CHAPTER IV

BRIDGES, CULVERTS AND RETAINING WALLS

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CHAPTER CONTENTS

Page No.

ANNE ARUNDEL COUNTY DESIGN MANUAL

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BRIDGES, CULVERTS, AND RETAINING WALLS

I. GENERAL

A. Introduction

This Chapter of the Design Manual outlines the criteria and guidelines for the structural design of bridges, culverts, and retaining walls. These guidelines are not intended to restrict the design professional in exercising proper engineering judgement. Alternative methods may be used subject to concurrence or approval of the Department of Public Works (DPW). The procedure, requirements, review, and approval of alternative methods are found in Chapter I, General Information. The concurrence by the DPW of a design criteria and method does not relieve the design professional of his/her responsibility for the design of a safe structure fully suitable for its intended function or purpose.

Projects that are funded by Federal or State aid may require compliance with the design criteria and standards of the funding agency.

II. STRUCTURAL DESIGN

A. Coordination

Bridges, culverts, and retaining walls are required for grade separations, stream crossings, and earth retention, usually as components of a broader road, street or site facility. Design of these structures shall conform to the road or street design criteria in terms of alignment, grade, typical section, and/or hydraulic capacity. The design of new, as well as widened, rehabilitated or replacement structures shall also be coordinated with the overall planning for the current and future use of the facility.

B. Pre-Design Meeting

Prior to commencing any design work on a Capital Project a pre-design meeting shall be held as provided in Chapter I, General Instructions. For Developer Projects, a pre-sketch meeting may be held at the request of the developer. These meetings will discuss, at a minimum, the following design parameters pertinent to this Chapter, in addition to items, which pertain to any other Chapters, which will govern the design of the project:

- Design criteria and method
- Will fish passage be required
- Future connections to drainage structures
- Loading for temporary bridge structures

- Contact persons and special requirements of railroads
- DPW shall provide any existing survey information, previously prepared reports concerning the project, any available information about nearby structures and defect or deficiency reports.
- Use of proprietary type retaining walls
- Use of weathering steel for beams and girders
- CAD format to be used for drawings

C. Specifications

1. In addition to the information provided in the Standard Specifications and Standard Details Manuals of Anne Arundel County, the references listed in Part V, References, of this Chapter may be used.

2. The design professional should also have at hand, for ready reference, textbooks in the areas of steel, concrete, and foundation design and current literature and publications of pertinent technical societies, manufacturers, and trade groups such as the Portland Cement Association, the Prestressed Concrete Institute, and the American Iron and Steel Institute.

3. Available computer programs for the analysis and design of various types of structures should also be utilized. These computer programs must have DPW approval. However, the approval or concurrence of the DPW staff shall in no way relieve the design professional of his/her responsibility to identify and properly utilize any design aid for the design of a safe structure suitable for its intended function or purpose.

D. Standard Details

The details found in the Standard Specifications and Standard Details Manual of Anne Arundel County shall be used on all projects. In certain circumstances after review and approval by the DPW, standard details from the "Structural Standards Manual" of the Division of Bridge Development, Maryland Department of Transportation, State Highway Administration may be incorporated into the project plans.

E. Preliminary Design

1. Culvert Waterway Opening Geometry

   a. Environmental Effects: It is necessary to comply with the policies of the Maryland Department of the Environment, Water Management Administration concerning maintenance of the natural environment. The design shall seek to preserve the natural character of the drainage course while maintaining a practical design meeting acceptable hydraulic design criteria.

Designs shall minimize erosion of the stream channel and deposition of sediments. Remedial measures shall be incorporated in the design where appropriate.

On perennial streams the designs shall provide for passages of fish. Barriers to fish passage will be permitted only by special permission of the DPW and PACE Environmental/Planning Section. Designs will address the hydraulic and waterway bed requirements for design fish. Information concerning the requirements for design of fish passages can be obtained from the U.S. Fish and Wildlife Service.

b. Location and Alignment: Culverts shall generally be located and aligned as closely as possible to the natural drainage course for which they are being designed. The design professional shall consider in the alignment any improvement that may be contemplated upstream or downstream of the culvert, which may result in a shift of present stream location. Where the culvert is to be installed near property boundaries and the backwater or tailwater crosses property lines, the culvert shall be designed so the backwater or tailwater surface elevation is maintained less than or equal to the pre-construction condition water level. If increases cannot be avoided, no increase in water surface elevations will be allowed without the prior approval of the affected property owner(s). Where the backwater or tailwater is contained within County right-of-way, water surface elevations shall not be increased by an amount equal to or greater than one (1) foot. All changes to the course, current or cross section of the 100-year floodplain are subject to State approval. Federal approval may also be required for floodplains designated by the Federal Emergency Management Agency (FEMA).

   Normally, the grade of the culvert shall conform to the natural slope of the drainage course with the line of the invert from 6" to 2'-0" below the natural streambed, depending upon the conditions. Except in unusual cases, the invert shall not be designed to lie more than 4 feet below the natural streambed.

c. Curves: Curves and changes in alignment under roadways will be permitted only by special authorization of the DPW.

d. Future Connection to Drainage System: Culverts, which at a future date might become part of a totally enclosed drainage system shall be designed in size, plan, profile, and end details to accommodate future connections to the drainage system. Approved land use maps, which are available in the Department of Planning and Code Enforcement should be used in sizing culverts.

e. Hydrologic and Hydraulic Design Methods:

   1) Hydrologic Design: Hydrologic design for determining structure size and flooding effects shall be performed in accordance with the methods specified in the Anne Arundel County Design Manual Stormwater Management

Chapter/Stormwater Management Technical Manual Section III. c. Design Methods.

2) Hydraulic Design: Hydraulic design for determining structure size and flooding effects shall be performed in accordance with the methods specified in the "Highway Drainage Manual", Maryland Department of Transportation, SHA. The recurrence interval for the design flood frequency for the design of culverts shall be the frequencies specified on Standard Storm Drains Design, Drawing SD-1, in Chapter V. The computed headwater elevation for the design flood shall be a minimum of 0.50 feet below the edge of road shoulders (for open road sections) or 2.0 feet below the top of curb grade (for closed road sections). In those cases where a future connection to a drainage system is anticipated, the design shall also meet or exceed the minimum requirements of Chapter V, Storm Drains, Section II. E.

2. Bridge Waterway Opening Geometry

a. Location and Alignment: Bridges shall be located and aligned to conform to the natural waterway as nearly as practical.

b. Size - The height, width, and span configuration of new bridges over waterways shall be based on the following considerations:

1) Roadway profile.

2) Hydraulic analysis. A minimum freeboard of one foot from the design high water level to the underside of the superstructure shall be maintained.

3) Economic analysis.

3. Roadway Clearances

a. Bridge Roadway Width: The roadway width of bridges shall be selected preferably to equal the full width of the approach roadway section including the shoulders. Minimum bridge roadway widths shall be in accordance with AASHTO "A Policy on Geometric Design of Highways and Streets." If the approach roadway section includes a sidewalk, the sidewalk shall be carried across the bridge.

b. Underpass Horizontal Clearance: For an open section roadway under a bridge, the piers or abutments shall be set to provide clearance for the full shoulder plus a guard rail or concrete barrier. The roadway face of the guardrail shall be at least 2'-0" from the face of the pier or abutment. The face of the guardrail or barrier shall be at least 2'-0" outside of the normal shoulder line. For closed section roadways, the face of pier or abutment shall be set a minimum of 8'-0" back of the curb line. Piers and abutments shall be protected by guardrail or crash walls.

c. Vertical Clearance: Vertical clearance for highway or railroad structures overpassing highways shall be 16'-0" minimum over any usable portion of the roadway and shoulder. A suitable vertical clearance allowance shall be made for the construction of one (1) paving surface course without prior surface milling.

4. Railroad Clearances

a. Horizontal Clearance: Horizontal clearances from railroad tracks to piers, abutments, or walls of an overpass structure shall be in accordance with the COMAR regulations, recommendations of the AREA Manual for Railway Engineering, and the policy of the specific railroad for the class of track involved. In the case of privately owned spurs, the clearances shall be at least equal to the requirements of the COMAR regulations and meet the approval of the railroad operating over the spur. In no instance shall the horizontal clearance be permitted to be less than is specified in the COMAR regulations.

b. Vertical Clearance: Vertical clearance over railroads shall be a minimum of 24’-3" (top of rail, or top of high rail in curves, to under clearance) for electrified railroads, and a minimum of 23'-0" for non electrified railroads. Clearance shall be subject to approval by the railroad owner and/or operator. In no instance shall the vertical clearance be permitted to be less than is specified in the COMAR regulations.

5. Bridge Roadway Section

a. Curbed (Closed) Section: The flow line of a curbed roadway section shall be continuous across the bridge. If the approach roadway section includes sidewalks, the sidewalks shall be carried across the bridge. Bridges with sidewalks shall have a 2'-3" high parapet wall (12" wide) and be topped with two-strand metal railing. If there is no sidewalk, a safety barrier meeting the AASHTO design requirements for "Traffic Railing" shall be provided. Safety barriers for bridges over electrified railroads shall meet the requirements of the National Electric Code.

b. Rural (Open) Section: The shoulder of a rural section, preferably, shall be carried across the bridge. The cross slope and longitudinal grade configurations shall conform to that of the approach roadway except that the cross slope in the shoulder area on the bridge shall be an extension of the adjacent traffic lane. The approach roadway shoulder slope shall be transitioned to meet the shoulder slope of the structure beginning at a minimum distance of 50 feet from the ends of the structure.

c. Railing Transition: Careful attention shall be given to the treatment of railing at the bridge ends. Exposed rail ends, posts, and sharp changes in the geometry of the railing shall be avoided. A smooth transition by means of a continuation of the bridge barrier, flared end posts, roadway guard rail anchored to the bridge barrier, continuation of bridge guard rail, or other effective means shall be provided to protect the traffic from direct collision with the bridge rail ends.

6. Horizontal and Vertical Alignment of Bridges

   The horizontal and vertical alignment of the bridge must be contiguous with the overall plan and profile of the approach roadway. Geometric design requirements concerning sight distances, minimum curve radii, superelevation, etc., shall be met. No sharp changes of longitudinal grade or cross slope will be incorporated in the bridge geometry to insure undetectable transition between approach roadway, paving and bridge dock paving or sidewalk.

7. Design Loadings - Highway Structures

   a. General: Loads, loading combinations, and adjustments to the allowable stresses for loading combinations shall be in accordance with the "Standard Specifications for Highway Bridges" by AASHTO, or the latest Maryland State Highway Administration Criteria for both load factor and service load design, except as modified by the following paragraphs. Load factor design will be permitted only with the approval of the DPW.

   b. Additional Dead Loads:

      1) Future Wearing Surface Over Concrete Bridge Decks: In addition to the dead load of the structure, for bridges utilizing a concrete bridge deck, an allowance shall be made in the design analysis for a future wearing surface at 25 lbs/sq. ft. for all except movable spans and exceptionally long spans. The additional deck load for these special spans shall be determined on an individual basis depending on the type of deck construction.

      2) Stay-in-place Forms: For bridges utilizing stay-in-place forms to support concrete bridge decks, an allowance shall be made in the design analysis for a 15-lbs/sq. ft. loading.

   c. Live Load: All permanent structures shall be designed for a live load of HS 25 or, for spans of 35 feet or less, HS 27. The loading for temporary structures will be determined by the DPW on the basis of the duration of time the temporary structure is expected to be in place and the anticipated traffic characteristics during that period. It shall not be less than H-15 with standard overload provisions as specified in the "Standard Specifications for Highway Bridges" by AASHTO.

   d. Earth Pressure: Structures, which retain earth, shall be proportioned to withstand pressure computed by Rankine's Formula. In the absence of more specific information, an equivalent fluid pressure of 35-lbs/cu. ft. shall be used. This pressure is based on the assumption that a layer of porous backfill and a drain system with weepholes will be provided to insure a low ground water elevation at the rear face of the structure. If conditions are such that it is not possible to control the water table behind the structure, the structure shall be designed recognizing, below the water level, the full hydraulic pressure in conjunction with pressures of the submerged soil.

A sloping finished grade line behind the structure may be accounted for by computing the pressure on the basis of the depth of earth in a vertical plane at the heel of the footing.

8. Design Loadings - Railroad Structures

   Railroad bridges shall be proportioned for loads and forces according to the recommendations of the AREA Manual for Railway Engineering.

   The specific railroad involved should be contacted for any additional requirements, amendments, or standard procedures applicable to structures on its system.

9. Selection of Structure Type, Size, and Location (Design Concept Evaluation)

   a. Preliminary Investigation:

      1) The first step in determining the preliminary type, size, and location (T.S., & L) of a structure, is to assemble and review all relevant available existing data in the vicinity of the proposed structure site. This existing data includes topographic maps, utility plans, survey information for the proposed project or adjacent projects, photogrammetry, previously prepared reports concerning the project, and any available information concerning nearby structures, particularly foundation information, and defect or deficiency reports.

      2) Information concerning the behavior of nearby structures following their construction should be used in determining the type of construction to select.

      3) Topographic surveys should be made to locate accurately the railroad, road, or stream channel to be crossed, existing profile, utilities, and right-of-way lines.

      4) Visual observation of the site shall be made by the design professional. Photographs and/or videos should be obtained for reference in the office and for documentation of all pre-existing structural and environmental conditions and constraints.

   b. Geometric Development: Beginning with a plot of the existing and newly acquired survey data, and with the preliminary project alignment, profile and roadway section; the design professional should determine the basic outline of the structure.

c. Hydraulic Analysis: Preliminary size and configuration requirements for the structure shall be determined in accordance with the instructions in Chapter V, Storm Drains, of this Manual.

d. Maintenance of Traffic: When existing traffic is required to be maintained develop maintenance of traffic in accordance with Chapter III, Roads and Streets of this Manual.

e. Selection of Structure Type for Stream Overpasses:

1) The type of structure selected shall be a safe economical alternative that will provide the most satisfactory service, operation and maintenance cost, based on hydraulic, topographical, and environmental conditions. The design of the structure must comply with the policies of the Maryland Department of the Environment, Water Resources Administration.

2) The following types of structures (listed in order of relative cost) shall be considered:

- Pipes and standard pipe arches (designed in accordance with Chapter V, Storm Drains of this Manual).
- Plate pipe and multi-plate arches (designed in accordance with the "Standard Specifications for Highway Bridges" by AASHTO and manufacturer's recommendations as approved by the DPW)
- Single-cell reinforced concrete box culvert
- Multi-cell reinforced concrete box culvert
- Bottomless arch
- Bridge

3) For streams of a size within the hydraulic capacity of a box culvert, the box culvert is usually less costly to construct and maintain than a bridge. In comparing the cost of a culvert with a bridge, the cost of maintaining and painting the bridge should be considered.

Other possible advantages of a box culvert over a bridge:

- Where road alignment necessitates special bridge design, the increased engineering and fabrication costs may increase the cost of a bridge over that of a culvert.
- Where poor soil conditions exist and piling would be required for bridge abutments, a culvert with its large foundation area may prove more economical.

Disadvantages:

- Where the design opening of the culvert is wider than the existing channel, undesirable channel modifications, are required

- Temporary stream relocation will be required during construction.
- Silting occurs during low flow.
- Interior walls obstruct flow and accumulate debris during flood flow.
- Where the cross-sectional area of the culvert is less than the downstream channel the water velocity increases in the culvert causing the potential for downstream scour.
- Paved culvert floor may present an impediment to fish migration in perennial streams.

f. Bridge Type Selection: Two important considerations are safety and aesthetics. Maximum traffic safety is provided by deck type overpass structures with adequately designed safety barrier parapet walls and open span underpass structures without piers or other structural elements adjacent to the roadway. Wider sidewalks for pedestrian use, bicycle lanes, special handrailing, and special lighting should be considered where it is appropriate to improve the appearance and utility of the bridge to make it more compatible with the other elements of the surrounding community.

Where possible, superstructures shall be of continuous design. The absence of joints in this type of construction results in better riding qualities and less maintenance. Curved beams and girders may be utilized to facilitate continuous span construction if approved by the DPW.

The use of cantilever abutments should be examined as an economic alternative to stub abutments with longer spans and/or extra piers.

g. Retaining Wall Type Selection: A retaining wall should only be constructed when there is no other feasible alternative available. The type of retaining wall to be constructed usually is determined by the cost of construction. However, some other factors such as critical clearances or right-of-way cost may affect the decision. The most economical type of wall to construct is primarily a function of the height of the wall. A gravity type wall is the most economical for low walls, a cantilever type wall for intermediate heights, and a counterfort type for high walls. Other factors that shall be considered in the comparison of alternate wall types are the lateral earth pressure, the type of foundation, the depth of piles, if required, and the allowable bearing pressure. The simplicity of construction and the durability of a gravity wall must also be considered in the final decision.

Proprietary or other alternative wall systems should be investigated for large-scale projects.

All retaining walls including proprietary or alternative wall systems require approval from the DPW.

When the design professional elects to use a proprietary retaining wall, he/she shall submit the following to the DPW:

1) System theory and the year it was first used.

2) Practical applications with descriptions, color photos, and videotape.

3) Any known failures of the system, including where, how and why it failed,

4) List of users (states, counties, etc.) Including contact names, addresses and phone numbers,

5) Details of wall elements, analysis of structural elements, design calculations, factors of safety, estimated life, corrosion design procedure for soil reinforcement elements, procedures for field and laboratory evaluation including instrumentation and special requirements, if any.

6) Sample material and construction control specifications -- showing material type, quality, certifications, fieldtesting, acceptance and rejection criteria (tolerances) and placement procedures.

7) A well documented field construction manual describing in detail, and with illustrations where necessary, the step-by-step construction sequence, and any special equipment required,

8) Typical unit costs, supported by data from actual projects.

10. Type, Size, and Location (T., S., & L.) Plans

After design concept selection by the DPW staff, drawings should be prepared showing the recommended structure. These drawings should show:

- A Plan, usually to a 1" = 20' scale, showing, in particular, span arrangement, span length, deck width and relation to approach roadway, alignment data, and clearances.
- An Elevation, to the same scale, showing vertical clearances, bearing arrangement, and anticipated foundation type.
- A Typical Section, showing the type of superstructure, and if not shown elsewhere, type of pier proposed.
- General Notes, giving proposed loading, design specifications, construction specifications, and other important information relevant to the structure.
- Boring Locations, showing an indication of proposed foundation-boring locations.

The T.S.,& L plans should form the basis for the final plans. Available similar plans should be utilized as models for content and format.

11. Type, Size, and Location Submission

The following information shall be submitted to the DPW for review and approval:

a. Prints of the design concept drawings (T.S., & L) showing the recommended structure or wall. This drawing should be accompanied by sufficient roadway drawings, if applicable, to depict the project site, the proposed general alignment and grades, and the approach roadway section.

b. Preliminary estimate of project cost.

F. Subsurface Investigation

1. The subsurface investigation shall take place following T.S., & L approval.

2. In order to determine the type of foundation, allowable bearing pressures and service-life of culverts, borings will be required at the proposed locations of walls, culverts, and bridge foundations. Borings shall be made between ends of walls and box culverts at 75-foot maximum intervals. The information obtained should include: elevation of the existing ground at the boring, a description and depth of the material encountered, number of blows per six inches on the sampling spoon, recovery of cored rock, total depth of boring, the water table level, pH range and resistivity of soils and the time of observation.

3. Split spoon samples shall be taken at every change in material and at intervals not exceeding five feet. All borings should be drilled to refusal and cored a minimum of five feet into rock.

4. All of the information obtained must be shown on the drawings including the boring logs. Borings logs shall also be bound in the project specifications.

5. Reports shall be made in accordance with Chapter I, General Instructions, Section II. C.

G. Final Design

1. Bridges

a. General: All components of highway bridge structures shall be designed in accordance with the “Standard Specifications for Highway Bridges” by AASHTO.

b. Piers: For bridges over flowing streams, single-column piers, T-piers, and solid-shaft piers should be considered to eliminate the possibility of floating debris being caught between pier columns.

For rigid frame piers, column spacing shall be in the range of from 12 feet to 20 feet. The spacing shall be set so that positive and negative moments in the pier cap are approximately equal. All columns shall be designed using load factor design as specified in the “Standard Specifications for Highway Bridges” by AASHTO.

Circular pier columns whose diameter is 5'-0" or less shall be designed using spiral reinforcing.

c. Foundations:

1) Depth: The footings of all piers and abutments subject to the action of stream currents shall be founded on undisturbed earth of suitable bearing capacity or on piles driven to suitable resistance. Waterway openings shall be evaluated for scour analysis and appropriate scour countermeasures shall be implemented to assure the survivability of all piers and abutments.

Footings not exposed to stream action shall be founded on a suitable uniform foundation below the frost line and not less than 2'-6" below finish grade.

Footings on rock shall be keyed into the bedrock a minimum depth of 12 inches when they are designed to transfer lateral forces. When a bedrock foundation is required for scour protection or design bearing pressure, footings shall be carried into bedrock a minimum of six inches.

2) Location of Resultant Loads on Spread Footings: Footings founded on materials other than bedrock shall be proportioned so that the resultant intersects the bottom of the footing within the middle third. The resultant force on footings founded in bedrock may be outside of the middle third provided that the maximum allowable bearing pressure is not exceeded.

3) Pile Foundations: Pile foundations shall be proportioned so that no pile receives more than the maximum allowable pile load and no pile is subjected to sustained uplift under any combination of design loads. Pile foundations should have batter piles to resist horizontal forces transmitted to the foundation and to increase the rigidity of the entire structure.

4) Foundation Report: A Foundation Report shall be prepared and submitted to the DPW for review and approval. The report shall include the following items:

a) Type of Foundation: (i.e. pile or spread footing). If there is a choice of foundation then a cost analysis should be performed for the final decision.

(1) Pile Foundation:

- Method of support - friction or end bearing, in rock or soil or both.
- Pile type
- Pile tip elevation
- Pile loading
- Test pile locations
- Settlement Analysis

(2) Spread Footing Foundation:

- Elevation of footing
- Material on which the footing is to be placed
- Allowable bearing pressure
- Settlement Analysis

b) Scour Evaluation: All bridges over water shall be evaluated for scour potential. Scour critical bridges shall require complete scour analysis in accordance with the guidance and direction contained in the FHWA Hydraulic Engineering Circular No. 8 entitled "Evaluating Scour of Bridges", 1991 or latest edition.

c) Scour Countermeasures: Evaluate scour countermeasures such as lowering the footings, spur dikes, stone blankets and revise pile alignment. Pile foundations shall be evaluated to assure structure stability relative to potential scour depth. Spread footings shall only be used on rock or in conjunction with subfoundation concrete on rock when piles are not feasible. Riprap scour countermeasures may be used for rehabilitation of existing structures and shall be designed in accordance with FHWA Hydraulic Engineering Circular No. 11, "Design of Riprap Revetment", 1989 or latest edition.

d. Superstructure Slab on Stringers:

1) Concrete: All superstructure concrete including parapets, abutment backwalls, and parapet portion of wingwalls shall be air entrained concrete with a minimum 28-day compressive strength of 4,500 psi. Slab concrete shall be low slump concrete.

2) Wearing Surface: Concrete slabs shall have an extra ½ inch concrete, which will serve as a wearing surface. This wearing surface shall be considered sacrificial and shall not be included when determining member strength.

3) Reinforcing: Epoxy coated reinforcing bars shall be used for the entire superstructure, including top and bottom mats of slabs, abutment backwalls, and parapet portion of wingwalls.

4) Forms: Concrete slabs shall be cast on stay-in-place forms where possible.

5) Slab Thickness: Slabs shall be designed to carry the dead and live load loading in accordance with the "Standard Specifications for Highway Bridges" by AASHTO with an allowable working stress, fc, equal to 1,350 psi. The minimum slab thickness including the concrete wearing surface shall be 7-1/2 inches.

e. Beams and Girders:

1) Spacing: In ordinary grade separation bridges, beams and girders should be spaced between six feet and eight feet center-to-center. For longer span structures, a wider spacing may prove to be more economical.

2) Composite and Non-composite Design: In superstructures consisting of concrete slabs supported on prestressed concrete beams or steel beams or girders, composite designs shall be used for simple spans exceeding 35 feet and, generally, for continuous spans exceeding 50 feet.

Continuous steel beam or girder spans shall be designed, as composite for positive moment regions only; however, shear connectors shall be provided at maximum allowable spacing through the negative moment regions even though composite action is not considered.

3) Camber:

a) Spans Less than 50 Feet: Steel beams with a span of less than 50 feet shall not be cambered for dead load deflection or vertical curve corrections. If the beams are not rolled exactly true, they shall be fabricated and erected with their natural camber up.

b) Spans 50 Feet or More: Steel beams and girders with spans of 50 feet and more shall be cambered to compensate for dead load deflection and vertical curve correction. Camber tolerance shall be zero (0) inches under to ½ inch over.

4) Steel Beams and Girders: Steel beams and girders for new bridges shall be designed for the use of ASTM A-588 Weathering Steel unless directed otherwise by the DPW at the pre-design meeting.

5) Prestressed Concrete Beams: In lieu of steel beams or girders, precast prestressed concrete beams may be used for simple spans with concurrence of the DPW. The length and weight of any prestressed concrete member shall not exceed the State of Maryland limitations for highway shipment without permits.

f. Bridge Drainage: Scuppers on bridges shall be avoided if possible. On closed systems, inlets shall be placed immediately off the bridge at the upgrade end of the bridge to prevent accumulated gutter flow from entering the structure. Inlets shall be placed downgrade from the bridge as required by the gutter flow design. On open section roadways, inlets shall be placed downgrade from the bridge to control water accumulated on the bridge.

Scuppers shall be placed on the bridge only if the ponding encroaches beyond the shoulder areas of the bridge onto the roadway. Where required, scuppers shall be

Maryland State Highway Administration standard scuppers. On stream crossings, scuppers shall be placed over the stream, and outlet pipes shall be extended six inches below the bottom of the bridge superstructure. Scuppers shall not be placed over stream banks or abutment slopes. On highway overpass structures, scuppers shall be placed adjacent to piers and away from traffic. Splash pads should be provided. Provision for stormwater quality management shall be incorporated into the design when the disturbance exceeds 5,000 square feet.

g. Expansion Joints: Watertight roadway expansion joints shall be provided at all abutments and at all piers supporting simple spans. These joints shall provide for the total thermal movement for a temperature range of 0 degree F to 120 degrees F.

2. Box Culverts

a. Analysis: Box culverts shall be analyzed as closed rigid frames. The dead and superimposed earth loads, the lateral earth pressures, and the live and impact loads are to be analyzed separately. The results of these separate loading conditions shall be assembled in various combinations to give maximum moments and shears at the critical points i.e., the corners and the positive moment areas. Appropriate live load positions shall be used to produce maximum positive and negative moments. A maximum of one-half of the moment caused by lateral earth pressure, including any live load surcharge, may be used to reduce the positive moment in the top and bottom slabs. The weight of the bottom slab of a box culvert will be resisted by an equal and opposite soil pressure without bending in the bottom slab. The structure should, therefore, be analyzed for a net soil reaction, excluding the reaction to the weight of the bottom slab.

b. Minimum Thickness: The thickness of walls and slabs of a box culvert shall be not less than 11 inches for members with reinforcing in both faces.

c. Roadway Wearing Surface: If the top slab is to be used as the roadway wearing surface, then it shall have a 2-1/2 inch minimum concrete top reinforcement cover. Additionally, the top slab concrete shall be 4,500-psi minimum strength, and the top mat of reinforcing steel shall be epoxy coated. When the top slab is not the riding surface, the earth cover provided shall be no less than nine inches (in addition to paving) at the minimum point.

d. Contraction and Expansion Joints: Contraction joints shall be provided at a spacing of approximately 30 feet. Expansion joints shall be provided at approximately 90-foot intervals. Reinforcement shall be stopped two inches clear of joints.

e. Headwalls: Headwalls shall be provided at the exposed ends of box culverts to retain the earth embankment and to act as edge distribution beams.

f. Cut-Off Walls: In order to provide for effects of scour, cut-off walls a minimum of three feet deep shall be provided at the exposed ends of the culverts. Wingwall footings shall be set at the elevations of the cut-off walls and securely tied to them with reinforcement.

g. Provisions for Future Extension: If the culvert is to be placed under a roadway which could be widened in the foreseeable future, provisions shall be made for extension of the culvert by placement of appropriate joint keys on the exposed inlet and outlet faces.

h. Aprons and Transitions: Aprons and transitions should be provided in all culverts to channel flow into conduits and prevent the undermining of wingwalls and foundations. For multi-cell culverts, flow shall be directed toward one conduit during low flow conditions.

i. Maintenance of Flow: The design professional must consider the requirements for maintaining stream flow during construction. It may be necessary to provide a temporary channel in order to provide for maintenance of flow.

3. Retaining Walls

a. Standard Details: Maryland State Highway Administration "Structural Standards Manual" and Federal Highway Administration standards should be consulted for typical cross sections for concrete cantilever retaining walls.

b. Earth Pressure: Earth pressures acting on walls should be computed using Rankine's Formula. The unit weight and friction angle of earth preferably should be estimated on the basis of the subsurface investigation. See Section II.E.7.d, Earth Pressure.

c. Factor of Safety - The factor of safety against overturning shall be:

1) Spread footing on earth .... 2 (minimum)

2) Spread footing on rock ....1-1/2 (minimum)

3). Pile foundations... Such that tension does not occur in the heel piles under sustained load

The factor of safety against sliding shall be held to a minimum of 1-1/2. It may be necessary or advisable to construct a key to resist sliding. If possible, cast the toe without a front form against undisturbed material as an added safety factor.

d. Wall Thickness: The thickness of the top of a wall shall be sufficient to accommodate any railing or appurtenance to be placed on it. However, for ease in placing concrete, it shall not be less than one foot.

e. Passive Pressure: Passive pressures on the front face of a wall are unpredictable and shall be neglected for normal wall footing depths. If, however, a wall footing has a ground cover in front of the wall of three feet or greater, the passive earth pressure may be calculated conservatively. Passive earth pressure shall not be considered in any case if the cover in front of the wall may be subject to scour.

f. Batter: For walls over 15 feet in height, consideration shall be given to provide a batter on the front face of wall.

g. Joints: Walls shall be detailed with approximately 90-foot spaced expansion joints through the portion above the footing. Gravity, semi-gravity, and cantilever walls shall have two equally spaced contraction joints located between the expansion joints. The face walls of counterfort and buttress walls are designed as continuous beams, and they cannot have contraction joints within a continuous unit. Counterfort and buttress walls shall be designed in continuous units not over 60 feet in length with expansion joints between units.

h. Pile Foundations: Walls on pile foundations shall be designed so that the major portion of the horizontal force is resisted by piles battered to a slope of 4:1 or, at most, 3:1. Vertical and battered piles may be considered as capable of resisting additionally a horizontal force up to 2 kips per pile in shear.

i. Foundations on Compressible Material: Due to possible movement of the tops of walls caused by tilting, walls founded on compressible material should be so proportioned that the resultant pressure intersects the base wall within the middle third section. As an alternate, a pile foundation should be considered.

4. Final Drawings

a. Bridge: Final drawings for a bridge should consist of a site plan, a plan and elevation drawing, foundation plan, substructure drawings, superstructure drawings, deck elevation plan and tabulation, and boring logs. They should be assembled in that general order.

The deck elevation plan shall show finished deck elevations along the centerlines of longitudinal beams or girders, gutter lines, breaks in roadway cross slope, and on tops of parapets. These elevations should be given at the centerlines of bearing and at the same point at which deflections are shown (quarter points, eighth points, or tenth points) but should not be further than 12 feet apart.

Culvert: Final drawings for a culvert should consist of a site plan, a plan and elevation drawing, culvert cross-section, wingwall cross sections, detail drawings, roadway surface elevation plan and tabulation (if top of culvert is roadway surface), and boring logs. It must also show any inlet and outlet protection measures proposed.

b. Retaining Wall: Final drawings for a retaining wall should consist of a site plan, the necessary number of plan and elevation sheets, detail drawings, and boring logs.

Walls shall be detailed with expansion joints spaced approximately 90 feet through the portion above the footing. Gravity, semi-gravity, and cantilever walls shall have two equally spaced contraction joints located between the expansion joints within a continuous unit. Counterfort and buttress walls shall be designed in continuous units not over 60 feet in length with expansion joints between units.

c. Standard Details: Anne Arundel County Standard Details shall be used in preparing final drawings by reference. Maryland State Highway Administration Standard Details may be utilized in the contract drawings if approved by the DPW.

III. CONTRACT DRAWINGS AND DOCUMENTS

A. Contract Drawings

Refer to Chapter I, General Instructions.

B. Contract Specifications

Refer to Specifications and Standard Details Manual and Chapter I, General Instructions.

If the structure is a part of a road contract, each individual structure in the contract shall be submitted for a separate final review, including the Special Provisions applicable to each structure.

C. Estimate of Project Costs

The design professional shall submit an estimate of quantities and costs involved in the construction of the project as specified in Chapter I, General Instructions.

If the structure is part of a roadway contract, a separate estimate should be prepared for each individual structure.

D. Design Calculations

The design professional shall submit design data and computations for the project as specified in Chapter I, General Instructions.

IV. SHOP DRAWINGS

Shop drawings and working drawings required for various construction items shall be reviewed and approved by the design professional. Drawings that are incorrect or incomplete shall be returned to the contractor or supplier for correction. The corrected shop drawings, as finally approved by the design professional, shall be returned to the DPW for distribution. The required number of shop drawings shall be specified by the DPW for each specific project. Each submittal of the shop drawings shall be stamped with a notation as to its disposition; i.e., "approved", "approved as noted", "resubmit", or "disapproved". The stamp shall also include the name of the engineering firm and a space for the date and signature of the reviewing engineer. Refer to the Maryland “Standard Specifications for Construction and Materials” for additional requirements regarding shop drawings. Refer to Chapter I, General Instructions, for an approved shop-drawing stamp.

V. REFERENCES

1. "Standard Specifications for Highway Bridges", American Association of State Highway and Transportation Officials (AASHTO), Washington, DC.

2. "Bridge Welding Code", ANSI/AASHTO/AWS D1.5, AASHTO, Washington, D.C.

3. "Guide Specifications for Horizontally Curved Highway Bridges", AASHTO, Washington, DC.

4. "Manual for Railway Engineering", American Railway Engineering Association (AREA), Washington, DC.

5. "Standard Specifications for Construction and Materials", Maryland Department of Transportation, State Highway Administration, Baltimore, MD.

6. "Manual of Steel Construction", American Institute of Steel Construction (AISC), New York, NY.

7. "Manual of Concrete Practice", American Concrete Institute (ACI), Detroit, MI.

8. "Structural Welding Code", ANSI/AWS D1.1, American Welding Society (AWS), New York, NY.

9. "Structural Standards Manual", Maryland Department of Transportation, State Highway Administration, Division of Bridge Development, Baltimore, MD.

10. "A Policy on Geometric Design of Highways and Streets", AASHTO, Washington, DC.

11. "Highway Drainage Manual", Maryland Department of Transportation, State Highway Administration.

12. Hydraulic Engineering Circular No. 11, "Design of Riprap Revetment", FHWA.

13. Hydraulic Engineering Circular No. 18, "Evaluating Scour of Bridges", FHWA.

14. Hydraulic Engineering Circular No. 20, "Stream Stability at Highway Structures", FHWA.