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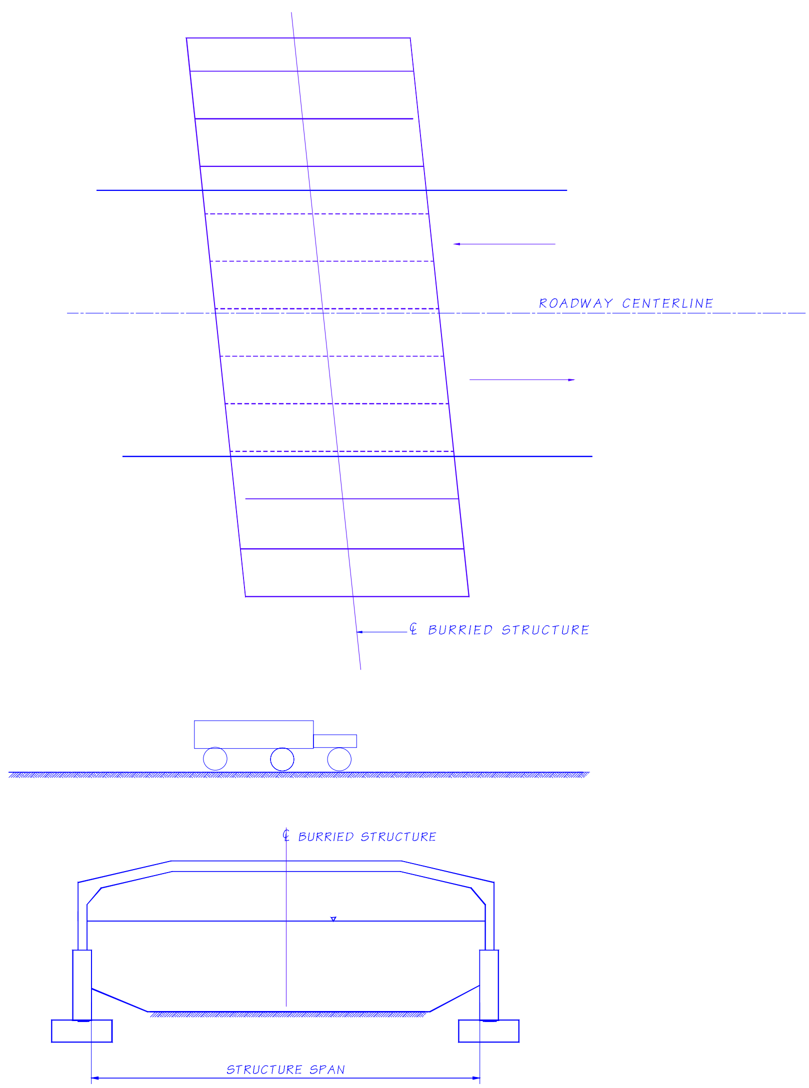
APPENDIX 8.3-B2

3-SIDED PRECAST BURIED STRUCTURES DESIGN CRITERIA



LRFD Otherwise Noted

I. GENERAL

The criteria is for the highway and hydraulic buried structures of precast or cast-in-place three sided, semi-arch, and arch systems.

The terminology of buried structure is used for all highway and hydraulic structures, and the culvert is used for hydraulic structures only.

The selection of type of structures is depending on span and rise requirements determined by Highway, Environmental, Hydraulic, and Geotech requirements. Bridge Office has developed the 3-sided structures with spans from 20' to 60', see Preliminary Culvert Standards 8.3.3-A3 to 8.3.3-A4, and 8.3.3-A9.

The buried structures to be designed for the following guidelines; any special consideration shall be consulted with the Bridge Design Engineer, Geotech Engineer, and Hydraulic Engineer.

II. DESIGN SPECIFICATIONS

A. AASHTO LRFD Bridge Design Specification, 8th Edition.

B. WSDOT Bridge Design Manual, M23-50, current edition (BDM).

C. WSDOT Geotechnical Design Manual, M46-03, current edition (GDM).

D. Technical Manual for Design and Construction of Road Tunnels - Civil Elements, FHWA-NHI-10-034.

E. NFPA 502 Standard for Road Tunnels, Bridges, and Other Limited Access Highways.

F. ASTM C 1504 - Three-sided structures for storm water and culverts

G. ACI 318, for tunnel and special design.

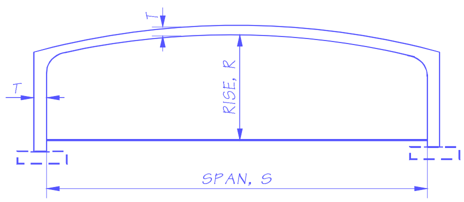
III. DESIGN PROCEDURES

After the structure type has been selected. The structure design is following into two steps:

A. For Service I and Strength I Limit States - Use Gstrudl, CSI Bridge, or other programs to determine the forces.

B. For Extreme I Limit State - Use "Racking Method" per the design specification D above, to determine the forces for the Earthquake. The analysis for racking may be done either GSTrudl, CSI Bridge, or other programs.

IV. GEOMETRY

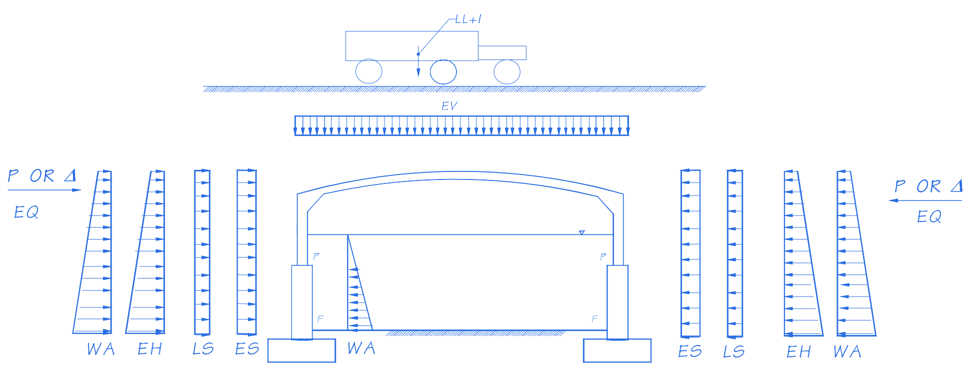


Use Preliminary Culvert Standard 8.3.3-A3
for thickness of deck and wall.

Wall Thickness T = 8" min. for span < 24' 12.14.4
T = 10" min. for span > 24'

Max skew = 45^o (to centerline of structure)

V. LOADING DIAGRAMS



LOADING DIAGRAMS

VI. DESIGN LOADING

A. DC and DW - Dead Load BDM Table 3.8-1

1. Concrete structure dead load = 155 lb/cf
2. Overburden fill = 125 lb/cf (or provided by the Geotech Engineer)
3. HMA overlay = 140 lb/cf
4. Backfill along walls = 125 lb/cf (or provided by the Geotech Engineer)

B. EH, EV, ES, LS, and ES - Earth Pressure

1. EH - Horizontal Earth Pressure

$$p = k.\gamma_S . z$$

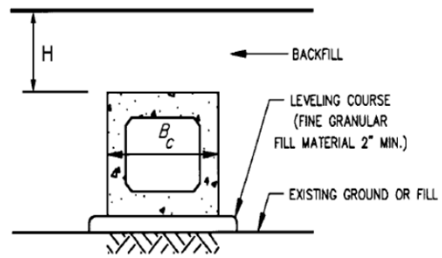
$k = k_0$ specified in sect. 3.11.5.2 for wall that not deflect, which applies for the frame type structure.

2. EV - Vertical Earth Pressure due to overburden soil above the structure — 12.11.2.2.1

A. Embankment Installation

EV = $W_e = F_e . \gamma_S . B_c H$ — (12.11.2.2.1-1)

$$F_e = 1 + 0.20\frac{H}{B_c}$$ — (12.11.2.2.1-2)

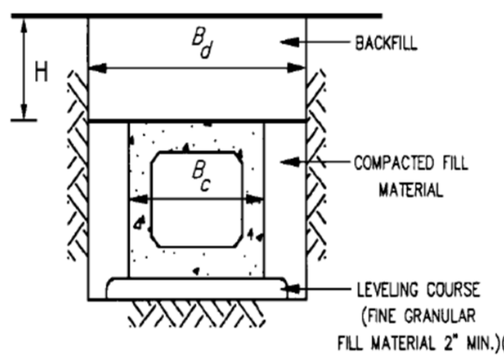


EMBANKMENT CONDITION

B. Trench Installation

EV = $W_e = F_t . \gamma_S . B_c H$ — (12.11.2.2.1-3)

$$F_t = \frac{C_d B_{d2}}{HB_c} \le F_e$$ — (12.11.2.2.1-4)



3. ES - Earth pressure Surcharge

The earth pressure surcharge to be provided by the Geotech engineer.

4. LS - Live Load Surcharge

2' live load surcharge to be used.

C. LL - Live Load on top of Culvert

Live load consists of standard AASHTO design truck load or tandum, with 1.2 single lane multiple presence factor.

Three conditions of liveload application on top of buried structure:

. 2' of fill or less.
. 2' to 8' of fill.
. > 8' of fill

`

Two cases of live load distribution on top of the buried structures to be considered:

. The live load <u>parallel</u> to the culvert span, and
. The live load <u>perpendicular</u> to the the culvert span.

In most cases of the buried structures, live load <u>parallel</u> to structure will control for the traffic on top of the structure.

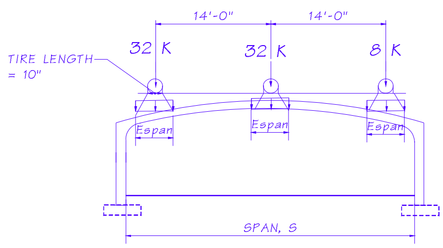
Condition 1 - 2' of fill or less
- live load distributed to top slab per sections 3.6.1.2.6 and 4.6.2.10

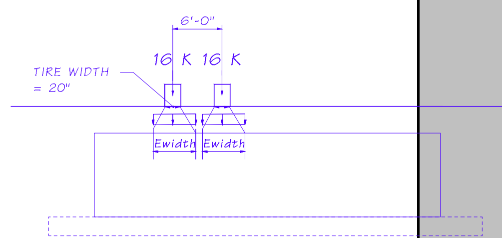
The distribution of the wheel load in both directions are analyzed below:

$$\boldsymbol{E_{WIDTH} = 96 + 1.44\,S}$$ S = span length

$$\boldsymbol{E_{SPAN} = L_T. + LLDF\ (H)}$$ H = Depth of ground cover on top of culvert

Case 1 - Traffic travels parallel to span of buried structure





Live load distribution parallel

Live load distribution transverse

Case 2 - Traffic travels perpendicular to span of buried structure
(not considered at this time)

Condition 2 - 2' to 8' of fill - Live load distributed to top slab per section 3.6.1.2.6a

Case 1 - Traffic travels parallel to span of buried structure
(see the loading pictures above)

Live load distribution parallel to the buried structure

$$H_{int-p} = \frac{S_a - \frac{l_t}{12}}{LLDF}$$

Where H < Hint-p

$$l_w = \frac{l_t}{12} + LLDF(\text{H})$$

Where H > Hint-p

$$l_w = \frac{l_t}{12} + s_a + LLDF(\text{H})$$

Live load distribution transverse to the buried structure

$$H_{int} = \frac{S_w - \frac{w_i}{12} - 0.06 * \frac{D_t}{12}}{LLDF}$$

Where H < Hint

$$w_w = \frac{w_i}{12} + LLDF * H + 0.06 * \frac{D_t}{12}$$

Where H > Hint

$$w_w = \frac{w_i}{12} + s_w + LLDF * H + 0.06 * \frac{D_t}{12}$$

Case 2 - Traffic travels perpendicular to span of buried structure

(not considered at this time)

Condition 3 Fill > 8' and > span length

Ignore the live load effects per 3.6.1.2.6a

For fill < 8', the live load effect shall be considered.

D. Live Load Impact 3.6.2.2

The dynamic load allowance for buried structures:

$$IM = 33\,(1.0 - 0.125 {*} D_E) = \text{or} > \text{than } 0$$

D_E (ft)	IM
1	0.29
2	0.25
3	0.21
4	0.17
5	0.12
6	0.08
7	0.04
8	0.00

D_E = depth of cover

Per inspection, the Impact Factor can be ignored for $D_E > 8'$

E. Truck and Train Impact

For the cases where the buried structures to be used for highway and railroad structure only.

F. Thermal, Creep, and Shrinkage

1. Thermal in transverse direction for joint between segments
   The thermal loading may be considered for joint gap between segments.

G. Post-Tensioning

Post-tensioning may be used to connection the segments together in longitudinal section due to settlement and other issues.

H. WA - Hydrostatic, Stream, and Buoyancy (for culvert structure only)

I. Seismic Load

The seismic design for the underground structures shall be analyzed according to the FHWA-NHI-10-034 "Technical Manual for Design and Construction of Roadway Tunnels - Civil Elements" on racking and vertical ground acceleration.

1. Racking Analysis

2. Vertical Ground Acceleration Effects

Design notes:

. Per design experience - no racking analysis is needed for culvert span of 25' or less, height 15' or less, and fill cover less than 10'. Due to the deflection and forces of the racking analysis is very small.

VII. LOAD COMBINATIONS

A. Limit States

Design per AASHTO Table 3.4.1-1

LIMIT STATE	DC		DW		EH /EV		ES		LS, LL+IM	WA	TU, CR, SH		EQ	IC
LOAD COMB.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.			Max.	Min.		
Strength I	1.25	0.90	1.50	0.65	1.35	0.90	1.50	0.75	1.75	1.00	1.20	0.50	0.00	0.00
Strength II	1.25	0.90	1.50	0.65	1.35	0.90	1.50	0.75	1.35	1.00	1.20	0.50	0.00	0.00
Strength III	1.25	0.90	1.50	0.65	1.35	0.90	1.50	0.75	0.00	1.00	1.20	0.50	0.00	0.00
Service I	1.00		1.00		1.00		1.00		1.00	1.00	1.20	1.00	0.00	0.00
Sevice IV	1.00		1.00		1.00		1.00		0.00	1.00	1.20	1.00	0.00	0.00
Extreme I	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
Extreme II	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	0.00	0.00	0.00	1.00

B. Resistance Factors

Strength Limit

Flexural, ϕ = 1.00 for Precast and 0.95 for Cast-in-Place — Table 12,5,5-1

Shear, ϕ = 0.90 — Table 12,5,5-2

Bearing, ϕ = 0.70 bearing on concrete — Table 12,5,5-3

Extreme Limit

Flexural, ϕ = 1.00

Shear, ϕ = 1.00

Bearing, ϕ = 1.00

C. Non-Reduncancy — 12.5.4

η_R = 1.05 per section 1.3.4

VIII. STRUCTURAL MATERIALS

A. Concrete

Class 5000, 6000, and 7000 for precast and 4000 for CIP elements.

Class 7000 SCC per manufacture's recommendation.

B. Reinforcement

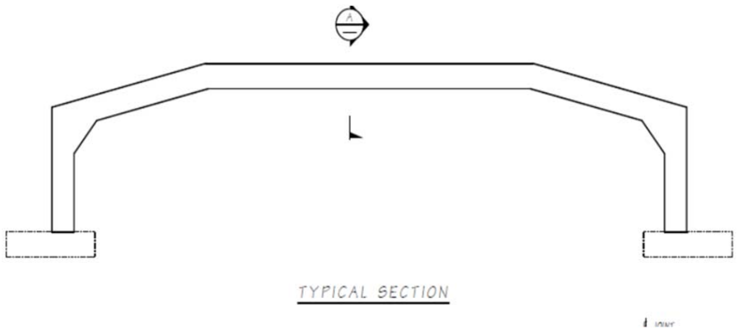
AASHTO M31 (ASTM A615) for all. Welded Wire fabric (ASTM A 1064) can be used in place of ASTM A615.

IX. SPECIAL STRUCTURAL DESIGN AND DETAILS

A. Joint Types

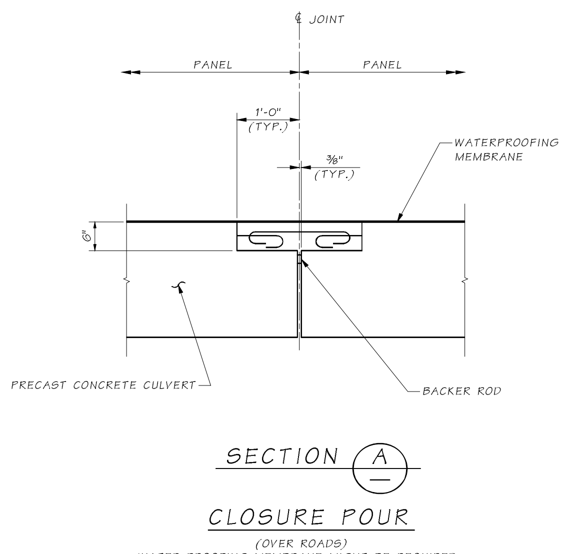
1. Longitudinal Connection - between segments

AASHTO Section 12.14.5.4 requires means of shear transfer with flat top and less than 2' fill.



Case A - for traffic inside the buried structure

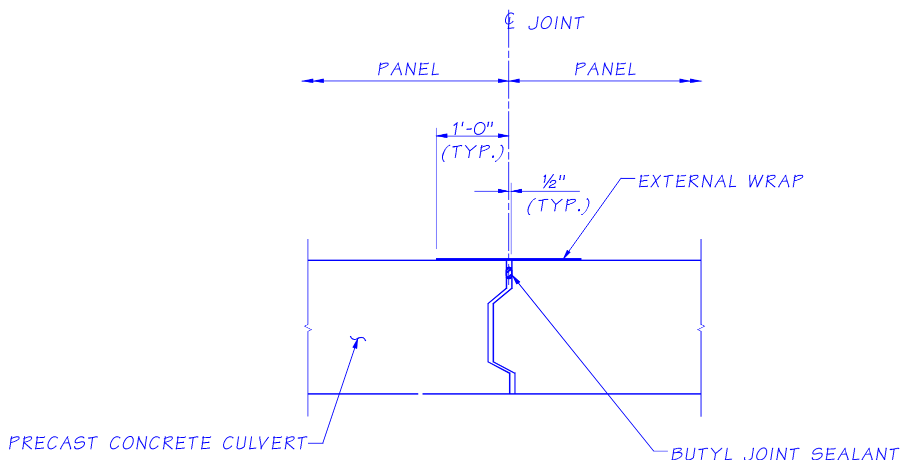
The precast segments need closure pour type of connection to prevent any water leaking down from top as shown below.



Case B - for general stream culvert

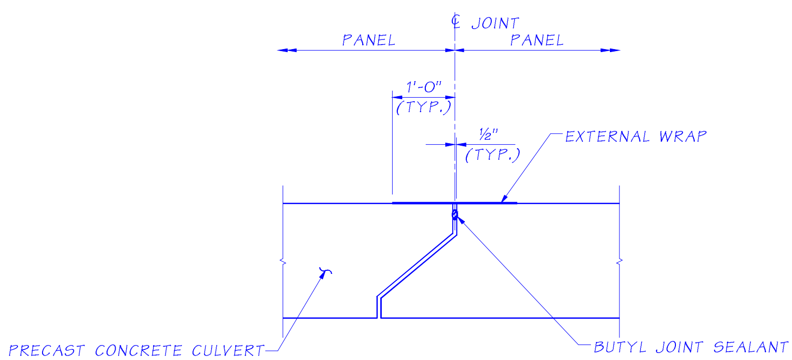
Either welded tie, tongue and groove, or shear key type of connection can be used, see below. (Other types of connection may be used per approval by the Engineer).

The butyl joint sealant shall be conformed to ASTM C 990.



SECTION A

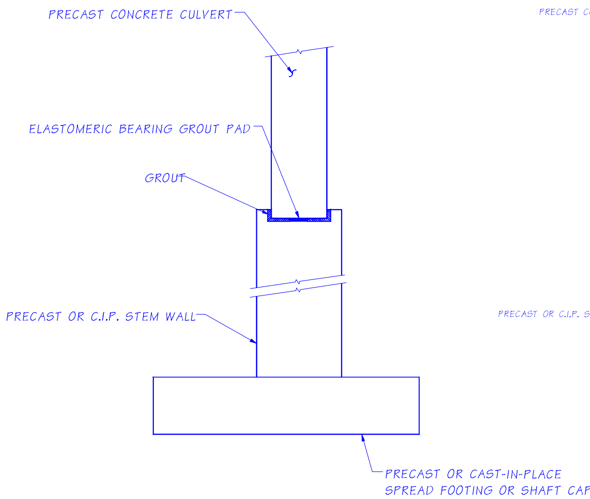
SHEAR KEY



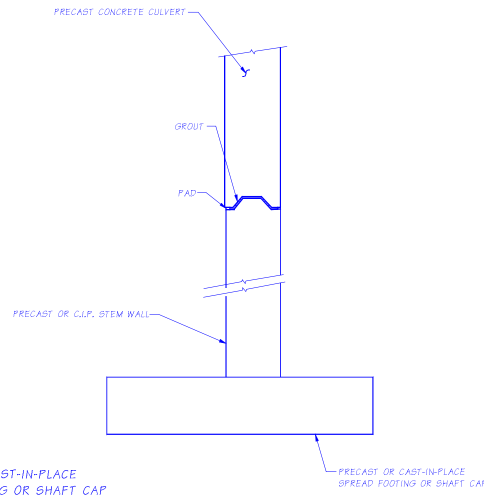
SECTION A

TONGUE-GROOVE

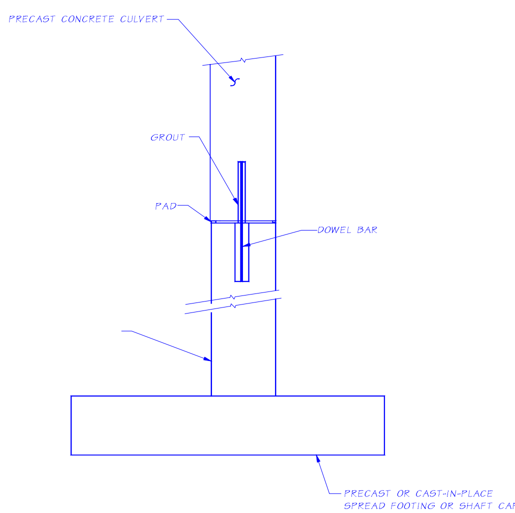
2. Connection between precast culvert and CIP footing



BEARING WITH GROUT



SHEAR KEY WITH GROUT



DOWEL BAR WITH GROUT

B. Waterproofing System

For buried structure that carries traffic inside the structure, the waterproofing to be used on top of the buried structures.

For the buried structure carries stream inside the structure, the external joint wrap over the joints between segments to be used. The external joint wrap shall be conformed to ASTM C 877.

C. Scour Protection

For buried structure that carries traffic inside the structure, the fire protection may required per NFPA 502.

D. Fire Protection System

For buried structure that carries traffic inside the structure, the fire protection may required per NFPA 502.

X. MISCELLENEOUS DETAILS

A. Cable Rail on Headwalls and Wingwalls

Fall protection shall be provided in accordance with WAC 296-155-24609 for exposed wall height of 4' or more.