Precast Concrete Structures for Fish-Passage Culverts

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Washington State Department of Transportation (WSDOT) is working to improve fish passage and reconnect streams to help keep our waterways healthy. Statewide, there are 3965 highway crossings over fish-bearing waters. Of these, 2073 are documented fish-passage barriers, including 2040 culverts, of which 1531 block a significant amount of upstream habitat. Consequently, WSDOT created a dedicated program to identify and correct barriers that restrict or completely block fish access to historic spawning and rearing habitat. With this program, WSDOT can identify high-priority barriers and correct them with dedicated fish-passage funds through planned transportation projects.

Structure Types and Selection

Buried structures and bridges are the two types of concrete structures used for fish-passage program delivery.

Buried structures are used:

- for smaller hydraulic openings that do not require bridges,
- where debris potential is tolerable, and
- when a buried structure is a more economical option than a bridge.

Bridges are used:

- where culverts are impractical,
- when a bridge is a more economical option than a culvert,
- to mitigate environmental harm caused by culvert construction,
- where stream migration and floodway encroachments are issues, and
- where large debris is an issue.

Precast concrete buried structures or bridges are commonly used for both new and replacement structures because of their advantages compared with other structure types and materials. The following are advantages of precast concrete for WSDOT's buried structures:

- Superior strength. Precast concrete can be manufactured and designed to support highway, pedestrian, seismic, and other loads.
- High quality. Precast concrete made in a controlled facility ensures good quality control during casting.
- Installation benefits. Precast concrete structures can be installed in both wet conditions and cold temperatures.
- Cost effectiveness and other benefits. Precast concrete structures are more economical, require less jobsite work, meet the requirements for environmental fish window times, accelerate construction, and ensure minimal impact on the environment.

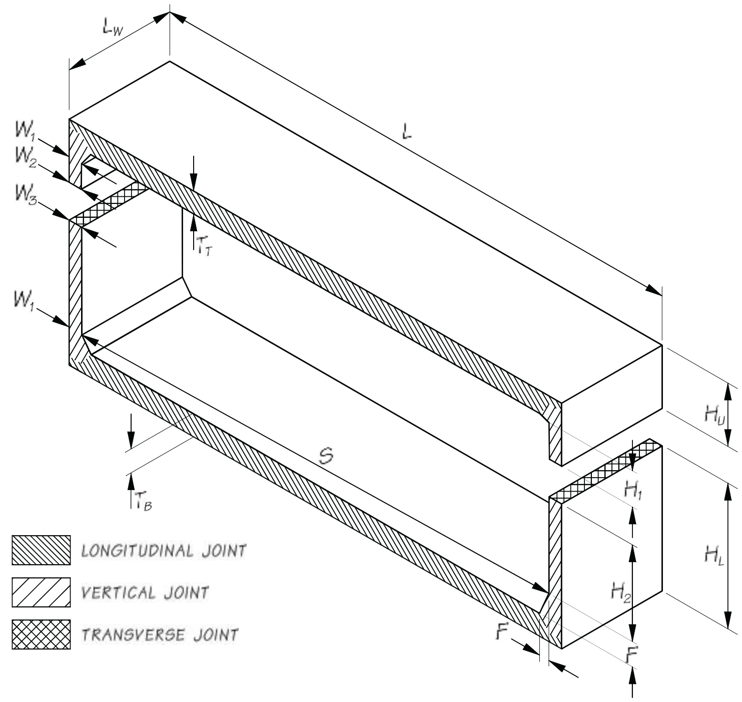

Figure 1. Details of the Washington State Department of Transportation standard precast concrete split-box unit. Joints are designed to carry the applied horizontal and vertical forces, and they are formed so that they can be assembled to transmit those forces and provide joint tightness. All Photos and Figures: Washington State Department of Transportation.

While WSDOT uses both bridges and buried structures for fish-passage culvert replacement projects, only buried structures are discussed in detail in this article.

WSDOT Buried Structures

The WSDOT Bridge and Structures Office has developed standard designs and drawings for precast reinforced concrete buried structures.[1,2] The two types of precast concrete buried structures are split boxes and three-sided structures. With either type, multiple units are joined to achieve the desired crossing width.

Precast Concrete Split Boxes

Concrete boxes are four-sided rigid frame structures. Split boxes consist of the upper unit, which is either a three-sided rigid frame lid or a flat top slab, and a three-sided rigid frame base that is the lower unit. In the precast concrete industry, the typical steel formwork used for three-sided rigid frame units of split boxes has span lengths that vary from 8 to 35 ft, in 1-ft increments. **Figure 1** shows the details of precast concrete split boxes.

The thicknesses of the top and bottom slabs can vary between 10 and 24-in., in 2-in. increments. The heights of the upper-

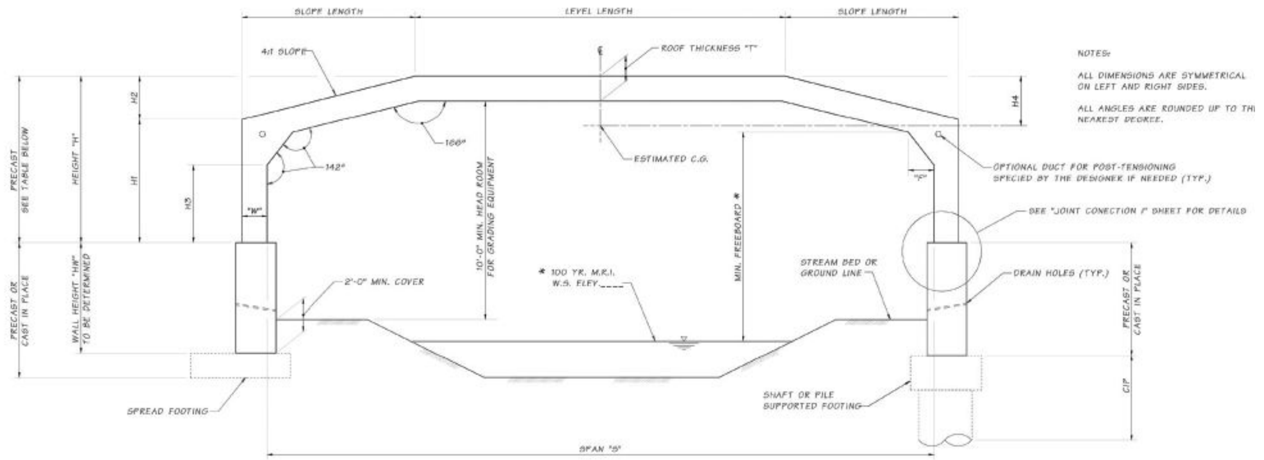

Figure 2. Details of the Washington State Department of Transportation standard precast concrete three-sided structure. The precast concrete unit is supported by either cast-in-place or precast concrete foundation units.

and lower-unit walls can vary between 0 ft (creating a three-sided base with a flat top slab) and 10 ft, in 1-ft increments. The wall thickness at the fillet is typically either 10 or 12 in., and tapers at 1 to 12 to accommodate removal from the form. The height limit is determined by shipping requirements and manufacturer's form capabilities. The widths of individual segments vary between 4 and 10 ft, in 1-ft increments. The fillets at the slab-to-wall junctures are 17.0 × 17.0 in. Skewed units are limited to skew angles of 45 degrees or less, in 1-degree increments.

Precast Concrete Three-Sided Structures

Three-sided structures are rigid frames, which may have open inverts and are supported by either cast-in-place or precast concrete foundation units consisting of a footing and possibly a stem wall.

Rigid three-sided structures have span lengths ranging from 8 to 35 ft, measured along the centerline of the roadway, and are constrained by the same geometric limitations that should be considered when establishing any structure's geometry. Wall heights are limited to a maximum of 10 ft. **Figure 2** shows the details of precast concrete three-sided structures.

Materials for Precast Concrete Buried Structures

Concrete Classes 5000 through 7000 (28-day design compressive strength being equal to the class of concrete) are commonly used for precast concrete buried structures. Self-consolidating concrete can be used for the fabrication of precast concrete units. Concrete cover is 2.0 in. minimum at all faces.

Welded wire reinforcement can be used to replace steel reinforcing bars in buried structures. Welded wire reinforcement is deformed and conforms to the requirements of AASHTO M 336.[3] The specified minimum yield strength for design is limited to a maximum of 80 ksi for reinforcing bars and 75 ksi for welded wire reinforcement.

When the fill depth of the buried structure is less than 2 ft at any point, all reinforcement in the top slab is required to be corrosion resistant, except reinforcement in the top slab need not be corrosion resistant when there is a 5.0-in. minimum composite cast-in-place concrete topping that meets the requirements for a Type 4 deck protection system.[1] (The Concrete Bridge Preservation article in the Fall 2020 issue of *ASPIRE*® presented details of WSDOT bridge protection systems.)

Consideration is given to the degradation of buried structure materials resulting from corrosive conditions. Corrosion-resistant reinforcement is used in both marine and nonmarine corrosive environments, and additional concrete cover may also be provided. The minimum cover requirements for direct exposure to salt water and coastal situations are in accordance with the *AASHTO LRFD Bridge Design Specifications*.[4]

Design of Buried Structures

The service limit state is used to determine stress limits, deflection, and control of cracking requirements, where applicable. Buried structures with span lengths greater than 20 ft are designed to accommodate the effects resulting from two types of seismic loading: ground shaking (transient ground displacement) and ground failure (permanent ground displacement).

For concrete structures where the top slab is less than 2 ft from the roadway surface, the design equalizes deflections by incorporating a structural connection capable of transferring the imposed shear between the top slabs of adjacent units. The structural connection includes cast-in-place reinforced concrete closures or grouted shear keys.

Joints are designed to carry the applied horizontal and vertical forces, and they are detailed to transmit those forces and provide joint tightness consistent with the required tolerances. Vertical joints between adjacent units and horizontal transverse joints between the upper units and foundation units are designed for the applied lateral forces by employing a shear key, block restrainer, or dowel bars.

When the top of a concrete buried structure is directly exposed to vehicular traffic, bridge approach slabs and a concrete or hot-mix asphalt (HMA) overlay or reinforced concrete deck are provided. When a HMA overlay is used, the minimum concrete cover for the top of the buried structure is 2.5 in. For a concrete overlay or reinforced concrete deck, the minimum concrete cover is 2.0 in.

Fish-Passage Culverts

About 60% of fish-passage projects are accomplished using buried structures. These precast concrete structures are an economical solution for removing fish-passage barriers and reconnecting streams to help keep our waterways healthy. The following are two examples of culverts replaced to provide fish passage:

- State Route 6 over Salmon Creek, a tributary to Rock Creek. A 24.3-ft-span concrete box culvert with 10.1-ft-high walls was used as a fish passage (**Fig 3**).
- Church Creek, tributary to the Stillaguamish River (**Fig. 4**). Because the old crossing, a 6-ft-wide, 8-ft-tall concrete box, was undersized for the channel, water velocities were excessive and the channel depth was insufficient

Figure 3. A new culvert was provided under State Route 6 at Salmon Creek to allow fish passage.

Figure 4. Church Creek, tributary to the Stillaguamish River. The old crossing (left) was replaced with a larger structure (right) to reduce channel velocities and increase depth for migrating salmon.

for migrating salmon. The new crossing is a 34.7-ft-wide, 14.8-ft-tall, three-sided precast concrete structure that provides access to 12.7 miles of potential habitat for chum and coho salmon, as well as trout.

Conclusion

WSDOT is efficiently using standardized precast concrete buried structures to meet the fish-passage program schedule and commitments. Precast concrete split boxes and three-sided buried structures are designed per applicable loads, seismic design requirements, and service life. WSDOT buried structures of various sizes are used to accommodate challenging stream conditions as well as shipping and handling constraints.

References

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