INDIANA DEPARTMENT OF TRANSPORTATION

Driving Indiana's Economic Growth

Design Memorandum No. 11-16
Technical Advisory

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TO: **All Design, Operations, and District Personnel, and Consultants**

FROM: ***/s/ Anthony L. Uremovich***
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SUBJECT: **Specialty Drainage Structures**

REVISES: ***Indiana Design Manual*** **Section 31-4.05**

ADDS: ***Indiana Design Manual*** **Section 31-4.06**

SUPERSEDES: **Design Memorandum 09-14 Technical Advisory**

EFFECTIVE: **September 8, 2011, Letting**

I. Types of Specialty Drainage Structures

Perpendicular-span length is measured between the inside faces of the structure walls, perpendicular to them. Structural-span length is measured between the inside faces of the structure walls, along the roadway centerline.

A. Precast-Concrete Box Culvert

A precast-concrete box culvert may be recommended by the Office of Hydraulics. The maximum perpendicular span for a box culvert is 12'-0". The recommended layout method for a box culvert is to extend it to the point where the roadway sideslope intercepts the stream flowline. The

sideslope at the end or outcrop of a box culvert should be protected with guardrail or be located beyond the clear zone.

B. Precast-Concrete Oversize Box Structure

A precast-concrete oversize box structure may be recommended by the Office of Hydraulics. A box structure is considered oversize if its clear-perpendicular-span length is more than 12'-0", but not more than 20'-0". Product information is available from local suppliers. If contacting a supplier, the designer should provide the most general information about project location. The designer should contact at least two suppliers of the same product.

The hydraulic recommendations letter will indicate if a three-sided structure with a base slab is an acceptable alternate to an oversize box structure. The designer should contact the Office of Hydraulics for guidance as to whether the two structure types are interchangeable for the specific site. A cost comparison should be used in making the final structure selection.

An oversize box culvert should be laid out so that the total structure length is a multiple of the box-segment length for the given box size. It is not necessary to add a tolerance for the joints between segments in determining the total structure length. The typically-available segment weights and lengths are shown in Figure 11-16A. For a 9-ft through 12-ft rise, at least one box-structure supplier should be contacted for available weights and lengths.

RISE	4 ft		5 ft		6 ft		7 ft		8 ft	
PERP. SPAN	Wt., T / ft	Lgth., ft	Wt., T / ft	Lgth., ft	Wt., T / ft	Lgth., ft	Wt., T / ft	Lgth., ft	Wt, T / ft	Lgth., ft
13 ft	2.00	6	3.15	6	3.30	6	3.45	6	3.60	6
14 ft	3.15	6	3.30	6	3.45	6	3.60	6	3.75	5
15 ft	3.30	6	3.45	6	3.60	6	3.75	5	3.90	5
16 ft	3.45	6	3.60	6	3.75	5	3.90	5	4.05	5
17 ft	3.60	6	3.75	5	3.90	5	4.05	5	4.20	5
18 ft	3.75	5	3.90	5	4.05	5	4.20	5	4.35	5
19 ft	3.90	5	4.05	5	4.20	5	4.35	5	4.50	4
20 ft	4.05	5	4.20	5	4.35	5	4.50	4	4.65	4

OVERSIZE-BOX-CULVERT SEGMENTS WEIGHT AND LENGTH

Figure 11-16A

C. Precast-Concrete Three-Sided Structure

A precast-concrete three-sided structure may be recommended by the Office of Hydraulics.

1. Structure Sizing and Selection. The designer will choose either the flat-topped, arch-topped, or true-arch structure section, show it on the plans and reference, by note, the other sections. The designer will determine the hydraulic size for the alternate structures.

   The hydraulic recommendations will include the Q_{100} elevation, the assumed flowline elevation, the required perpendicular span, and the required waterway opening for all structure sections. The designer will determine the rise of the structure for all structure sections. The minimum desirable freeboard requirement will be 1 ft for a flat-topped or an arch-topped structure, with the low-structure elevation determined at the structure centerline for each section. The minimum desirable freeboard requirement will be 2 ft for a true-arch structure. If the designer elects to use a freeboard of less than desirable, the designer should obtain the concurrence of the Office of Hydraulics manager.

   Figure 11-16B should be used as guidance for determining the acceptable alternates to show on the plans.

Case	Freeboard Specified	Acceptable Structure Alternates to be Shown on Plans
1	≥ 1 ft	Flat-topped, arch-topped, true-arch
2	< 1 ft	Those indicated in hydraulics recommendation letter

DETERMINATION OF ACCEPTABLE THREE-SIDED-STRUCTURE ALTERNATES

Figure 11-16B

The arch-topped structure will likely have a greater perpendicular-span requirement than the flat-topped structure where it is used with less than 2 ft of freeboard. The arch-topped structure will not be included as an alternate in the hydraulics recommendation letter if its required perpendicular span exceeds that of the flat-topped alternate by more than 4 ft. The true-arch structure will likely have a greater perpendicular-span requirement than the flat-topped or arch-topped structure.

Where the required structural span exceeds 30 ft, the designer will also provide the required waterway opening for a spill-through bridge. The designer will size an appropriate bridge and perform an economic comparison between the bridge and the three-sided structure options.

The dimensional designation shown in Figure 11-16C for perpendicular span, and Figure 11-16D for rise, should be used for designating each required three-sided structure. The plans should show the structure size in feet.

Feet	Inches	Feet	Inches
12	144	24	288
13	156	25	300
14	168	26	312
15	180	27	324
16	192	28	336
17	204	29	348
18	216	30	360
19	228	32	384
20	240	34	408
21	252	36	432
22	264	42	504
23	276	48	576

THREE-SIDED STRUCTURE
PERPENDICULAR-SPAN DESIGNATIONS

Figure 11-16C

Feet	Inches	Feet	Inches
4	48	10’-4”	124
5	60	10’-8”	128
6	72	11’	132
7	84	11’-4”	136
8	96	11’-8”	140
9	108	12	144
10	120	---	---

THREE-SIDED STRUCTURE
RISE DESIGNATIONS

Figure 11-16D

A rise of greater than 10 ft should be specified in 4 in. increments as shown in Figure 11-16D.

2. Segment Configuration and Skew. Skew should be rounded to the nearer most-practical 5 deg, although the nearer 1 deg is permissible where necessary.

It is not necessary for the designer to determine the exact number and length of segments. The final structure length and segment configuration will be determined by the fabricator and may deviate from that implied by the plans. However, a minimum horizontal clearance of 6 ft must exist between the front face of guardrail and the outside face of the structure headwall where the drainage-structure end is within the clear zone.

Square segments are more economical if the structure is skewed. Laying out the structure with square segments will result in the greatest right-of-way requirement and thus allow ample space for potential redesign by the contractor, if necessary, to another segment configuration.

For a structure with a skew of 15 deg or less, structure segments may be laid out square or skewed. Skewed segments are preferred for a structure of less than 80 ft length. Square segments are preferred for a longer structure. However, skewed segments have a greater structural span. A structure with a skew of greater than 15 deg requires additional analysis as described in the AASHTO *LRFD Bridge Design Specifications*. Skewed segments and the analysis both contribute to higher structure cost.

For a structure with a skew of greater than 15 deg, structure segments should be laid out square. If hydraulic conditions dictate the use of a flat-topped structure only, the segments may be laid out skewed if the structure is relatively short.

A number of flat-topped structures are built with skewed segments, i.e., segments shaped, in plan view, like parallelograms. However, some INDOT structures have been redesigned to use only square segments. Where a flat-topped structure is laid out with ends parallel to the roadway, skewed segments are implied by the designer.

The preferred layout scheme for an arch-topped structure with a skew of greater than 15 deg should assume square segments with a sloping top of headwall to yield the shortest possible wingwalls. Where an arch-topped structure is laid out with skewed ends, therefore, headwalls parallel to the roadway, the skew will be developed within the end segments by varying the lengths of the legs as measured along the centerline of the structure. The maximum attainable skew is controlled by the difference between the full-segment leg length as recommended by the arch-topped-structure fabricator and a minimum leg length of 2 ft.

If the roadway above the structure is to be constructed in two phases, a segment-skew configuration should be proposed which is compatible with the anticipated construction-

phasing line between construction phases. Therefore, if the structure length is 80 ft or greater, a unique special provision should be included to require the contractor to design and detail segments or cast-in-place construction required to conform to the construction line between phases. These details should be reviewed by the designer at the time of the working-drawings submission.

3. Plans Requirements for Structure Layout and Detailing. The designer should use the perpendicular span and rise for the structure section shown on the plans as a reference for the information required on the title sheet. The structure type to be shown on the title, Layout, and General Plan sheets should be precast reinforced-concrete three-sided structure.

The General Plan should include a note as follows:

> An alternate structure type with a _____-ft perpendicular span and a _____-ft rise may be substituted for the structure shown on the Layout sheet.

Where a flat-topped structure is the only option permitted, the General Plan should include a note as follows:

> A three-sided arch-topped or true-arch structure will not be permitted at this location.

The elevations to be provided on the General Plan or other detail sheet are as follows:

a. Q_{100};
b. flow line, at both structure ends and the roadway centerline;
c. the low structure at the centerline of the structure;
d. the tops of headwalls; and
e. the tops of wingwalls.

The assumed elevations of the top of the footing and the base of the structure leg should also be shown. For structure-layout purposes, a 2-ft footing thickness should be assumed with the base of the structure leg seated 2 in. below the top-of-footing elevation. With the bottom of the footing placed at the standard depth of 4 ft below the flowline elevation, the base of the structure leg should therefore be shown as 2'-2" below the flowline. An exception to the 4-ft depth will occur where the anticipated footing thickness is known to exceed 2 ft, where the footing must extend to rock, or where poor soil conditions dictate that the footing should be deeper.

The footing should be kept level if possible. If the stream grade prohibits a level footing, the wingwall footings should be laid out to be constructed on the same plane as the structure footings.

The structure length and the flare angle, and the length and height of wingwalls should be shown. For a skewed structure, the wingwall geometrics should be determined for each wing. The sideslope used to determine the wing length should be shown on the plans.

A structure should extend to a point where the headwall height can be kept to a minimum, preferably 1 ft. All headwalls should have standard-length-post guardrail protection unless the structure cover does not permit it. Where structure cover does not permit a standard headwall and standard-length-post guardrail installation, another option as shown on the INDOT *Standard Drawings* should be shown, with the selected low-cover guardrail option. A minimum of 6 ft of clearance should exist horizontally between the face of guardrail and the outside face of the structure headwall.

For a shallow cover of less than 1'-8" as measured at the base of the roadside barrier and a structure width of greater than 24'-3", a bridge railing type FC, FT, or CF-1 should be mounted on the structure headwall.

If a bridge railing type FC or FT is shown on the plans, the epoxy-coated reinforcing steel and concrete for the railing should be quantified separately from the three-sided structure. If a bridge railing type CF-1 is shown on the plans to be integral with the headwall, the epoxy-coated reinforcing steel required for the railing should be shown in the headwall as shown on the INDOT *Standard Drawings*. The epoxy-coated reinforcing steel, railing anchors, and concrete in the headwall should not be quantified. The entire headwall should be quantified with the structure. The portion of the bridge railing type CF-1 that is mounted on top of the headwall should be quantified separately from the structure.

If the height of the structure legs exceeds 10 ft, pedestals should be shown in the structure elevation view. For illustration purposes, the pedestals should be drawn at approximately 2-ft width, but the dimensions and details should not be shown. The pedestal height should be included in the rise dimension specified in the pay-item name.

The design and details for footings or base slabs, wingwall footings, wingwalls, and headwalls will be provided by the structure manufacturer once the working drawings are submitted. The designer who prepared the contract plans will review the design calculations and working drawings. For a federal-aid local-agency project, such documents are reviewed and approved by the local agency or its design consultant.

Wingwall-anchorage system, wing thickness, wall thickness of precast units, corner chamfer dimensions of precast units, footing-width, or footing-reinforcement information

that suggest a proprietary product should not be identified as such on the plans. Such details will be shown on the working drawings.

The General Plan should include the design-data information as follows:

> Designed for HL-93 loading in accordance with AASHTO *LRFD Bridge Design Specifications*, [current-edition year], and all subsequent interim specifications.
>
> Dead load increased 35 psf for future wearing surface.

Quantities for the structure and wingwall footings should be included with those for the structure and the wingwalls, respectively. Quantities for headwalls and foundation excavation should also be included in those for the structure.

4. Foundations. The allowable soil bearing pressure should be shown on the plans. If the footing is on piling, the nominal driving resistance should be shown.

   Where a pile footing is required, the type and size of pile and the required pile spacing, and which piles are to be battered, should be shown on the plans. The final design of the pile cap will be performed by the fabricator, and the details will be shown on the working drawings as is the practice for other footing types. If the geotechnical report recommends that piling be used, the structure-type selection should be re-evaluated to consider a spill-through bridge due to the added expense of pile footings.

   The plans for a three-sided structure should include a sheet showing the soil boring logs for the structure.

II. Specialty-Structures Requirements

A. Wingwalls and Headwalls

Wingwalls and headwalls are required without regard to structure type or size. Such wingwalls and headwalls may be precast or cast in place.

The information to be shown on the plans is as follows:

1. a plan view showing the total length of the structure, skew angle, distance from roadway centerline to each end of structure, and the flare angle of all wingwalls;

2. an elevation view of the end of the structure including wingwalls and headwall if applicable. The perpendicular span and rise of the structure should be dimensioned. The height of the headwall should be shown;

3. wingwalls labeled A through D with a table showing all dimensions and elevations for each wingwall, and summarizing the wingwall areas required; and

4. the allowable soil bearing pressure. A table should be included on the plans listing the soil parameters for wingwall design as follows:

    a. angle of friction between wingwall footing and foundation soil, δ;
    b. angle of internal friction of the foundation soil, φ;
    c. ultimate cohesion of foundation soil, *C*; and
    d. ultimate adhesion between foundation soil and concrete, C_A.

    These soil parameters will be provided in the geotechnical report for the structure. If the geotechnical report is lacking this information, it should be requested from the Office of Geotechnical Services.

Quantities should be determined for headwalls and wingwalls.

If a project includes at least one precast-concrete box structure, and at least one precast-concrete three-sided drainage structure, each with wingwalls, the wingwalls' quantities for both types of structures should not be combined.

B. Reinforcement Treatment

If the distance between the top of the pavement and the top of the structure is less than 2 ft as measured at the edge of travel lane, all reinforcement in a three-sided structure or an oversized box structure should be coated. Coated reinforcement should be indicated in the Structure Data Table's structure-description name.

C. Scour Considerations

The standard footing depth of 4 ft below the flowline and the riprap protection shown on the INDOT *Standard Drawings* will suffice for scour protection in a routine installation. Riprap and geotextile used in the waterway should be shown on the plans in the plan view and labeled as Scour Protection.

Figure 11-16E should be used to determine the type of scour protection required for a three-sided structure, or the channel. The riprap type and quantity should be shown on the plans. A note should be placed on the plans, similar to the following:

> Quantities of ___ tons of [Class 1] [Class 2] [revetment] riprap and _____ sys of geotextile shall be placed as scour protection.

AVERAGE STREAM VELOCITY, v, ft/s	RIPRAP AT STR.	RIPRAP AT OUTSIDE CURVED BEND IN CHANNEL	BASE-SLAB CONCRETE AT STR.
< 6.5	Revetment	Class 1	n/a
$6.5 \leq v < 10$	Class 1	Class 2	n/a
$10 \leq v < 13$	Class 2	Base Slab	Class B
≥ 13	Base Slab	Base Slab	Class B

Note: The maximum average stream velocity at the structure can occur at a lesser event than the design storm if roadway overtopping is present during the design storm.

SCOUR PROTECTION OF CHANNEL
AT THREE-SIDED STRUCTURE

Figure 11-16E

For a routine installation, the riprap and geotextile shown on the INDOT *Standard Drawings* will suffice for scour protection on the stream banks adjacent to the wingwalls or projecting ends of the structure. Quantities of riprap and geotextile used on the stream banks adjacent to the wingwalls or projecting ends of the structure should be shown on the plans.

If an INDR Floodway Construction, IDEM Water Quality 401, or a U.S. Army Corps of Engineers 404 permit application is required, the required scour quantities of riprap or cast-in-place concrete should be incorporated into the application. If one or more of these permits has already been granted, the designer must provide the quantities information to the Environmental Services Division's Ecology and Permits Team. The Team leader will then apply for a permit amendment.

For a three-sided structure, if the allowable soil bearing pressure is less than 1000 lb/ft^2, or where the stream velocity exceeds 13 ft/s, a concrete base slab should be provided instead of a conventional strip footing. Details of the base-slab method of scour protection are shown on the INDOT *Standard Drawings*. If the allowable soil bearing pressure is not extremely low or where the stream velocity does not exceed 13 ft/s, the cost effectiveness of providing a base slab versus

providing a strip footing with scour protection should be considered. The input of the district Office of Construction should be requested at the preliminary field check if the costs appear to be equal.

D. Backfilling

Where there is less than 2 ft of cover between the top of the structure and the top of the proposed pavement structure, as measured at the edge of travel lane, the backfill should be structure backfill type 5 to the top of the structure. The backfill above the top of the structure should be structure backfill type 2.

Where there is 2 ft or more of cover between the top of the structure and top of the proposed pavement structure, as measured at the edge of travel lane, all backfill should be structure backfill type 2.

The minimum and maximum cover distances should be shown in the Structure Data Table. The material used to backfill the structure should be also used to backfill the wingwalls.

The minimum cover distance between the top of the structure and the top of the pavement section should be equal to the pavement-section thickness. If the minimum cover distance is less than the pavement-section thickness, the Planning Division's Office of Pavement Engineering should be consulted for the minimum pavement thickness to be used above the structure.

For a three-sided structure, the structure and wingwall backfill limits should be shown on the plans. The backfill limits should have a width of 1.5 ft at the bottom of the footing and should extend upward at a slope rate of 1:4. The wingwalls' backfill should extend upward at a 1:1 slope from the bottom of the wingwall footings. The structure fabricator will also be required to show the backfill limits on the shop drawings. The backfill pay limits should be based on the neat-line limits shown on the plans. The type of structure backfill and the quantities for excavation and structure backfill should be shown on the plans.

E. Plans Details, Design Computations, and Working Drawings

Only the conceptual layout for a precast-concrete three-sided or box structure, or precast wingwalls and headwalls, should be shown on the plans. The structure centerline, minimum perpendicular span, minimum structural span, minimum rise, and minimum Q_{100} hydraulic-opening area should be shown on the Layout sheet.

Once the work is under contract, the fabricator will design and detail the structure. For each cast-in-place structure, three-sided structure, or for each box structure of perpendicular span greater

than 12'-0" or of a size not described in ASTM C 1577, the fabricator will provide design computations and working drawings which are to be checked by, and are subject to the approval of, the designer.

F. Pay Items

1. Box Structure. The new pay item names are as follows:

Structure, Coated Reinforced Concrete, Box Sections, ___ ft x ___ ft
span rise

Structure Extension, Coated Reinforced Concrete, Box Sections, ___ ft x ___ ft
span rise

Structure Extension, Reinforced Concrete, Box Sections, ___ ft x ___ ft
span rise

Structure, Reinforced Concrete, Box Sections, ___ ft x ___ ft
span rise

The pay unit is linear foot.

For the structure box sections and structure-extension box sections pay items listed in INDOT *Standard Specifications*, the size increments are as follows.

a. Structure of 12-ft Perpendicular Span or Less. Span and rise range from a minimum of 2 ft through a maximum of 12 ft, in 1-ft increments. The span used in the pay-item description is the perpendicular span, and not the structural span.

The rise should generally be less than or equal to the perpendicular span, although in some instances the rise may be greater than the perpendicular span.

b. Oversize Structure. Perpendicular span ranges from 13 ft through a maximum of 20 ft, in 1-ft increments. Rise is 4, 5, 6, 7, 8, 9, or 10 ft.

The pay length for a skewed box structure should be measured along the skew at the structure centerline.

The pay item for each perpendicular span and rise has its own code number. Once the perpendicular span and rise are known, the Contract Administration Division's administrator analyst should be contacted for a pay-item code number. The specifications reference number for all box-structure-related pay items is 714.

2. Three-Sided Structure. The pay item names are as follows:

Structure, Coated Reinforced Concrete, Three-Sided Sections, ___ in. x ___ in.
span rise

Structure Extension, Coated Reinforced Concrete, Three-Sided Sections, ___ in. x ___ in.
span rise

Structure Extension, Reinforced Concrete, Three-Sided Sections, ___ in. x ___ in.
span rise

Structure, Reinforced Concrete, Three-Sided Sections, ___ in. x ___ in.
span rise

The pay unit is linear foot.

The pay length for a skewed three-sided structure should be measured along the skew at the structure centerline. The span used in the pay-item description is the perpendicular span, and not the structural span.

The pay item for each perpendicular span and rise has its own code number. Once the correct pay items have been determined, the correct pay-item code numbers can be obtained from the estimating software or the Contracts and Construction Division's administrator analyst. The specifications reference number for all three-sided-structure-related pay items is 723.

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