinforced securement locations cast into each arch piece

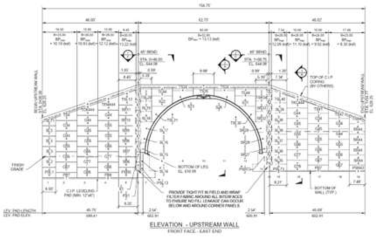
VistaWall MSE Design

VistaWall MSE Design Topics

- General Dimensions & Design Assumptions
- Sound Limestone & Leveling Pad
- Perforated Drains
- Grid Strip Design
- Rapid Drawdown Considerations

General Wall Dimensions

CONTECH ENGINEERED SOLUTIONS



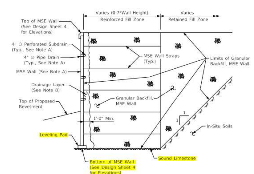
Mechanically Stabilized Earth Wall with Segmental Concrete Panels.

Max. Height = 44.67'
Length = 154.75'

100 Yr Water Elevation = 627.00'

Leveling Pad & Sound Limestone

CONTECH ENGINEERED SOLUTIONS



MSE Wingwall Detail

Notes:
See Design Sheet 4 for minimum clearances between culvert footings and existing piers.

Note A:
1. MSE walls are to be designed for an equivalent height of 42" of hydrostatic pressure, applied to the back face of the MSE wall from the Q_{100} water elevation to the base of the wall.
2. MSE walls shall be founded on sound limestone. The weathered limestone and shale indicated in the boring logs shall be removed to expose sound limestone. The excavation quantities for MSE walls are included on the Summary Quantities sheet.
3. A 4" dia. perforated PVC subdrain pipe shall be run along the MSE walls at 5'-0" elevation increments, starting at elevation 616.00 and stopping at elevation 626.00. The pipe drain outlets shall be provided every 10'-0" on center max. along the 4" perforated PVC pipes, with a minimum of 2 pipe drain holes per subdrain line. The 4" ○ drain pipes shall be sloped 2% down from the 4" ○ perforated PVC pipe. Perforated pipes shall be wrapped in engineering fabric and the pipe drain outlets capped with a galvanized wire mesh. The drainage details shall be shown on the shop drawings and are subject to approval of the Engineer.

- Vista Walls sit on a field poured, unreinforced, leveling pad (concrete)
- Sound limestone elevation varied, creating a ripple effect….taller walls, lower leveling pad, and varied in all four corners. This forced a number of wall redesigns.

Perforated Pipe Drains (behind MSE Wall)

CONTECH ENGINEERED SOLUTIONS

Notes:
See Design Sheet 4 for minimum clearances between culvert footings and existing piers.

Note A:
1. MSE walls are to be designed for an equivalent height of 42" of hydrostatic pressure, applied to the back face of the MSE wall from the Q_{100} water elevation to the base of the wall.
2. MSE walls shall be founded on sound limestone. The weathered limestone and shale indicated in the boring logs shall be removed to expose sound limestone. The excavation quantities for MSE walls are included on the Summary Quantities sheet.
3. A 4" dia. perforated PVC subdrain pipe shall be run along the MSE walls at 5'-0" elevation increments, starting at elevation 616.00 and stopping at elevation 626.00. The pipe drain outlets shall be provided every 10'-0" on center max. along the 4" perforated PVC pipes, with a minimum of 2 pipe drain holes per subdrain line. The 4" ○ drain pipes shall be sloped 2% down from the 4" ○ perforated PVC pipe. Perforated pipes shall be wrapped in engineering fabric and the pipe drain outlets capped with a galvanized wire mesh. The drainage details shall be shown on the shop drawings and are subject to approval of the Engineer.

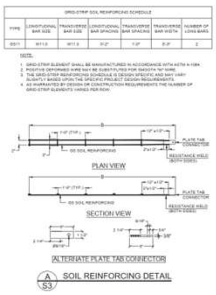
Note B: Provide drainage layer as required by design with a minimum 1'-0 thickness.

Note C: Quantities for flowable mortar are included in the roadway plans.

The contract plans originally called for several rows of 4" diameter pipe drains to allow water to leave the MSE system.

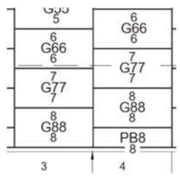
For a single 5x10 panel, taking the top and side joint will allow 135 sq.in of drainage area vs the 12.5 sq.in a 4" pipe would provide

Grid strip design & installation



The Grid-Strip soil reinforcing system is comprised of two Longitudinal bars and several Transverse bars every 12”. The length of the Grid-Strip is 0.70H per plans.

Each Grid-Strip can resist about 7.8kips in tension. Quantities per panel will increase as the wall depth increases.



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Rapid Drawdown Design Considerations

HYDRAULIC DATA

DRAINAGE AREA = 21.9 SQ. MI.
STREAM SLOPE = 11.8FT./MI.
AVG. LOW WATER STAGE = 611.5

Q_{50} = 6,330 CFS
STAGE = 626.10 FT.
BACKWATER = 0.80 FT.
AVG. BRIDGE VELOCITY = 9.20 FPS

Q_{100} = 7,670 CFS
STAGE = 627.10 FT.
BACKWATER = 1.10 FT.
AVG. BRIDGE VELOCITY = 10.40 FPS

Project Information

VAWS #:	629.184
Name:	IA 1 OVER LITTLE LICK CREEK
Location:	Van Buren Co, IA
Project #:	
Design Engineer:	raf
Wall Name:	Van Buren Walls

Soil Parameters

	Unit Weight	Friction Angle
MSE Backfill:	0.120 (kcf)	34 (deg)
Retained Backfill:	0.120 (kcf)	30 (deg)
Foundation Backfill:	0.120 (kcf)	34 (deg)
Earth Surcharge:	0.125 (kcf)	
Depth to Water Table:		0.00 (ft)

LRFD Procedure
Stiffness Method

Rapid Draw Down External Stability Calculation - All Records

Record #1

Wall Height (H):	45.71 (ft)
Soil Reinforcing Length (B):	32.00 (ft)
Height of Surcharge (S):	10.00 (ft)
Slope of surcharge (ψ):	6.24 (deg)
Depth from the top of wall to the high water level (Zw):	16.98 (ft)
Depth from the top of Zw to the draw down level (Zrd):	3.50 (ft)

Limiting Eccentricity Check

	Min	Max	Service
Eccentricity (ft)	6.24	6.82	6.09
Limiting (ft)	8.00	8.00	8.00
Effective Width (ft)	19.53	18.36	19.82

Bearing Capacity Check

	Min	Max	Service	Critical
Eccentricity (ft)	6.11	6.72	6.02	9.33
Limiting (ft)	8.00	8.00	8.00	
Effective Width (ft)	19.78	18.56	19.97	13.34
Stress (ksf)	7.27	10.44	7.18	10.78

Sliding Check

CDR Sliding:	1.54
CDR Sliding Service:	2.25

Rapid Drawdown is required when 50% of the wall height is inundated.

At a 100 Yr Water Elevation of 627.00’, about 62% of the wall is under water.

Soil reinforcing longer than 0.70H is required to resist pullout.

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Thank You!

IA 1 Over Little Lick Creek (Van Buren County)

Jake Vogel
Senior Bridge Consultant
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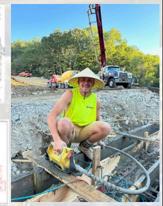
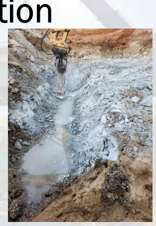
General Construction Schedule

Pre-construction
- Confirmation borings
  - Dug holes onsite to confirm rock elevations and quality of rock
  - Would recommend this occurs in design phase in the future
- Submittals
  - MSE/ Arch submittals move forward after borings
- Design changes
  - Footings needed to be lowered based on findings for both MSE and arch
  - Did not affect arch submittals, but MSE submittals were changed



Foundation Construction

- Excavation was done with large excavators and hammers
- Rock quality was very hard for the most part
- The NE side had poor rock quality. Had to work with Schemmer for some quick design changes to add a step to bear on good quality rock
- We found it difficult to “key” in the footing. Poured it, stripped, added a concrete lug to both sides to act as a key.



Precast Concrete Arch Culvert Construction

- Custom falsework
  - 1-3 months of initial concept
  - 1-2 months of design
  - 1-2 months of procurement
  - 6 weeks of heavy fabrication
  - Received arches on lane closure and tracked to the bottom of the hill with a hydro-crawler crane

MSE Wingwall Construction

- We had many custom pieces due to matching arch and top slopes
- Corners were built incorrect (90 instead of 45)
- Arch matching pieces were matched to arch on ground, arch deflected in place and didn't match perfect
- M&D for this massive amount of sand is essentially impossible (water falls down in 1-3 minutes)

Backfill Procedures

- Used the same material for the arch envelope, floodable backfill, and MSE granular backfill- sand
- Heavily flooding is not easy, nor- in my opinion necessary on these large fills-we ran water per spec, we could achieve compaction without water
- Used skid loaders and skid loader rollers along with plate compactors for compaction

Placement of Flowable Fill

- Hole frequency was called out but sizing was unclear. Used 4" holes for air and 8" for placement
- Filled on outsides as much as possible before going through the deck
- Used 2 concrete buckets with custom built funnels to fill through deck
- We used spray foam as a flange filler material. Only took 2 days.

Arch Construction

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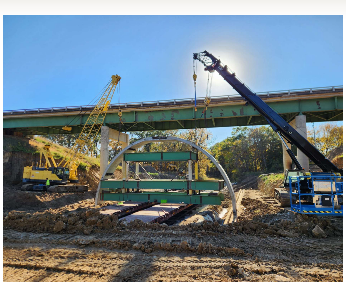
IA 1 over Little Lick Creek | Van Buren County, IA

Q&A SLIDES



Q&A SLIDES

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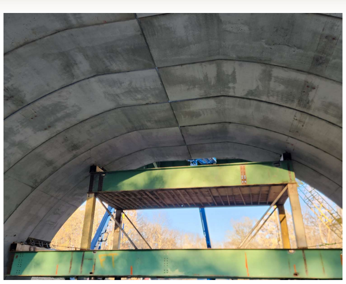

Q&A SLIDES

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