INDIANA DEPARTMENT OF TRANSPORTATION

INTER-DEPARTMENT COMMUNICATION

Standards Section ***C*** *Room N642*

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DESIGN MEMORANDUM No. 01-11
TECHNICAL ADVISORY

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

FROM: ***/s/ Anthony L. Uremovich***
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SUBJECT: **Design Guidelines for Three-Sided Drainage Structures**

SUPERSEDES: **Design Memoranda 00-17 Technical Advisory, 98-06 Policy Change, and 98-06 Technical Advisory**

EFFECTIVE: **November 20, 2001, Letting**

Introduction

These guidelines should be used for all three-sided drainage structures on both INDOT projects and federally funded LPA projects. Recurring Special Provision 714-R-282 has been revised and renumbered to 723-R-282 to complement these guidelines. Recurring Special Provision 723-R-282f has been developed for use on those projects where the arch structure is not allowed as an option. The revised provisions are attached herewith.

Structure Sizing and Selection

If the project is on a state-maintained route and the structure qualifies as a bridge or a stand-alone "small structure replacement," the INDOT Hydraulics Unit will furnish the required minimum size for both the flat-topped and the arch structure in the hydraulic recommendations letter. The designer will choose the most appropriate alternate for the structure layout scheme shown on the plans and reference, by note, the other alternate. On projects for which the INDOT Hydraulics Unit has not prepared a hydraulic recommendation, the designer will determine the hydraulic size for both alternates.

The hydraulic recommendations will include the Q100 elevation, the assumed flow line elevation, the required span and the required waterway opening for both structure alternates. The designer will select the rise of the structure for both alternates. The minimum desirable freeboard requirement will be 0.3 m (1 ft) for both an arch structure and a flat-topped structure with the low structure elevation determined at the structure centerline for both alternates. If the designer elects to use a freeboard less than that specified in the hydraulic recommendations letter, he or she should obtain the concurrence of the Hydraulics Unit Supervisor. Generally, the flat-topped structure will be the only acceptable alternate if the freeboard is less than 0.3 m (1 ft).

Where the required structure span exceeds 9.14 m (30 ft), the INDOT Hydraulics Unit 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 following metric equivalents and english span and rise dimensions should be used for designating three-sided structures in the Schedule of Pay Items. The plans should show the structure size in meters (feet). The plan dimensions in meters should be shown to two decimal places.

Spans

Meters	Feet	Milli-meters	Inches	Meters	Feet	Milli-meters	Inches
3.66	12	3660	144	7.31	24	7 310	288
3.96	13	3960	156	7.62	25	7 620	300
4.26	14	4260	168	7.92	26	7 920	312
4.57	15	4570	180	8.23	27	8 230	324
4.87	16	4870	192	8.53	28	8 530	336
5.18	17	5180	204	8.84	29	8 840	348
5.48	18	5480	216	9.14	30	9 140	360
5.79	19	5790	228	9.75	32	9 750	384
6.10	20	6100	240	10.36	34	10 360	408
6.40	21	6400	252	10.97	36	10 970	432
6.71	22	6710	264	12.80	42	12 800	504
7.01	23	7010	276	14.63	48	14 630	576

Rises

Meters	Feet	Milli-meters	Inches	Meters	Feet	Milli-meters	Inches
1.22	4	1220	48	3.15	10’-4”	3150	124
1.52	5	1520	60	3.25	10’-8”	3250	128
1.83	6	1830	72	3.35	11’	3350	132
2.13	7	2130	84	3.45	11’-4”	3450	136
2.44	8	2440	96	3.56	11’-8”	3560	140
2.74	9	2740	108	3.66	12	3660	144
3.05	10	3050	120				

Rises greater than 3.05 m (10 ft) are to be specified in 0.10 m / 100 mm or 0.11 m / 110 mm (4 in.) increments as in the examples shown above.

Segment Configuration and Skew

Skews should generally be in 5° intervals, although 1° intervals are 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 1.8 m (6'-0") 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 generally more economical even 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 any potential redesign by the contractor to another segment configuration.

For structures with skews less than 15°, structure segments may be laid out square or skewed, with skewed segments generally preferred for structures less than 25 m (80 ft) in length and square segments preferred for longer structures. However, skewed segments have a greater structural span. Skews greater than 15° require special analysis per AASHTO Standard Specifications for Highway Bridges Section 17.8.5.3. Skewed segments and the special analysis both contribute to higher structure cost.

The preferred layout scheme for arch structures with skews greater than 15° should assume square segments with a sloping top of headwall to yield the shortest possible wingwalls. For structures with skews greater than 15°, 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.

According to industry publications, a significant number of flat-topped structures are built with skewed segments, i.e., segments shaped, in plan view, like parallelograms. However, several 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.

Where an arch structure is laid out with skewed ends (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. Generally, the maximum attainable skew is controlled by the difference between the full segment leg length as recommended by the arch structure fabricator and a minimum leg length of 0.6 m (2 ft).

If the roadway above the structure is to be constructed in two phases, the designer should propose a segment skew configuration compatible with the anticipated construction line between construction phases. Therefore, if the structure length is 25 m (80 ft) or greater, a unique special provision should be included to require the contractor to design and detail special segments or cast-in-place construction required to conform to the construction line between phases. These details should be carefully reviewed by the designer when shop drawings are submitted.

Plan Requirements for Structure Layout and Detailing

The designer should select the most appropriate structure alternate for the structure layout scheme and show that alternate on the plans. The designer should use the span and rise for this alternate 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 shall be Precast Reinforced Concrete Three-Sided Structure.

The General Plan should include a note or a detail indicating that an alternate structure type with a ____ m (_____ ft) span and _____ m (_____ ft) rise may be substituted for the structure indicated in the layout scheme. Where a flat-topped structure is the only option permitted, the note should state that a three-sided arch structure will not be permitted at this location.

The designer should provide the elevations on the General Plan or other detail sheet as follows:

Q100,
flow line, at both structure ends and the roadway centerline
the low structure at the centerline of the structure,
the tops of headwalls, and
the tops of wingwalls.

The assumed elevations of the top of the footing and the base of the structure leg should also be given. For structure layout purposes, assume a 0.6 m (2 ft) footing thickness with the base of the structure leg seated 50 mm (2 in.) below the top of the footing elevation. With the bottom of the footing placed at the standard depth of 1.2 m (4 ft) below the flow line elevation, the base of the structure leg should therefore be shown as 0.65 m (2’-2”) below the flow line. Exceptions to the 1.2 m (4 ft) depth will occur where the anticipated footing thickness is known to exceed 0.6 m (2 ft), where the footing must extend to rock, or where poor soil conditions dictate that the footing be deeper.

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

The designer should indicate the structure length and the flare angle, and the length and height of wingwalls. For structures that are skewed, the wingwall geometrics should be determined for each individual wing. The side slope used to determine the wing length should be clearly shown on the plans.

The pay length for skewed structures should always be measured along the skew at the centerline of the structure.

Generally, structures should extend to a point where the headwall height can be kept to a minimum, preferably 0.3 m (1 ft). All three-sided structures should have headwalls with standard-length-post guardrail protection provided unless the structure cover does not allow it. Where structure cover does not allow a standard headwall and standard-length-post guardrail installation, the designer should call for Standard Drawings 601-NWGA-02, -03, or –04, and show the selected low cover guardrail option on the plans. The designer must ensure that a minimum of 1.8 m (6’-0”) of clearance exists horizontally between the face of guardrail and the outside face of the structure headwall.

For shallow cover of less than 500 mm (1'-8") and a structure width of greater than 7400 mm (24'-3"), the designer may elect to use a concrete barrier railing or type CF-1 bridge railing mounted on the structure headwall. Such railing should be shown on the plans with cast-in-place concrete and reinforcing steel detailed.

If the necessary height of the structure legs exceeds 3.05 m (10 ft), the designer should show pedestals in the structure elevation view. For illustration purposes, the pedestals should be drawn approximately 0.6 m (2 ft) wide, but the dimensions and details should not be shown. The pedestal height should be included in the rise dimension specified in the pay item.

The design and details for footings or base slabs, wingwall footings, wingwalls, and headwalls will be provided by the structure manufacturer when the shop drawings are submitted. The designer who prepared the contract plans will review the design calculations and shop drawings. For federal-aid local agency projects, such documents are subject to approval by the local agency or its design consultant.

The designer should refrain from showing details on the plans such as wingwall anchor systems that suggest a proprietary product. Such details should be shown on the shop drawings.

The cost of the structure and wingwall footings will be included in the cost of the structure and the wingwall, respectively. Headwalls and foundation excavation will also be included in the cost of the structure.

Foundations

The allowable soil bearing pressure should be shown on the plans. If the footing is on piling, the ultimate pile bearing load should be shown.

A table should be included on the plans listing the soil parameters for wingwall design as follows:

Angle of friction between wingwall footing and foundation soil (*),
Angle of internal friction of the foundation soil (N),
Ultimate cohesion of foundation soil (C),
Ultimate adhesion between foundation soil and concrete (C_A).

These soil parameters will be provided in the geotechnical report for the three-sided structure. If the geotechnical report is lacking this information, it should be requested from the INDOT Geotechnical Section.

Where a pile footing is required, the designer should determine the type and size of pile and the required pile spacing and show this information on the plans along with any piles that are to be battered. The final design of the pile cap will be performed by the fabricator and the details will be shown on the shop drawings as is the practice for other footing types. Payment for the pile cap will be included in the cost of the structure or the wingwall. The piling will be measured in meters (linear feet) and paid for separately in accordance with 701.15. If the geotechnical report recommends piling be used, the designer should re-evaluate the structure type selection versus a spill-through bridge in light of the added expense of a pile footing.

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

Backfill Requirements

The structure and wingwall backfill limits should be shown on the plans. The backfill limits for all three-sided structures should have a width of 0.45 m (1.5 ft) at the bottom of the footing and should extend upward at a slope rate of 1:4. The wingwall backfill should extend upward at 1:1 slope from the bottom of the wingwall footing. 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.

Where there is less than 0.3 m (1 ft) of cover between the structure and the proposed pavement structure, the structure shall be backfilled with flowable mortar. If an arch structure is specified, the flowable mortar backfill should extend upward to the elevation of the outside crest of the arch. This elevation shall be designated as the fill line for flowable mortar. Compacted aggregate should be used between the flowable mortar and the underside of the proposed pavement structure. The pavement design engineer should be consulted for the minimum pavement thickness to use above the structure.

Riprap and geotextile should be used on the stream banks adjacent to the wings to stabilize and protect the B borrow for structure backfill.

Scour Considerations

The standard footing depth of 1.2 m (4.0 ft) below the flow line and the riprap protection as shown in Standard Drawings 714-CCSP-01 through -03 will suffice for scour protection in most routine installations.

Where the allowable soil bearing pressure is extremely low or where the stream velocity exceeds 3.0 m/s (10 ft/s) the designer should provide a concrete base slab instead of a conventional strip footing. Details of the base slab method of scour protection are shown on Standard Drawings 714-CCSP-04 and -05. For borderline cases, the designer should study the cost effectiveness of providing a base slab versus providing a strip footing with riprap scour protection. The input of district construction should be requested at the preliminary field check if the costs appear to be equal.

The table shown below must be used to determine the type of scour protection required for three-sided structures, or channels.

MIN. AVG. STREAM VELOCITY m/s (fps)	MAX. AVG. STREAM VELOCITY m/s (fps)	RIPRAP AT STR.	RIPRAP AT OUTSIDE CURVED BEND IN CHANNEL	BASE SLAB CONCRETE AT STR.
$\leq$ 2 ($\leq$ 6.5)	----------	Revet.	Class 1	Class B
> 2 (> 6.5)	< 3 (< 10)	Class 1	Class 2	Class B
----------	$\geq$ 3 ($\geq$ 10)	--------	Class 2	Class B

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

Once the riprap type is determined, the riprap quantities should be determined and then shown on the plans. Standard Drawings 714-CCSP-01, and either -02 or -03, should be called for as required standard drawings for the contract.

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

Schedule of Pay Items

Payment for three-sided structures will be made under the following:

Pay Item	**Pay Unit Symbol**
Structure, Precast Three-Sided, _____mm x _____mm (span rise)	m
(Structure, Precast Three-Sided, _____in. x _____in. (span rise)	LFT)
723-06660 Wingwall	m2 (SFT)

The pay item for each span and rise, of course, has its own code number. Once the designer has determined the correct pay items, he or she may get the correct pay item code numbers from the estimating software or the Contracts and Construction Division's Administrator Analyst. The specifications reference number for all of these pay items is 723.

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