4.01 MAJOR STRUCTURE - BRIDGE

The purpose of this section is to provide for preliminary plan submittal and approval for bridges, tunnels, geotechnical features, and hydraulic structures. The usage of a bridge rather than a large culvert is determined from estimated construction and maintenance costs, structural aesthetics, hydraulic needs, and environmental considerations.

Major structures are bridges and culverts with a total length greater than 20 feet, and retaining walls with both a total length greater than 100 feet and a maximum exposed height at any section of over 5 feet. The length is measured along the centerline of roadway for bridges and culverts, and along the top of the wall for retaining walls. Overhead sign structures (sign bridges, cantilevers and butterflies extending over traffic) also are major structures.

Refer to the *CDOT Bridge Design Manual*, Section 3, for minimum design loading. Major structures should be analyzed individually for the most optimal design. Any substantial costs of deviations from the most economical design need to be considered in the structure selection process and must be agreed to by the Resident Engineer.

The Resident Engineer is responsible for submitting to the Project Structural Engineer the preliminary information including the following:

1. Current and proposed roadway plans/profiles and cross-sections, for both upper and lower roadways, with alignment data.
2. Bridge situation sheet with all topography including contours, utilities, and railroads (bridge site data).
3. Any hydraulics report, right-of-way restrictions, or guardrail types.
4. Any region design recommendations, including deviations from M Standards.
5. Requirements for electrical conduit, lighting and locating utilities.
6. Corridor aesthetics, environmental consideration, architectural concepts, if applicable.
7. Any subsequent revisions to the roadway alignments or profiles shall be transmitted to the Project Structural Engineer without delay.

The Project Structural Engineer's responsibilities include (for a complete description of responsibilities, see Section 19.1 of the *CDOT Bridge Design Manual*):

1. Review preliminary alignments and bridge site data.
2. Conduct structure concept study, including appropriate engineering and economic studies.
3. Prepare structure layouts and specific details that reflect a specific structure type, size, and locations.
4. Prepare selection report and/or wall selection report.
5. Request foundation report.

The Resident Engineer should compare the roadway and bridge plans to verify grade, alignment and clearances.

The following is a brief overview of the bridge design process, outlining the responsibilities of the Project Structural Engineer:

1. Structure concept study
   a. Attend Design Scoping Review meeting.
   b. Obtain and review bridge site data.
   c. Review preliminary alignment to determine structure location.
   d. Determine conceptual structure layout and type alternatives.

2. Preliminary bridge design
   a. Conduct engineering and economic studies.
   b. Prepare general layouts and special details.
   c. Prepare selection report and drawings for foundation investigations.
   d. Attend Field Inspection Review and make required revisions to layout.

3. Final bridge design
   a. Review bridge site data.
   b. Design all structural elements.
   c. Prepare all plans and specifications.
   d. Provide independent design, detail, and quantity check.
   e. Attend Final Office Review and make required revisions to Plans and Specification. At the discretion of the Resident Engineer, a separate structure Final Office Review or a structure advance plan review meeting may be held prior to the overall project Final Office Review.
   f. Provide final structural submittal (see Subsection 19.1 of the *CDOT Bridge Design Manual*).
   g. Provide revised plans and specifications for the construction plans.

Additional References:
1. *AASHTOLRFD Specifications for Highway Bridges*
2. Major/Unusual Structures (Section 4.03 of this manual)

4.02 MAJOR STRUCTURE – CULVERT

A culvert is used in lieu of a bridge based on estimated construction and maintenance costs, when hydraulically efficient and cost effective to improve drainage under the roadway structure.

A culvert is considered a major structure if it has an opening measured along the center of the roadway of more than 20 feet between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it may also include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening.

For structures equal to or exceeding 20 feet, the Resident Engineer must contact the Project Structural Engineer for a structure selection report. For structures with openings less than 20 feet, the determination to use a culvert is at the regional level with the approval of the Hydraulic Engineer. The decision to use a concrete box culvert or other culvert may be affected by the presence of other structures in the vicinity of equal or similar drainage pattern.

All culverts not included in the *CDOT M&S Standard Plans* shall be designed by the Project Structural Engineer.

An adequate survey of channel cross-section and channel length, normally 500 feet upstream and downstream from the roadway alignment centerline, is needed (see the *CDOT Survey Manual*). An analysis should be made of the existing structure capacity adequacy and associated roadway alignment (horizontal and vertical). A drainage basin survey using United States Geological Survey (USGS) maps, drainage reference maps, plans and profile sheets, and geology evaluations should be conducted.

Hydraulic design of a drainage structure, such as a concrete box culvert, shall be completed by a qualified engineer with knowledge of hydrology and hydraulics. However, this knowledge requirement varies according to the complexity of design. Larger drainage structures, for example, concrete box culvert, storm sewers and channel improvements, shall be designed by an engineer specialized in that field.

The following procedures and documentation are required when providing a culvert or concrete box culvert on the project:

1. For structures less than 20 feet in length, the hydraulic engineer and roadway designer will develop the most economical alternative between a concrete box culvert and a bridge. Concrete box culverts are likely to be economically viable when:
   a. The cover on the concrete box culvert is less than 30 feet and the concrete box culvert clear span is less than 23 feet.

   b. The cover on the concrete box culvert is less than 3 feet and the concrete box culvert clear span is less than 36 feet.

2. A cost comparison should be made to determine what structure is the best choice to be constructed. The above criteria should not override the results of this cost comparison. Project grade adjustments should be included in the cost comparison alternatives.

Additional References:

1. *CDOT Design Guide*
2. *CDOT Drainage Design Manual*

4.03 MAJOR STRUCTURE - UNUSUAL

The purpose of this section is to prescribe policy for preliminary plan submissions and approvals for major and unusual bridge construction.

An unusual bridge is one involving: (1) difficult or unique foundation problems, (2) new or complex designs with unique operational or design features, (3) exceptionally long spans, or (4) designs with procedures that depart from currently recognized acceptable practices. Examples of unusual bridges include cable-stayed, suspension, arch, segmental concrete, movable, or truss bridges. Other examples are bridge types that deviate from AASHTO bridge design standards or AASHTO guide specifications for highway bridges are: bridges requiring abnormal dynamic analysis for seismic design; bridges using three-dimensional computer analysis; bridges with spans exceeding 500 feet; and bridges with major supporting elements of "ultra" high strength concrete or steel.

Unusual structures are tunnels, geotechnical structures featuring new or complex wall systems or ground improvement systems, and hydraulic structures that involve complex stream stability countermeasures, designs or design techniques that are atypical or unique, or an unusual hydraulic structure, such as those serving, large storm drainage systems, stormwater pumping facilities, dams or levees.

FHWA Washington Headquarters shall approve all movable bridges and unusual bridges, tunnels, hydraulic structures, and geotechnical structures. A Structure Selection Report should be submitted to the FHWA for review and approval. On federal-aid projects, Regional FHWA shall approve all other bridges (not included in the previous sentence) that have an estimated total deck area greater than 125,000 square feet and all bridges on the National Highway System, major hydraulic structures, and major geotechnical features.

The Resident Engineer shall submit a Structure Selection Report as well as the Field Inspection Review and Final Office Review plans to the FHWA. The Project Structural Engineer will provide the Resident Engineer with plans for bridges, earth retaining structures and tunnels. The local FHWA Division will review those submittals and may forward them to the Washington Headquarters for approval as appropriate.

The Resident Engineer should coordinate the required submittals with the Project Structural Engineer. The Structure Selection Report submitted with the initial request for review and approval shall include environmental concerns and suggested mitigation measures, and studies of alternate spans and bridge types.

4.04 PEDESTRIAN OVERPASS / UNDERPASS

Pedestrian facilities should be provided where pedestrian volume, traffic volume or other conditions merit their use. These facilities are usually located in central business districts, factory areas, school zones, athletic fields, parks and other major activity centers.

Pedestrian separation, either over or under, is usually desirable at freeways or expressways where cross streets are terminated or when a situation imposes an extreme inconvenience or safety hazard due to heavy vehicle traffic. They are also desirable at locations where the need for a pedestrian crossing is otherwise warranted and the separation is economically and environmentally feasible.

When designing pedestrian over/underpasses, the requirements should be the same as for any other highway structure where the same geometric and architectural consideration should be given (see Section 4.01 of this manual). The Resident Engineer is responsible for providing the Project Structural Engineer with the preliminary geometric layout, vertical profiles and cross sections for the location of the over/underpass. Additionally, topography of the surrounding area should be provided in electronic format.

The Project Structural Engineer is responsible for reviewing and commenting on the proposed alignments submitted and preparing a structure selection report including a general layout for the selected structure with appropriate widths, clearances, and accommodations for the physically handicapped. The Project Structural Engineer shall request that the appropriate foundation investigations be completed.

The design of pedestrian over/underpasses should accommodate accessibility for the physically handicapped, and bicycle traffic, where warranted.

Public safety features such as vertical clearance, fencing and lighting should be included in the design of the over/underpasses. Design criteria for over/underpass are in the *CDOT Design Guide*.

Additional References:

1. *AASHTO Policy on Geometric Design of Highways and Streets*
2. *CDOT Bridge Design Manual*
3. *Design of Pedestrian Overpass and Underpass to Accommodate the Handicapped*, Publication N5040.38, FHWA
4. *Pedestrian and Bicycle Accommodations and Projects,* Code of Federal Regulations, Title 23, Highways, Part 652

4.05 ARCHITECTURAL / AESTHETIC TREATMENT

The purpose of this section is to promote aesthetically pleasing features and treatments that can be economically incorporated into a structure.

Aesthetically pleasing structures should be compatible with their surroundings and include features and treatment that prove to be timeless. Care must be exercised when incorporating architectural features and aesthetic treatment in a structure because some structures could be in service 50 to 75 years.

The Project Structural Engineer and Resident Engineer will develop architectural treatment guidelines. An architect may be consulted for ideas on features and treatments.

Preliminary design and architectural details must be documented in the Structure Selection Report (see Section 4.07 of this manual.)

Visually appealing structures should be adopted and developed early before final design commences as inclusion of these details is not easily accomplished after the structure design has begun. Some aesthetically pleasing features can be incorporated in a structure at low cost while others increase cost significantly. New or untried features and treatments must be thoroughly investigated before incorporating those details in a structure. Aesthetics are important in high-profile, frequently viewed structures.

Additional References:

1. *CDOT Bridge Design Manual*
2. *Bridge Aesthetics Around the World*, Transportation Research Board (TRB) National Research Council, 1991
3. *Bridgescape – The Art of Designing Bridges*, Frederick Gottemoeller, 1998

4.06 FOUNDATION INVESTIGATION AND RECOMMENDATION

The purpose of the foundation investigation is to gather data and provide foundation recommendations based on existing subsurface conditions. Typical requests include foundation studies for bridges, major concrete box culverts, high-mast lighting, sign structures, sound walls, and retaining walls. Requests should be done at the conceptual stages for inclusion in the Structure Selection Report prepared by the Project Structural Engineer.

When a boring or a geotechnical study is required, the Project Structural Engineer will send a foundation investigation request, including the proposed boring schedule, to the Resident Engineer. A copy of the request and the general layout with approximate location of the structure borings requested will be sent to the Geotechnical Engineer.

The Resident Engineer will be responsible for obtaining access and staking the boring locations. When the Resident Engineer has completed the access and staking, he shall notify the Geotechnical Engineer and the Project Structural Engineer in writing. Any questions the Geotechnical Engineer may have related to the boring locations shall be addressed to the Project Structural Engineer.

The Geotechnical Engineer is responsible for examining the site and scheduling utility locates, if needed.

The Geotechnical Engineer will analyze subsurface data and provide an engineering geology plan sheet and geotechnical report.

The Geotechnical Engineer should be included in the Design Scoping Review and should participate in the follow-up and resolution of the problems identified.

Additional References:

1. *CDOT Bridge Design Manual*

4.07 STRUCTURE SELECTION REPORT

The purpose of preparing a structure selection report is to document the important factors that lead to the recommended selection and to establish the basis upon which the final structure design will proceed.

During the conceptual stage of a project, the Project Structural Engineer shall develop a structure selection report for all major structures in accordance with the *CDOT Bridge Design Manual*.

Selection of the best structure type alternative may be based in part on the lowest cost, but other requirements to be considered include:

1. Site requirements (topography, alignment)
2. Safety (during construction, traffic, detours)
3. Structural (future widening, foundation conditions)
4. Environmental (appearance, wetlands, public exposure)
5. Construction (ease of construction, false work, season)
6. Hydraulics (stream flow, bank and pier protection, culvert alternates)
7. Life cycle costs (maintenance, durability)
8. Other (commitments to officials and community, team studies)

The Resident Engineer will provide the Project Structural Engineer the information required to prepare a structure layout, structure selection report, and final design. See Section 4.01 of this manual.

The documentation shall comply with the *Bridge Design Manual*, Section 19.

Prior to commencing the final structure design, the Project Structural Engineer will prepare and distribute a structure selection report including an economic analysis to the Resident Engineer. The Resident Engineer shall make distribution within the region and, if appropriate, to the FHWA. The structure selection report should be reviewed and approved prior to the Field Inspection Review meeting.

4.08 RETAINING WALLS

Retaining walls are used primarily for retaining soils or roadway fills to form a more stable slope.

Retaining walls are classified into three categories according to basic mechanisms of retention and source of support:

1. An external stabilized system uses a physical structure to hold the retained soil provided by the embankment of a wall into the soil.
2. An internal stabilized system uses soil reinforcement to make the retained soil self-supporting.
3. A hybrid or mixed system combines elements of both externally and internally stabilized systems.

Factors affecting the selection of a retaining wall are:

1. Spatial constraints -- Functions of a wall, space limitations, proposed profile.
2. Behavior constraints -- Earth pressure, water table, foundation pressure.
3. Economic considerations -- Environmental, aesthetic.

Retaining walls should be designed to resist corrosion or deterioration and other environmental factors compromising the durability of the wall. Permanent retaining walls should be designed for a minimum service life of 75 to 100 years.

The Project Structural Engineer in cooperation with the Resident Engineer will be responsible for the selection and design of the best-suited wall type and where appropriate alternate wall designs. The Project Structural Engineer will request a preliminary geology report from the Geotechnical Engineer.

The required documentation is outlined in the *CDOT Bridge Design Manual* (Section 5).

The default wall design and design alternative documentation provided by the Project Structural Engineer will include:

1. Default design -- Defined to mean the best wall obtained from the selection process (see the *Bridge Design Manual*, Subsection 5.6).
2. Design alternatives -- The products of the design selection process (see the *Bridge Design Manual,* Subsections 5.4 and 5.5).

For a propriety wall, refer to Section 8.16 of this manual.

4.09 NOISE WALLS

This section will assist the Resident Engineer in designing sound barriers and noise walls.

The Resident Engineer, in cooperation with the Project Structural Engineer, will be responsible for the selection of the best-suited wall type. Based on the noise analysis, the Resident Engineer will provide the Project Structural Engineer with the alignment, height, and configuration. The Project Structural Engineer will be responsible for the structural design and requesting the foundation investigation. Because of the nature of sound walls, a substantial foundation is required and interference with buried utilities must be considered.

4.10 ANALYSIS OF STRUCTURES TO BE RESURFACED

The purpose of this section is to assist the Resident Engineer in determining if an existing structure can be resurfaced.

An analysis is done because resurfacing may affect the load carrying capacity of the structure, vertical clearance, bridge rail height and/or bridge expansion devices. Additional pavement can be placed on a structure if there is adequate load carrying capacity. The total thickness of asphalt after resurfacing shall be limited to 3 inches on the structure.

The Resident Engineer should request recommendations from the Project Structural Engineer for resurfacing of structures.

The Project Structural Engineer will send a surfacing recommendation memo to the Resident Engineer. The memo will include conditions related to the structure resurfacing, recommended repairs and bridge rail upgrades.

The Resident Engineer will inform the Project Structural Engineer of the proposed resurfacing method.

4.11 DETERMINE EXISTING STRUCTURAL ADEQUACY

The purpose of this section is to give the Resident Engineer guidance in determining if an existing structure is adequate when a highway construction project is proposed.

To leave an existing structure in place, the structure shall meet certain criteria as determined by FHWA and CDOT requirements.

The Resident Engineer will furnish the Project Structural Engineer pertinent data involving the existing structures and proposed design.

The Resident Engineer shall request recommendations from the Project Structural Engineer regarding the adequacy of the existing structure and recommendations for repair or replacement.

The Resident Engineer shall compare the bridge width with the requirements shown on the Form 463a, Design Data, to determine adequacy of the bridge width.

The decision to leave bridges that are narrower than the proposed roadway should be documented.

Additional References:
1. See Appendix A for forms

4.12 CRASHWORTHY BRIDGE RAIL

FHWA approved crashworthy bridge rail must be provided on all new bridges. Rehabilitated bridges on federal-aid routes or projects utilizing federal funds shall use crashworthy bridge rail unless a variance is approved. The variance shall include an analysis based on criteria presented in the *CDOT Bridge Design Manual*, Section 2.

It is desirable to upgrade rail on all non-federal-aid projects. If a bridge rail is to remain in place and meets current AASHTO specifications, a design decision can be documented in the project file. Safety or resurfacing projects may not require upgrading of the bridge rail.

Approved documentation for variances and design decisions shall be in the project file.

Crashworthy rail is defined as crash tested in accordance with the National Cooperative Highway Research Program Report 350 or rail, which has been approved by the FHWA as being equivalent to crash-tested rail.

The Project Structural Engineer will provide a recommendation to the Resident Engineer regarding the replacement of existing bridge rail. The Resident Engineer is responsible for determining whether to install new bridge rail or to leave the existing bridge rail in place.

The following bridge rails are required for new or rehabilitated bridges on the following roadway classifications:

1. Type 7 or Type 10M on National Highway System (NHS) and non-NHS state highways projects.
2. Type 3 or any approved crash tested bridge rail on local roads. Type 3 has limited applications because of its 27-inch height and its cost relative to the type 10M. Therefore, CDOT has elected to use type 10M for all new construction requiring a steel bridge rail on the state highway system.

When a bridge also serves pedestrians or cyclists and the speed limit is 45 mph or greater, a barrier to shield them from the traveled way and a pedestrian rail at the bridge edge may be warranted.

Working drawings with currently approved bridge rail are available from the Bridge Design and Management Branch.

Detailed drawings of bridge rail with revisions or modifications are to be included in the Construction Plans.

Additional References:

1. 23 CFR Part 625, Design Standards for Highways
2. *AASHTO Guide for Selecting, Locating, and Designing Traffic Barriers*
3. *AASHTO LRFD Specifications for Highway Bridges*
4. *AASHTO Roadside Design Guide*, AASHTO
5. *AASHTO Standard Specifications for Highway Bridges*

4.13 VERTICAL CLEARANCE OF STRUCTURE

All highway projects shall meet or exceed minimum vertical clearances according to guidelines set by the FHWA and CDOT. These clearances shall pertain to all overpasses, underpasses, railroad and transportation facilities, bicycle and pedestrian facilities, overhead lines, sign bridges, signal mast arms, navigational streams, channels, and canals. The Resident Engineer is responsible for determining the appropriate clearances.

Vertical clearance applies to the full pavement width, including provisions for future widening. A formal variance is required if less clearance than the minimum is achieved.

Minimum vertical clearances are listed in the *CDOT Design Guide*, Chapter 6.

The Resident Engineer should verify vertical clearances for all phases on detours and traffic shifts. Clearances to false work and shoring should be considered during construction. If minimum clearances cannot be maintained during construction, appropriate signing shall be included in the plans. Vertical clearances shall be shown on the highway construction plans for all structures.

Additional References:

1. 23 CFR Part 625, Design Standards for Highways
2. *AASHTO Policy on Geometric Design of Highways and Streets*
3. *AASHTO Guide for the Development of Bicycle Facilities*
4. *AASHTO LFRD Specifications for Highway Bridges*
5. *AASHTO Standards Specifications for Highway Bridges*
6. *CDOT Bridge Design Manual* (Section 2)