Buried Bridge Solutions for Short Span Bridge Applications

Short Span Steel Bridge Design Workshop

West Virginia LTAP
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Presentation Outline

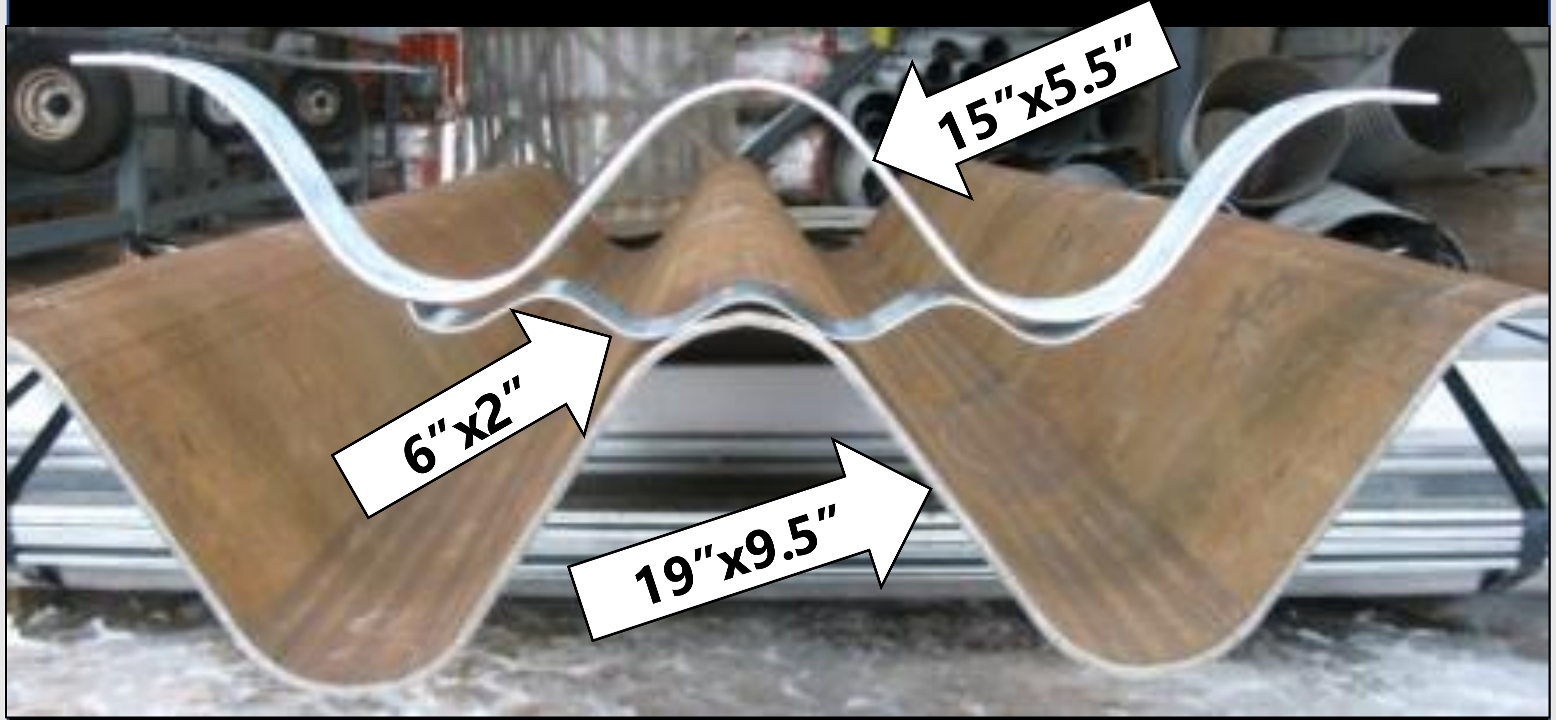
- Buried Bridges Introduction
  - Definition / materials / fabrication
  - Applications & advantages
  - Design & construction considerations
- Case Studies
  - Lawrence Road Bridge Replacement – Gray, Maine
  - Hockamin Creek Culvert Replacements – Lake County, Minnesota
  - St Johnsbury Bridge – St Johnsbury, Vermont
  - Project Snapshots

Buried Bridge Introduction

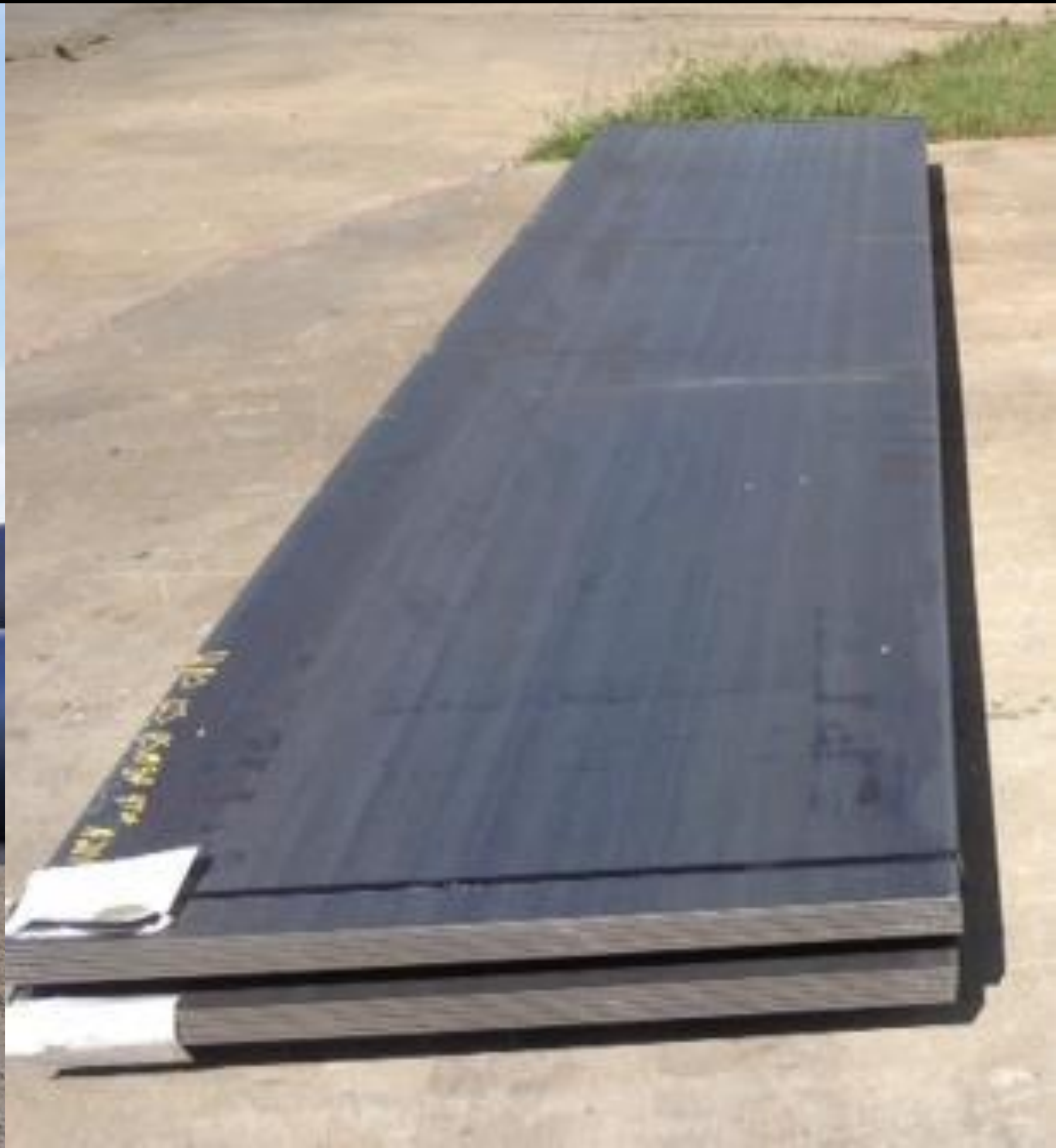
- >20’ span buried structure that works with granular backfill to support loads through soil-structure interaction
- Flexible & able to accommodate differential movement
- Subject of TRB, NACE, DOT webinars, conference sessions, & workshops – design, ABC, resilience, durability / service life, large span applications, load rating, low volume roads
- Meets all AASHTO LRFD materials, design, construction, and load rating requirements and is <u>not proprietary.</u> Analyzed using FEA.

Flexible Buried Bridge Materials

- Shallow Corrugated Steel Structural Plate (6” x 2” profile)
- Aluminum Structural Plate (9” x 2.5” profile)
- Deep Corrugated Steel Structural Plate (15” x 5.5” & 19” x 9.5” profiles)
- Deep Corrugated is ~9x stiffer than shallow corrugated & 6.25x stiffer than aluminum
- Deep Corrugated is ~33% stronger than shallow corrugated & ~100% stronger than aluminum.
- Differential settlement tolerance of ~6” over 50 ft.



Raw Materials – Steel Coil



Corrugating

Punching Bolt Holes

Forming – Computerized 3-Roll

Galvanizing

Shipping

Advantages & Applications

- Wildlife Crossings / AOP
- Value Engineered Solutions
- Grade Separation
- Challenging Geotechnical Conditions
- Bridge Replacement / Rehabilitation
- Structurally Redundant / Resilient
- Single Span Alternative to Multi-Cell Crossings

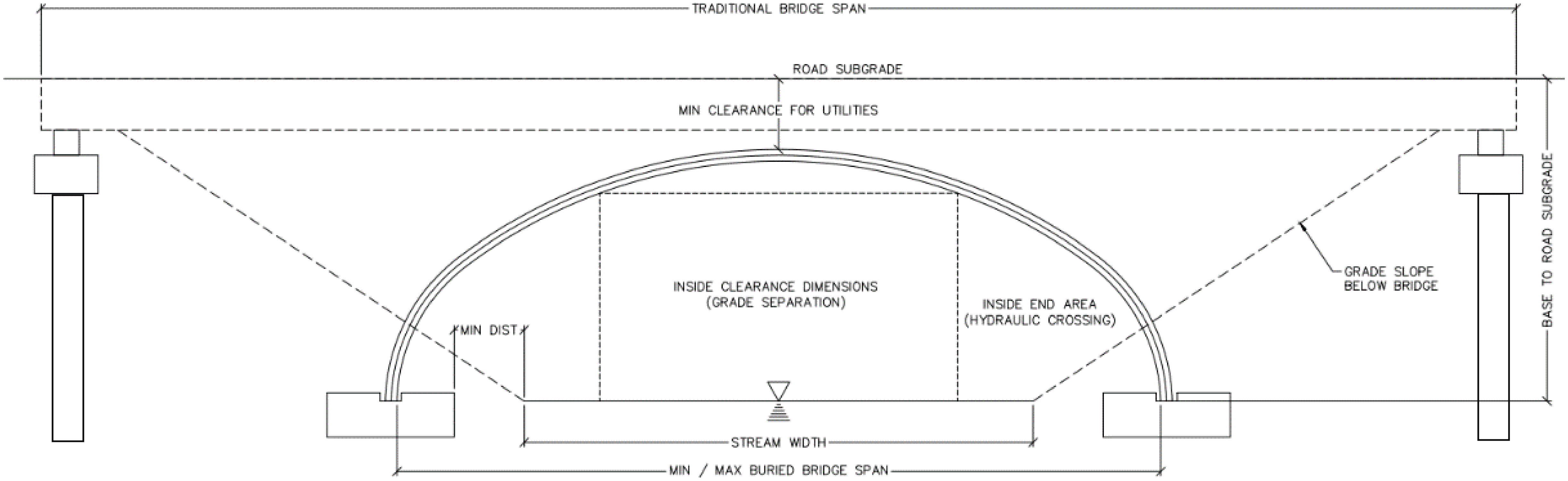
- Lower Cost Foundations
- Emergency / Temp / Detour Bridges
- No “Bump at the end of the bridge”
- Reuse Bridge Foundations
- Staged Construction
- Low Maintenance Cost & Easy to Inspect
- Able to Carry Heavy Loads

Material & Design Properties

- Material properties provided in AASHTO M167 / ASTM A761
- Design properties provided in AASHTO LRFD Section 12 (Appendix A12)
- Construction specifications in AASHTO LRFD Section 26
- Thicknesses up to 0.380” thick.
- Hot dipped galvanized with 3.0 oz/ft^2 coating weight (50% more than CSP)
- ¾” or ⅞” diameter high strength steel bolts (ASTM A449)

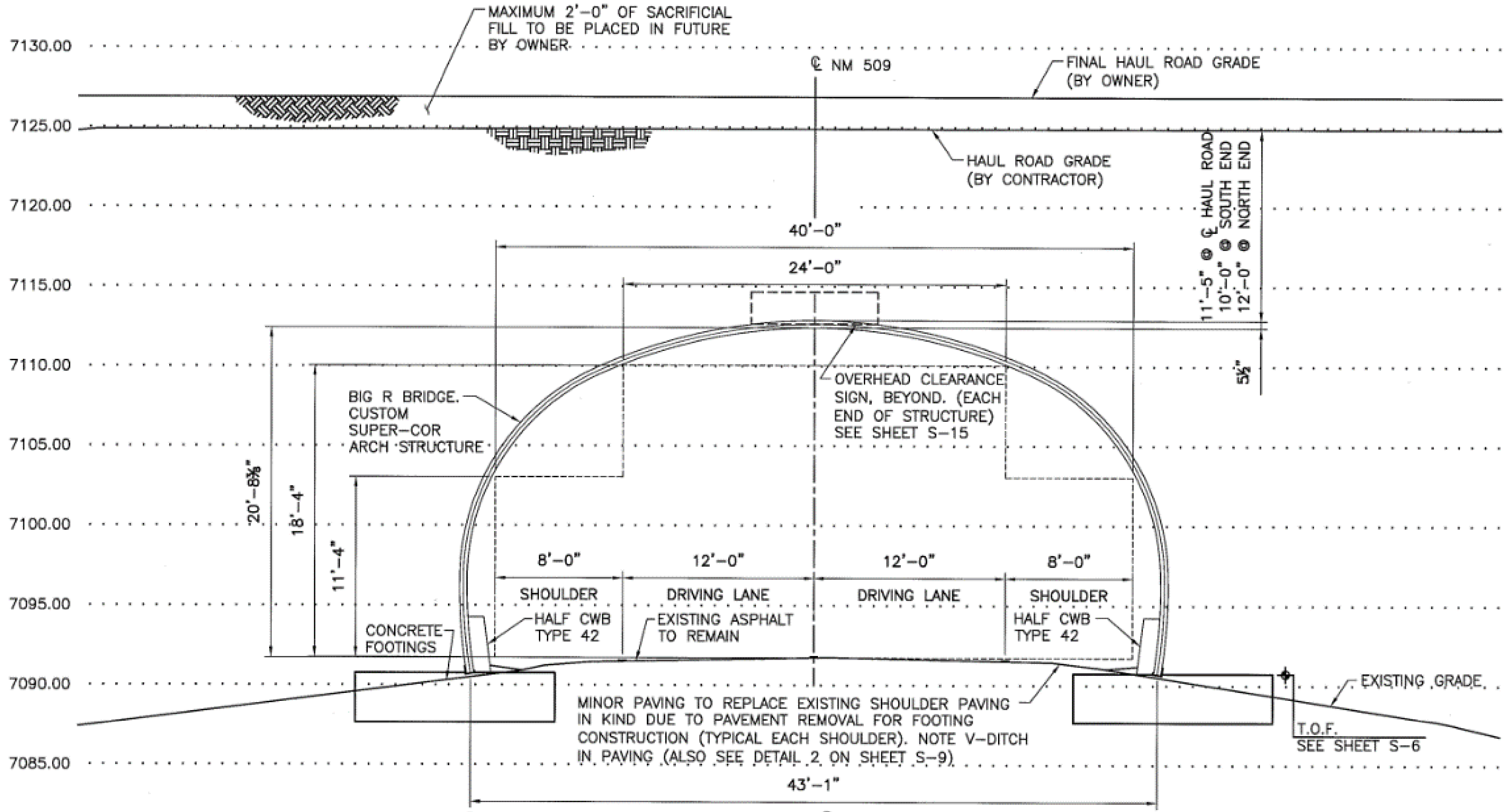
Property	Aluminum (ALSP)	Shallow Corrugated Steel	Deep Corrugated Steel
Geometry Types	Small arch, box, closed shapes	Arches, closed shapes	Arch, box, pipe, multi-radius arches
Corrugation Profile	9” x 2.5”	6” x 2”	15” x 5.5”
Design Yield Strength	24 ksi	33 ksi	44 ksi
Relative Stiffness	~1.5 x shallow	1 (baseline)	~9 x shallow ~6.25 x ALSP

Evaluation as a Conventional Bridge Alternative



SITE CONDITIONS & CONSTRAINTS

https://www.shortspansteelbridges.org/flexible-buried-bridges-part-1/



PROFILE @ ℄ HAUL ROAD (LOOKING NORTH)


Peabody
18 FT 8 IN

Allowable Settlement

- Once the structure has been backfilled over the crown, settlement of the supporting backfill relative to the structure must be limited to control downdrag forces. If the sidefill will settle more than the structure, a detailed analysis may be required.

- Settlement along the longitudinal centerline of arch structures must be limited to maintain slope and preclude footing cracks in arches.

Calculated differential settlement across the structure taken from springline-to-springline, Δ, shall satisfy:

$$\Delta \leq \frac{0.01S^2}{R} \quad (12.8.4.1\text{-}1)$$

where:

S = span of structure between springlines of long-span structural plate structures (ft)

R = rise of structure (ft)

More restrictive settlement limits may be required where needed to protect pavements or to limit longitudinal differential deflections.

Once the top arc of the structure has been backfilled, downdrag forces may occur if the structure backfill settles into the foundation more than the structure. This results in the structure carrying more soil load than the overburden directly above it. If undertaken prior to erecting the structure, site improvements such as surcharging, foundation compacting, etc., often adequately correct these conditions.

Where the structure will settle uniformly with the adjacent soils, long-spans with full inverts can be built on a camber to achieve a proper final grade.

For design, differential settlement between the footings taken across the structure is limited to avoid excessive eccentricity. The limit on any settlement-induced rotation of the structure maintains the top arc centerline within one percent of span, as shown in Figure C12.8.4.1-1.

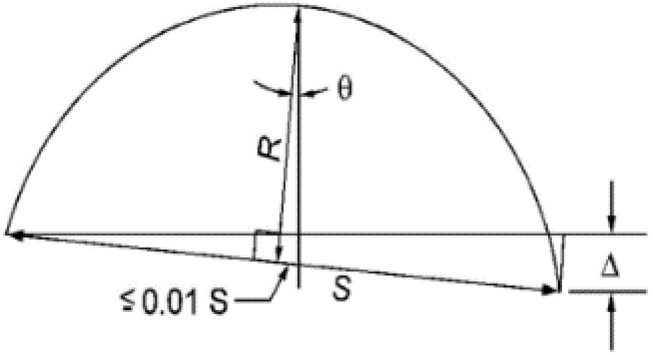


Figure C12.8.4.1-1—Differential Settlement

The rotation of the structure, θ, may be determined as:

$$\theta = \tan^{-1}\left(\frac{\Delta}{S}\right) \quad (C12.8.4.1\text{-}1)$$

From AASHTO LRFD Section 12.8.4.1:

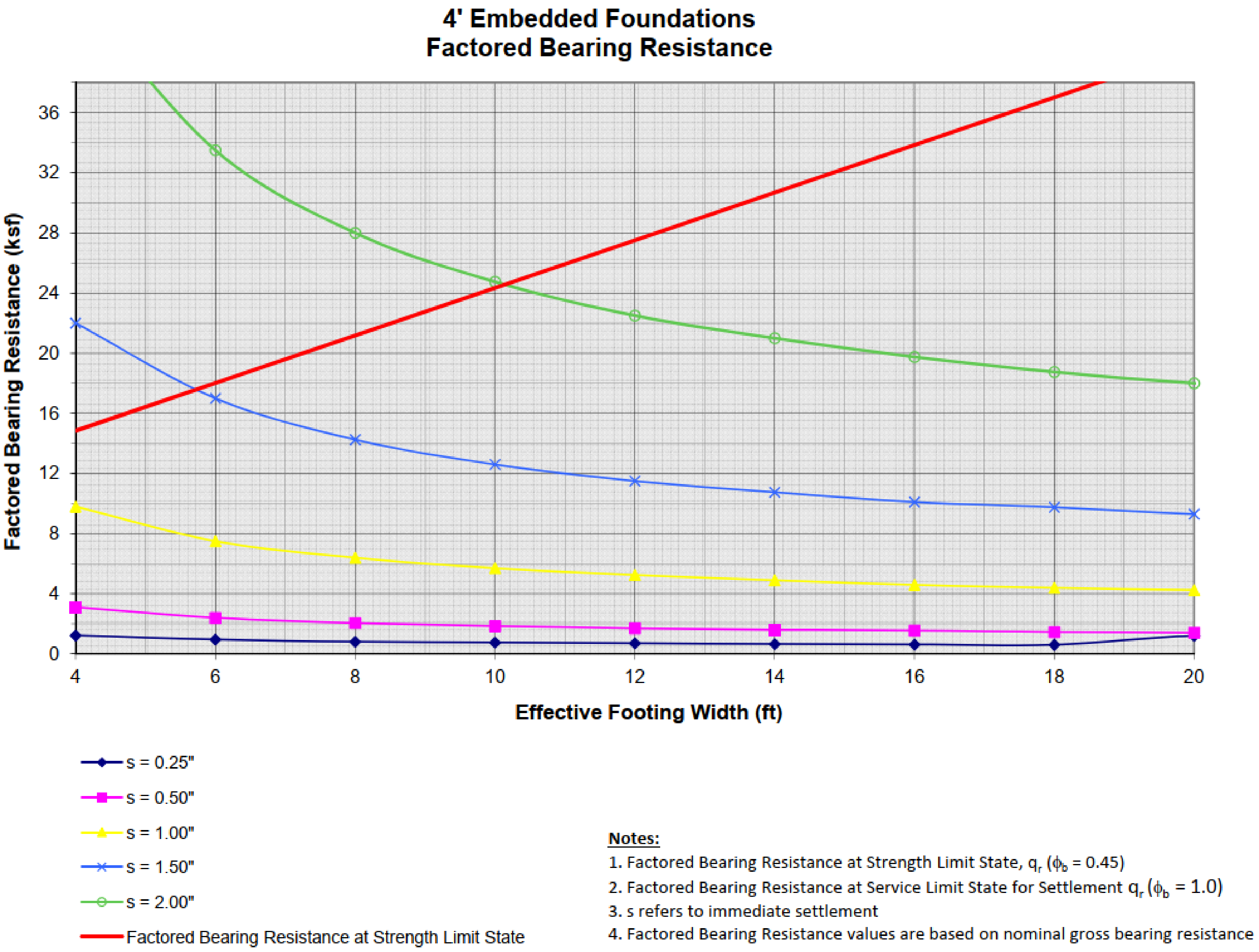
Notes on Settlement:

- Allowable differential settlement is a function of structure span & rise
- Structural plate structures can usually accommodate more than conventional bridges & precast structures
- Eq 12.8.4.1-1 results in higher allowable differential settlement as structure size increases – in some cases much higher than we are comfortable with.
- Rule of thumb is 6” over 50 ft across the span and 6” over 50 ft if gradual along the length for structural plate.
- Settlement tolerance of footings will sometimes govern (usually in 2-4” range)
- Considering settlement tolerance of structure will always result in smaller foundation

AASHTO LRFD Considers Settlement & Footing Width

Factors Impacting Settlement:

- Stiffness / compressibility of foundation soils (function of friction angle, soil type, cohesion, relative density, presence of water, etc.)
- Thickness of compressible layers
- Footing width
- Applied footing loads
- Original stress state (original vs final grade elevation)
- **No matter what footing design method is used (LFD or LRFD), there should be an option to increase bearing pressure by incorporating soil improvement – almost always more economical than larger foundations**



Case Studies

- Lawrence Rd Bridge Replacement – Gray, Maine
- Hockamin Creek Culvert / AOP Replacements – Lake County, Minnesota
- St Johnsbury Bridge Replacement – St Johnsbury, Vermont
- Additional Projects

Lawrence Rd. Bridge Replacement
Gray, Maine

Custom Box Structure
28’ 1½ ” span x 6’ 3½ ” rise

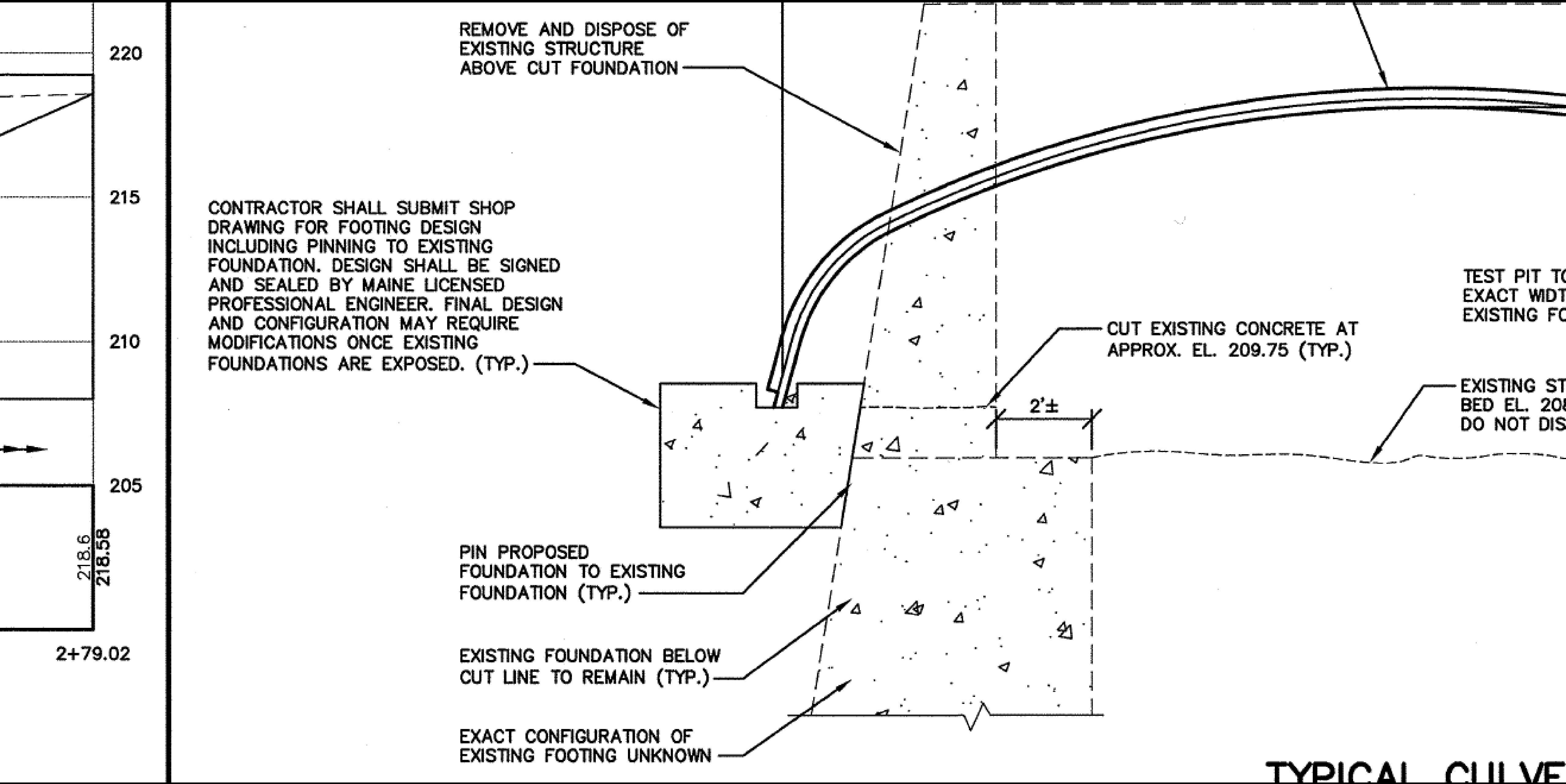
<u>Design Considerations:</u>

- Short span bridge replacement
- Height limitations
- Bridge foundations to remain
- New headwall configuration

Existing Bridge


Existing Bridge

Foundation Detail



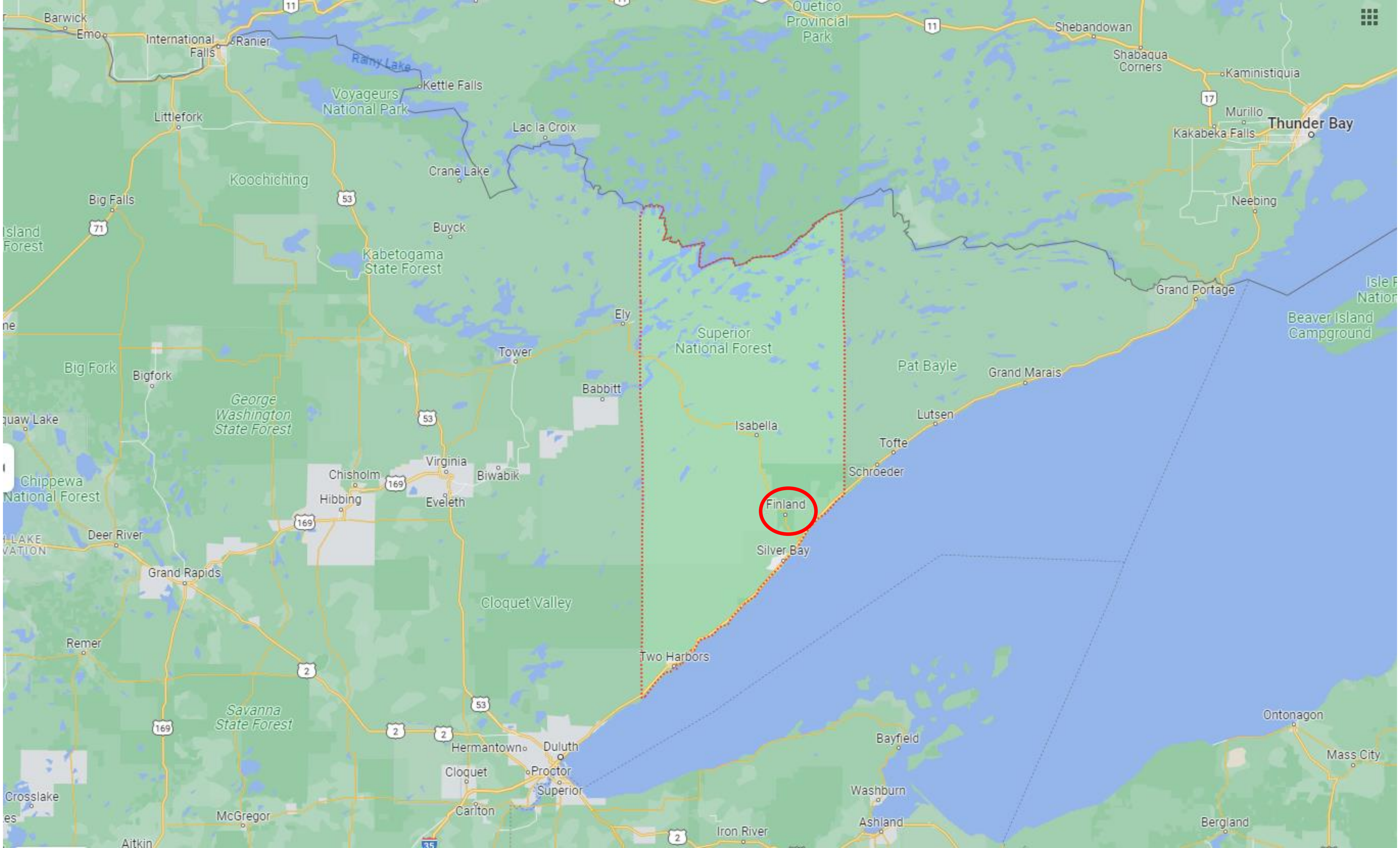
Getting Started


MATSU

Backfilling & Headwalls

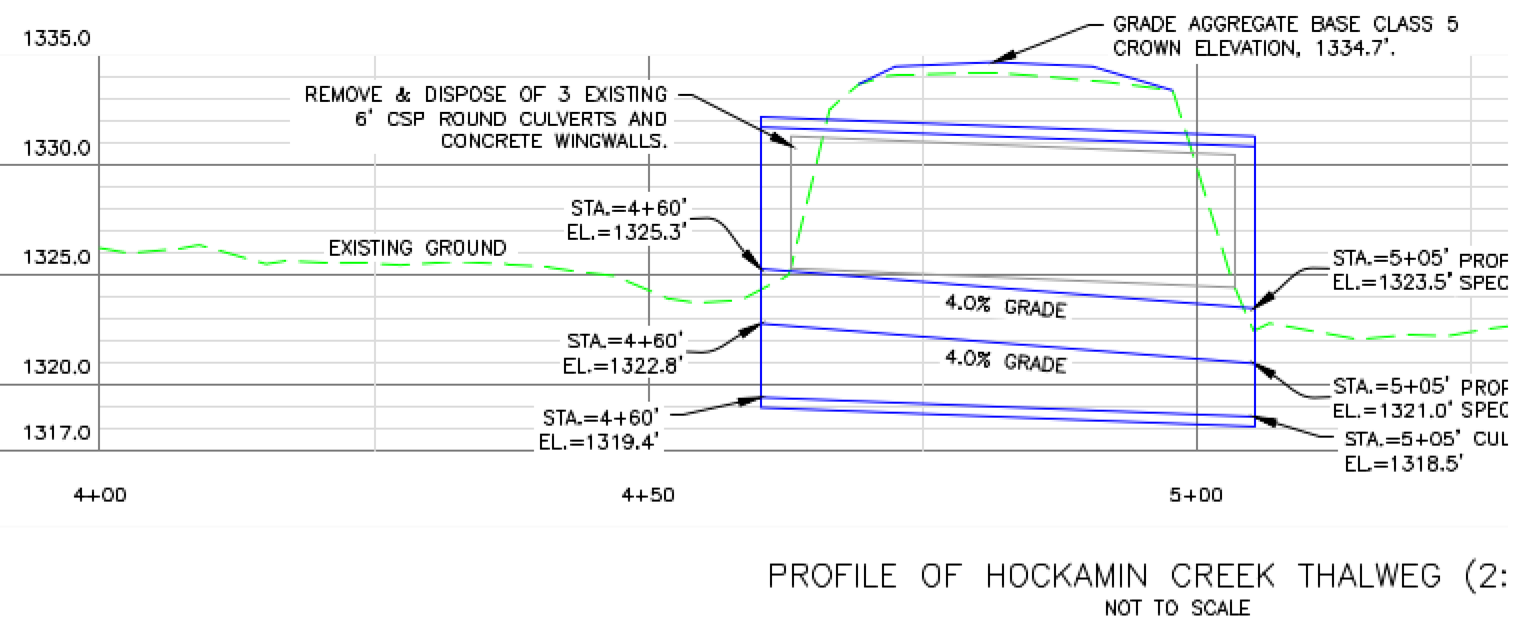

No Walers or Deadmen
KOMATSU
MACK
DEERE

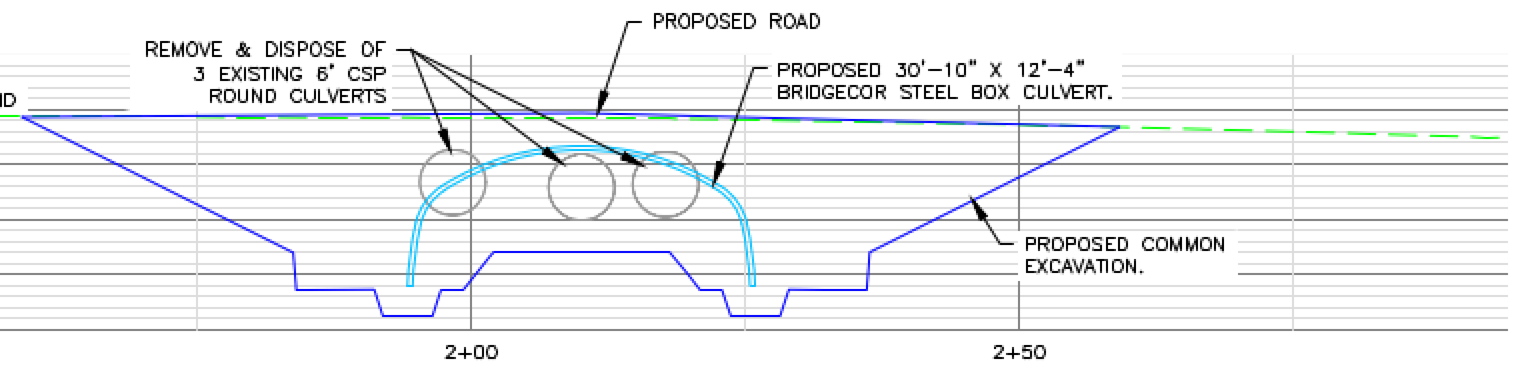

Hockamin Creek Culvert / AOP Replacements
Lake County, Minnesota
HITACHI
DEERE
30’10” span x 12’4” rise Box Structure (Breezy Lane)
26’ span x 8’4” rise Low Profile Arch (Heffelfinger Road)

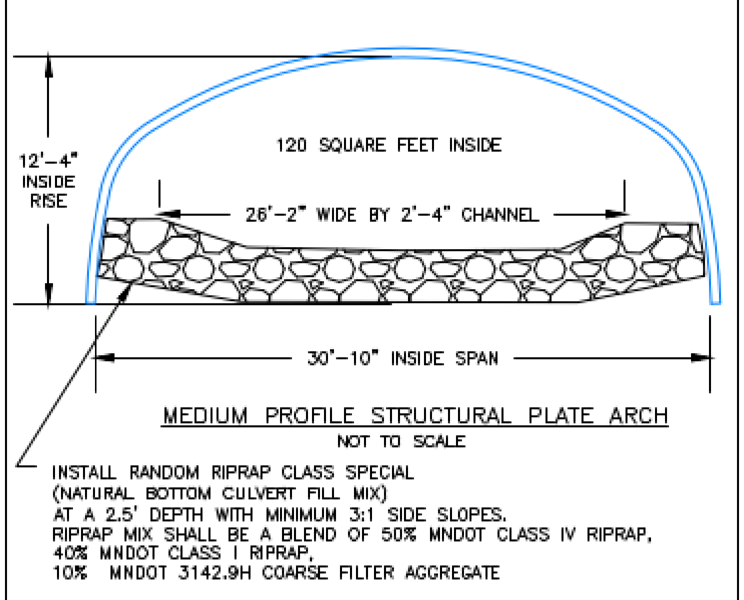

Barwick
Emo
International Falls
Ranier
Rainy Lake
Kettle Falls
Voyageurs National Park
Littlefork
Lac la Croix
Crane Lake
Koochiching
Big Falls
Buyck
Kabetogama State Forest
Quetico Provincial Park
Shebandowan
Shabaqua Corners
Kaministiquia
Murillo
Kakabeka Falls
Thunder Bay
Neebing
Grand Portage
Beaver Island Campground
Superior National Forest
Ely
Tower
Babbitt
Big Fork
Bigfork
George Washington State Forest
Pat Bayle
Grand Marais
Lutsen
Isabella
Tofte
Schroeder
Finland
Silver Bay
Chisholm
Virginia
Biwabik
Hibbing
Eveleth
Chippewa National Forest
Deer River
Grand Rapids
Cloquet Valley
Two Harbors
Remer
Savanna State Forest
Hermantown
Duluth
Proctor
Cloquet
Superior
Carlton
McGregor
Aitkin
Crosslake
Bayfield
Washburn
Ashland
Iron River
Ontonagon
Mass City
Bergland

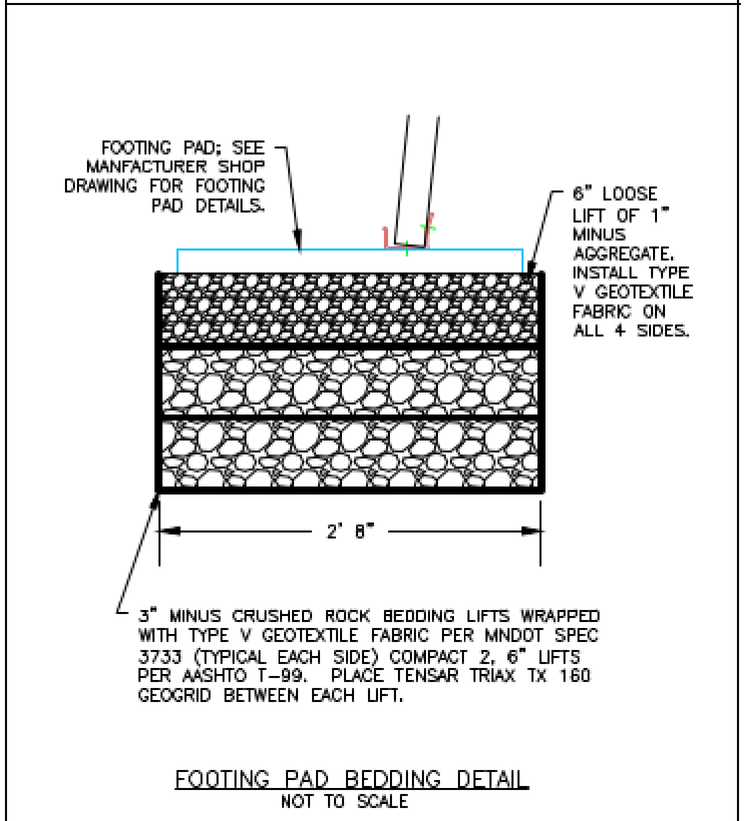
<u>Breezy Point Lane</u>

- Replace 3 culverts
- Maintain existing road grade
- Flexible foundations extended to frost depth
- Sloped grades to eliminate need for headwalls









Breezy Lane

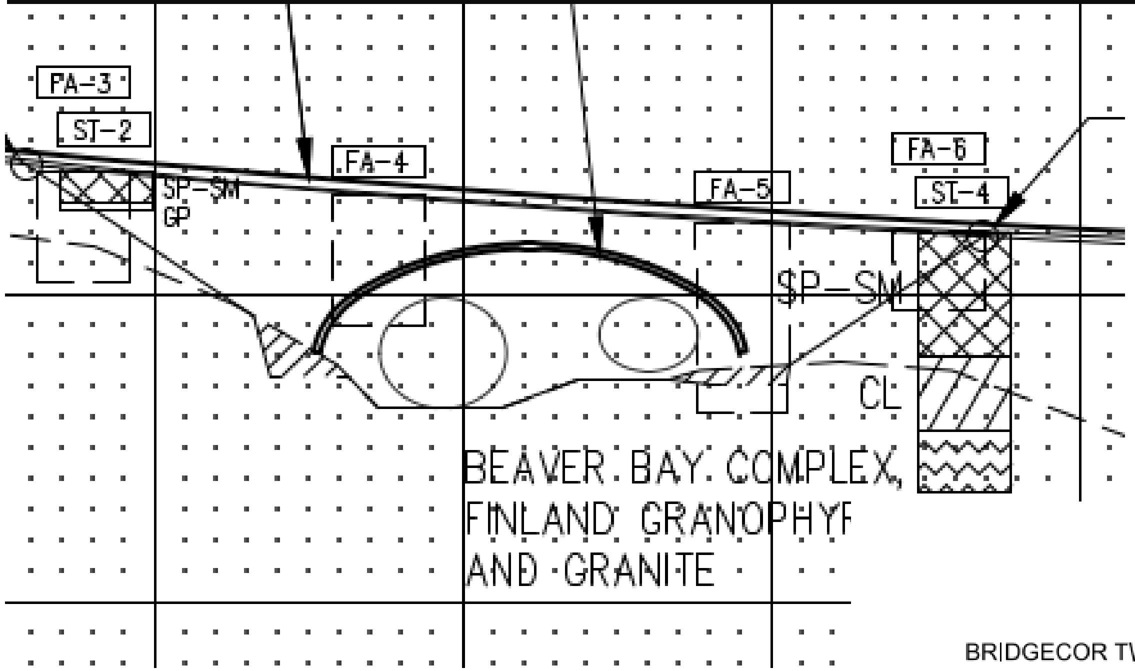
Breezy Point Lane

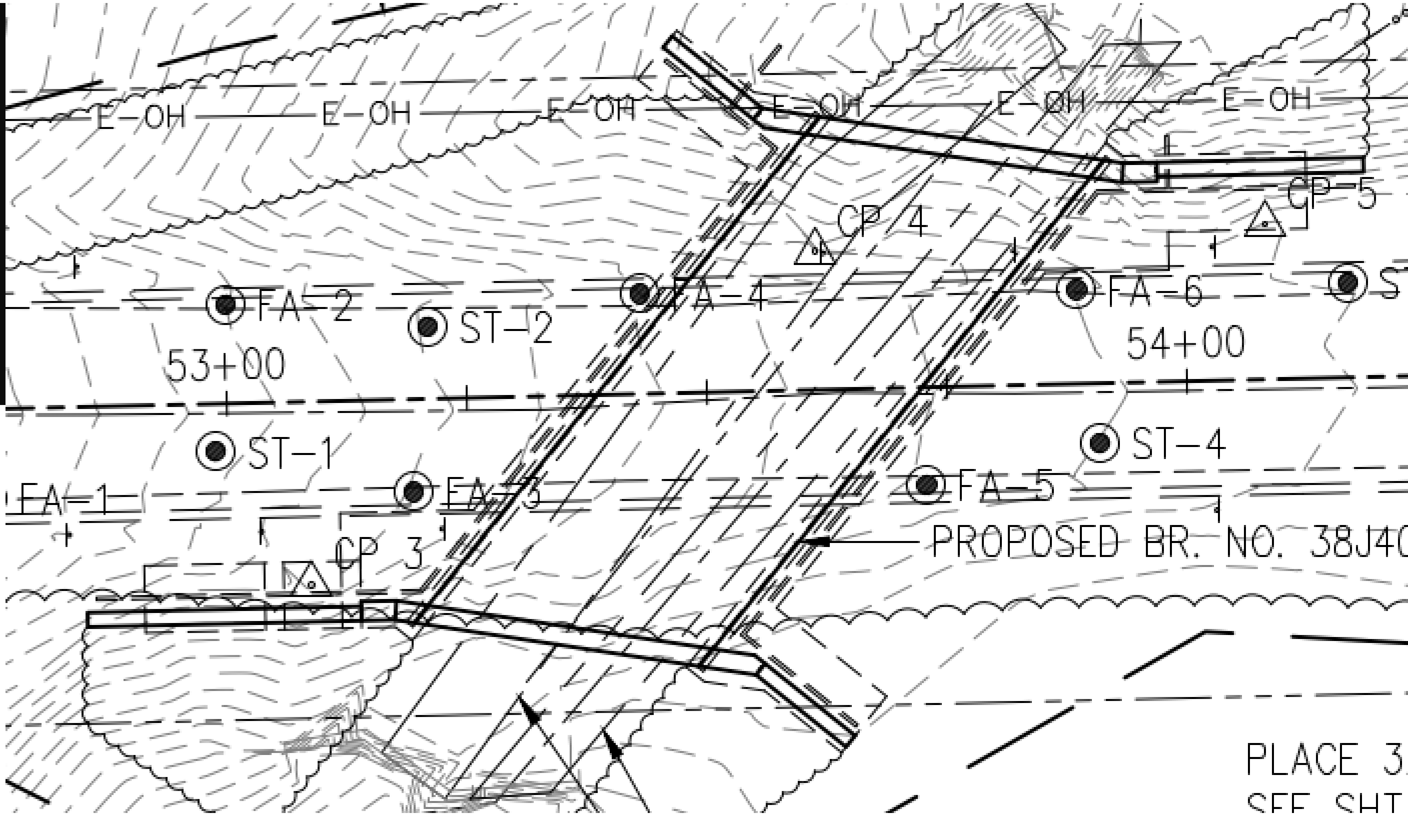
Breezy Point Lane

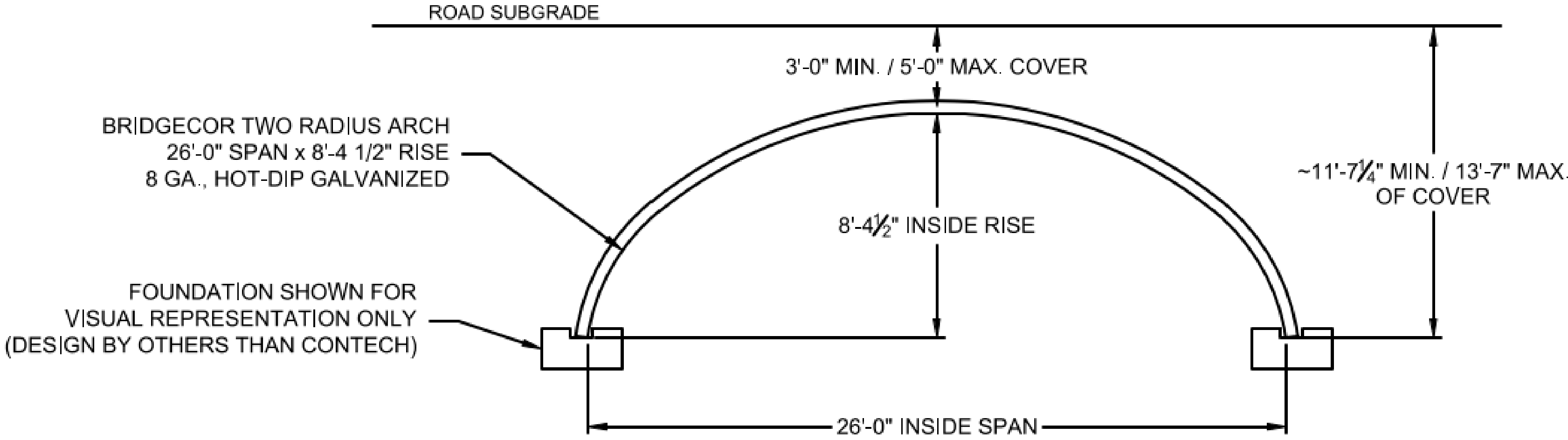

Breezy Point Lane

Hefflefinger Road

- Replace 2 culverts
- Raise road grade
- Skewed alignment with road grade
- Concrete headwalls to limit structure footprint & maintain stream alignment







Hefflefinger Road

Hefflefinger Road

Hefflefinger Road

VT Route 2B Bridge Replacement
St. Johnsbury, Vermont

47’11” span x 26’9” rise Arch

- Replacement for 139 ft 3-span steel & concrete bridge built in 1936
- Sized for AREMA clearance
- 28 day max. trail closure / 50 day road closure for all work
- 1.5 days for assembly by first time contractor, open to public in 45 days
- Incorporated MSE precast panel headwalls on curve.
- Used precast footings – sized to match anticipated settlement of approach embankments.


CAT
Genie S-40
Genie S-40
CAT
336E


8050
CAT

Randolph, Nebraska 50’ x 17’
Grade Separation with E80 Loading

Lawrence County, Missouri
I-44 Bridge Replacements (4 bridges replaced with 2 buried bridges)

Case Study Slides:
https://www.shortspansteelbridges.org/wp-content/uploads/2022/09/I44-Missouri-Buried-Bridge-J
Hahm-Contech.pdf

Case Study Video:
https://www.youtube.com/watch?v=FmGANs1WqzO&t=4s


Union Township, Pennsylvania
Bridge Replacement, Skewed Ends


Craig, Alaska
Built by tribal forces


Knoxville, Tennessee
~33’+ span with step beveled ends

Skagway, Alaska 75'x25'
75' cover with RCC

Banff, Alberta Wildlife Crossing

Findlay, Ohio 48’ x 21’
I-75 Bridge Replacement, Staged Construction

Spokane, Washington

40’ cover, phased construction

Topeka, Kansas
Reline of 40’ span x 200’ long concrete arch under I-70


Houston, Texas
Phased Construction
Recycled Concrete Backfill
Architectural Requirements

LaCygne, Kansas 53’ x 25’
Grade Separation

Knox County, Indiana 53' x 24'
E80 Loading

Irvine, California
Pedestrian Crossing, Sustainable Construction

Greensboro, South Carolina 53’ x 25’
Significant Settlement of Backfill

Thank You!

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Durability & Service Life

- **Buried bridges typically have no invert**
- **50% more galvanizing than CSP and are available in much higher steel thicknesses**
- **Electrochemical requirements apply for soil & water _in contact with_ the structure – not necessarily site soil conditions.**
- **Use same backfill electrochemical requirements as those in AASHTO LRFD Design Section 11.10.6.4.2 for MSE walls:**

  - pH = 5 to 10
  - Resistivity ≥3000 ohm-cm
  - Chlorides ≤100 ppm
  - Sulfates ≤200 ppm
  - Organic Content ≤1 percent

- **Added features/detailing like splash walls, secondary coatings, barriers, etc. can limit exposure.**
- **Design considerations (site conditions, foundations, grading, proper hydraulic design, etc.) & quality of construction can have a significant impact on service life.**
- ***Service life primarily depends on proper design & installation, maintenance, and what structure is exposed to. End user (owner) has greatest impact on and control over service life.***