

# BRIDGE PRACTICE GUIDELINES

## SECTION 2 - GENERAL DESIGN & LOCATION FEATURES

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## **SCOPE**

This section is intended to provide the Designer with sufficient information to determine the configuration and overall dimensions of a bridge.

In recognition that many bridge failures have been caused by scour, hydrology and hydraulics are covered in detail.

For a complete discussion of the information presented here, refer to the AASHTO LRFD Bridge Design Specifications, Section 2.

## **DEFINITIONS**

**Aggradation:** A general and progressive buildup or raising of the longitudinal profile of the channel bed as a result of sediment deposition.

**Bridge Designer:** The design team who produced the structural drawings and supporting documents for the bridge.

**Clear Zone:** An unobstructed, relatively flat area beyond the edge of the traveled way for the recovery of errant vehicles. The traveled way does not include shoulders or auxiliary lanes.

**Clearance:** An unobstructed horizontal or vertical space.

**Degradation:** A general and progressive lowering of the longitudinal profile of the channel bed as a result of long-term erosion.

**Design Discharge:** Maximum flow of water a bridge is expected to accommodate without exceeding the adopted design constraints.

**Design Flood for Bridge Scour:** The flood flow equal to or less than the 100-year flood that creates the deepest scour at bridge foundations. The highway or bridge may be inundated at the stage of the design flood for bridge scour. The worst-case scour condition may occur for the overtopping flood as a result of the potential for pressure flow.

**Detention Basin:** A stormwater management facility that impounds runoff and temporarily discharges it through a hydraulic outlet structure to a downstream conveyance system.

**Drip Groove:** Linear depression in the bottom of components to cause water flowing on the surface to drop.

**Five-Hundred-Year Flood:** The flood due to storm and/or tide having a 0.2 percent chance of being equaled or exceeded in any given year. Commonly referred to as the Superflood, used to check the structural adequacy of bridge foundations for that extreme design event.

**General or Contraction Scour:** Scour in a channel or on a floodplain that is not localized at a pier or other obstruction to flow. In a channel, general/contraction scour usually affects all or most of the channel width and is typically caused by a contraction of the flow.

**Hydraulics:** The science that deals with practical applications (as the transmission of energy or the effects of flow) of water or other liquid in motion.

**Hydrology:** The science concerned with the occurrence, distribution, and circulation of water on the earth, including precipitation, runoff, and groundwater. In highway design, the process by which design discharges are determined.

**Local Scour:** Scour in a channel or on a floodplain that is localized at a pier, abutment, or other obstruction to flow.

**One-Hundred-Year Flood:** The flood due to storm and/or tide having a 1 percent chance of being equaled or exceeded in any given year.

**Overtopping Flood:** The flood flow that, if exceeded, results in flow over a highway or bridge, over a watershed divide, or through structures provided for emergency relief. The worst-case scour condition may be caused by the overtopping flood.

**Stable Channel:** A condition that exists when a stream has a bed slope and cross-section that allows its channel to transport the water and sediment delivered from the upstream watershed without significant degradation, aggradation, or bank erosion.

**Stream Geomorphology:** The study of a stream and its floodplain with regard to its land forms, the general configuration of its surface, and the changes that take place due to erosion and the buildup of erosional debris.

**Superelevation:** A tilting of the roadway surface to partially counterbalance the centrifugal forces on vehicles on horizontal curves.

**Superflood:** Any flood or tidal flow with a flow rate greater than that of the 100-year flood but not greater than a 500-year flood. Estimated magnitude equals 1.7 times the 100-year flood.

**Watershed:** An area confined by drainage divides, and often having only one outlet for discharge; the total drainage area contributing runoff to a single point.

**Waterway:** Any stream, river, pond, lake, or ocean.

**Waterway Opening:** Width or area of bridge opening at a specified stage, and measured normal to principal direction of flow.

## **LOCATION FEATURES**

### ***Route Location***

#### **GENERAL**

The choice of location of bridges shall be supported by analyses of alternatives with consideration given to economic, engineering, social, and environmental concerns as well as costs of maintenance and inspection associated with the structures and with the relative importance of the above-noted concerns.

Attention, commensurate with the risk involved, shall be directed toward providing for favorable bridge locations that:

- Fit the conditions created by the obstacle being crossed;
- Facilitate practical cost effective design, construction, operation, inspection and maintenance;
- Provide for the desired level of traffic service and safety; and
- Minimize adverse highway impacts.

#### **WATERWAY AND FLOODPLAIN CROSSINGS**

Waterway crossings shall be located with regard to initial capital costs of construction and the optimization of total costs, including river channel training works and the maintenance measures necessary to reduce erosion. Studies of alternative crossing locations should include assessments of:

- The hydrologic and hydraulic characteristics of the waterway and its floodplain, including channel stability and flood history.
- The effect of the proposed bridge on flood flow patterns and the resulting scour potential at bridge foundations;
- The potential for creating new or augmenting existing flood hazards; and
- Environmental impacts on the waterway and its floodplain.

Bridges and their approaches on floodplains should be located and designed with regard to the goals and objectives of floodplain management, including;

- Prevention of uneconomic, hazardous, or incompatible use and development of floodplains;
- Avoidance of significant transverse and longitudinal encroachments, where practicable;
- Minimization of adverse highway impacts and mitigation of unavoidable impacts, where practicable;
- Consistency with the intent of the standards and criteria of the National Flood Insurance Program, where applicable;
- Long-term aggradation or degradation; and
- Commitments made to obtain environmental approvals

It is generally safer and more cost effective to avoid hydraulic problems through the selection of favorable crossing locations than to attempt to minimize the problems at a later time in the project development process through design measures.

Experience at existing bridges should be part of the calibration or verification of hydraulic models, if possible. Evaluation of the performance of existing bridges during past floods is often helpful in selecting the type, size, and location of new bridges.

### ***Bridge Site Arrangement***

#### **GENERAL**

The location and the alignment of the bridge should be selected to satisfy both on-bridge and under-bridge traffic requirements. Consideration should be given to possible future variations in alignment or width of the waterway, highway, or railway spanned by the bridge.

Where appropriate, consideration should be given to future addition of mass-transit facilities or bridge widening.

#### **TRAFFIC SAFETY**

##### **Protection of structures**

Consideration shall be given to safe passage of vehicles on or under a bridge. The hazard to errant vehicles within the clear zone should be minimized by locating obstacles at a safe distance from the travel lanes.

Pier columns or walls for grade separation structures should be located in conformance with the clear zone concept as contained in Chapter 3 of the AASHTO Roadside Design Guide. Where the practical limits of structure costs, type of structure, volume and design speed of through traffic, span arrangement, skew, and terrain make conformance with the Roadside Design Guide impractical, the pier or wall should be protected by the use of guardrail or other barrier devices. The guardrail or other device should, if practical, be independently supported, with its roadway face at least 2.0 FT from the face of pier or abutment, unless a rigid barrier is provided. The intent of providing structurally independent barriers is to prevent transmission of force effects from the barrier to the structure to be protected.

The face of the guardrail or other device should be at least 2.0 FT outside the normal shoulder line.

### **Protection of Users**

Railings shall be provided along the edges of structures conforming to the requirements of Section 13 of AASHTO LRFD Bridge Design Specifications.

All protective structures shall have adequate surface features and transitions to safely redirect errant traffic.

### **Geometric Standards**

Requirements of the AASHTO publication A Policy on Geometric Design of Highways and Streets shall either be satisfied or exceptions thereto shall be justified and documented. Width of travel lanes and shoulders shall meet the requirements established by the roadway engineer.

### **Road Surfaces**

Road surfaces on a bridge shall be given antiskid characteristics, crown, drainage, and superelevation in accordance with A Policy on Geometric Design of Highways and Streets.

## ***Clearances***

### **NAVIGATIONAL**

Permits for construction of a bridge over navigable waterways shall be obtained from the U.S. Coast Guard and/or other agencies having jurisdiction. Navigational clearances, both vertical and horizontal, shall be established in cooperation with the U.S. Coast Guard.

The Colorado River is the only navigable waterway in Arizona with U.S. Coast Guard jurisdiction. Certain reservoirs have bridges over navigable waterway passage with other agencies having jurisdiction.

## **VERTICAL CLEARANCE AT STRUCTURES**

The following are minimum vertical clearance standards for highway traffic structures, pedestrian overpasses, railroad overpasses, tunnels and sign structures. Lesser clearances may be used only under very restrictive conditions, upon individual analysis and with the approval of the Assistant State Engineer-Roadway Group and the State Bridge Engineer.

### **HIGHWAY TRAFFIC STRUCTURES**

The design vertical clearance for overpass and underpass structures, regardless of the highway system classification, shall be at least 16'-6" over the entire roadway width, including auxiliary lanes and shoulders. An allowance of 6 inches is included to accommodate future resurfacing.

The designer is reminded that this is a minimum requirement and that consideration should be given to possible future widening of the roadway under the structure and the possible future widening of the structure.

### **PEDESTRIAN OVERPASSES**

Because of their lesser resistance to impacts, the minimum design vertical clearance to pedestrian overpasses shall be 17'-6" regardless of the highway system classification. An allowance of 6 inches is included to accommodate future resurfacing.

### **TUNNELS**

The minimum design vertical clearance for tunnels shall be at least 16'-6" for freeways, arterials, and all other State Highways and at least 15'-6" for all other highways and streets.

### **SIGN STRUCTURES**

Because of their lesser resistance to impacts, the minimum design vertical clearance to sign structures shall be 18'-0" regardless of the highway system classification. An allowance of 6 inches is included to accommodate future resurfacing.

## **HORIZONTAL CLEARANCE AT STRUCTURES**

The bridge width shall not be less than that of the approach roadway section, including shoulders or curbs, gutters, and sidewalks.

No object on or under a bridge, other than a barrier, should be located closer than 4.0 FT to the edge of a designated traffic lane. The inside face of a barrier should not be closer than 2.0 FT to either the face of the object or the edge of a designated traffic lane.

## **RAILROAD OVERPASSES**

Structures designed to pass over a railroad shall be in accordance with standards established and used by the affected railroad in its normal practice. These overpass structures shall comply with applicable federal, state, county, and municipal laws.

Structures over railways shall provide a minimum clearance of 23'-6" above top of rail, except that overhead clearance greater than 23'-6" may be approved when justified on the basis of railroad electrification. No additional allowance shall be provided for future track adjustments.

Regulations, codes, and standards should, as a minimum, meet the specifications and design standards of the American Railway Engineering and Maintenance-of-Way Association (AREMA), the Association of American Railroads, and AASHTO.

Requirements of the individual railroads in Arizona are contained in regulations published by the Arizona Corporation Commission.

Attention is particularly called to the following chapters in the Manual for Railway Engineering (MRE):

- Chapter 7 – Timber Structures,
- Chapter 8 – Concrete Structures and Foundations,
- Chapter 9 – Seismic Design for Railway Structures,
- Chapter 15 – Steel Structures, and
- Chapter 18 – Clearances.

The provisions of the individual railroads and the AREA Manual should be used to determine:

- Clearances,
- Loadings,
- Pier protection,
- Waterproofing, and
- Blast protection.

## ***Environment***

The impact of a bridge and its approaches on local communities, historic sites, wetlands, and other aesthetically, environmentally, and ecologically sensitive areas shall be considered. Compliance with state water laws; federal and state regulations concerning encroachment on floodplains, fish, and wildlife habitats; and the provisions of the National Flood Insurance Program shall be assured. Stream geomorphology, consequences of riverbed scour, and removal of embankment stabilizing vegetation, shall be considered.

Stream, i.e., fluvial, geomorphology is a study of the structure and formation of the earth's features that result from the forces of water. For purposes of this section, this involves evaluating the stream's potential for aggradation, degradation, or lateral migration.

## **FOUNDATION INVESTIGATION**

### ***General***

A subsurface investigation, including borings and soil tests, shall be conducted in accordance with the provisions of AASHTO to provide pertinent and sufficient information for the design of substructure units. The type and cost of foundations should be considered in the economic and aesthetic studies for location and bridge alternate selection. For bridge replacement or rehabilitation, existing geotechnical data may provide valuable information for initial studies.

### ***Topographic Studies***

Current topography of the bridge site shall be established via contour maps and photographs. Such studies shall include the history of the site in terms of movement of earth masses, soil and rock erosion, and meandering of waterways.

## **DESIGN OBJECTIVES**

### ***Safety***

The primary responsibility of the Bridge Designer shall be providing for the safety of the public.

### ***Serviceability***

## **DURABILITY**

### **Materials**

The contract documents shall call for quality materials and for the application of high standards of fabrication and erection.

Structural steel shall be self-protecting, or have long-life coating systems.

Reinforcing bars and prestressing strands in concrete components, which may be expected to be exposed to airborne or waterborne salts, shall be protected by an appropriate combination of epoxy and/or composition of concrete, including air-entrainment and a nonporous painting of the concrete surface.

Prestress strands in cable ducts shall be grouted or otherwise protected against corrosion.

Attachments and fasteners used in wood construction shall be of stainless steel, malleable iron, aluminum, or steel that is galvanized, cadmium-plated, or otherwise coated. Wood components shall be treated with preservatives.

Aluminum products shall be electrically insulated from steel and concrete components.

Protection shall be provided to materials susceptible to damage from solar radiation and/or air pollution.

Consideration shall be given to the durability of materials in direct contact with soil, sun and/or water.

### **Self-Protecting Measures**

Continuous drip grooves shall be provided along the underside of a concrete deck at a distance not exceeding 10.0 IN from the fascia edges. Where the deck is interrupted by a sealed deck joint, all top surfaces of piers and abutments, other than bearing seats, shall have a minimum slope of 5 percent toward their edges. For open deck joints, this minimum slope shall be increased to 15 percent. In the case of open deck joints, the bearings shall be protected against contact with salt and debris.

Wearing surfaces shall be interrupted at the deck joints and shall be provided with a smooth transition to the deck joint device.

### **INSPECTABILITY**

Inspection ladders, walkways, catwalks, covered access holes, and provision for lighting, if necessary, shall be provided where other means of inspection are not practical.

Where practical, access to allow manual or visual inspection, including adequate headroom in box sections, shall be provided to the inside of cellular components and to interface areas, where relative movement may occur.

### **MAINTAINABILITY**

Structural systems whose maintenance is expected to be difficult should be avoided. Where the climatic and/or traffic environment is such that the bridge deck may need to be replaced before the required service life, either provisions shall be shown on the contract plans for the replacement of the deck or additional structural resistance shall be provided.

Areas around bearing seats and under deck joints should be designed to facilitate jacking, cleaning, repair, and replacement of bearings and joints.

Jacking points shall be indicated on the plans, and the structure shall be designed for the jacking forces. Inaccessible cavities and corners should be avoided. Cavities that may invite human or animal inhabitants shall either be avoided or made secure.

### **RIDEABILITY**

The deck of the bridge shall be designed to allow for the smooth movement of traffic. On paved roads, a structural transition slab should be located between the approach roadway and the abutment of the bridge. Construction tolerances, with regard to the profile of the finished deck, shall be indicated on the plans or in the specifications or special provisions.

The number of deck joints shall be kept to a practical minimum. Edges of joints in concrete decks exposed to traffic should be protected from abrasion and spalling. The plans for prefabricated joints shall specify that the joint assembly be erected as a unit, if feasible.

Where concrete decks without an initial overlay are used, an additional thickness of 0.5-IN to permit correction of the deck profile by grinding, and to compensate for thickness loss due to abrasion will be provided.

## **UTILITIES IN STRUCTURES**

Where utility conflicts exist; water, power, telephone, cable TV and gas lines will be relocated as required for construction of the project. Where it is feasible and reasonable to locate utility lines elsewhere, attachment to structures will not be permitted. Trenching in the vicinity of existing piers or abutments shall be kept a sufficient distance from footings to prevent undercutting of existing footings or to prevent disturbing foundation soils for future foundations.

Where other locations prove to be extremely difficult and very costly, utility lines, except natural gas, may be allowed in the structures.

Natural gas encroachments will be evaluated under the following policy:

- A. Cases were gas line attachments to structures will not be considered under any condition:
  - 1. Grade separation structures carrying vehicular traffic on or over freeways.
  - 2. Inside closed cell-type box girder bridges.
  - 3. High pressure transmission lines over 60 psi and/or distribution lines of over 6 inches in diameter.
  - 4. Gas lines over minor waterway crossings where burial is feasible
- B. Gas line attachments on structures will be considered under the following cases or conditions:
  - 1. Each case will be judged on its own merit with the utilities providing complete justification as to why alternative locations are not feasible.
  - 2. Economics will not be a significant factor considered in the feasibility issue.
  - 3. Open girder type structures across major rivers.
  - 4. Pedestrian or utility bridges where proper vented casings and other safety systems are used.
  - 5. All lines are protected by casements.

Provisions for accommodation of relocated and future utilities on structures shall be coordinated through the Utility and Railroad Engineering Section for ADOT projects, or as appropriate, through Statewide Project Management Section and/or a consultant for other projects.

## **General Policy**

Support bracket details and attachments for all utilities will require Bridge Group approval.

All approved utilities shall have individual sleeved casings, conduits or ducts as appropriate.

All utilities carrying liquids shall be placed inside casing through the entire length of the structure. The casing shall be designed to carry full service pressure so as to provide a satisfactory containment in case the utility is damaged or leaks.

Water lines, telephone conduits, power lines, cable TV lines, supports or other related items will not be permitted to be suspended below or attached to the exterior of any new or existing structure.

Product lines for transmitting volatile fluids will not be permitted to be attached to or suspended from or placed within any new or existing structure.

Manholes or access openings for utilities will not be permitted in bridge decks, webs, bottom slabs or abutment diaphragms.

On special major projects, ADOT design costs will be assessed to the company

## **Utility Company Responsibility**

The utility company is responsible for obtaining necessary information regarding the proposed construction schedule for the project. The company shall submit a request including justification for attaching to the structure and preliminary relocation plans including line weights and support spacing as early as possible but no later than the completion of preliminary structural plans. The company shall submit complete plans and specifications of their proposed installation at least 20 working days prior to the schedule C & S Date.

The utility company shall be responsible for the design of all conduits, pipes, sleeves, casings, expansion devices, supports and other related items including the following information:

1. Number and size of conduits for power, telephone and cable TV lines.
2. Size and schedule of carrier pipe for water lines.
3. Size and schedule of sleeved casings.
4. Spacing and details of support brackets.

5. Expansion device details.
6. Total combined weight of carrier pipe and transmitted fluids, conduits, casings, support brackets, expansion joints and other related items.
7. Design calculations.
8. Submit permit request through the District.

### **Bridge Designer Responsibility**

The Bridge Designer shall be responsible for the following aspects of the design :

1. Determination of how many lines, if any, the structure can accommodate.
2. Determination of where such lines should be located within a structure.
3. Determination of the size of the access openings and design of the required reinforcing.
4. Identification of installation obstacles related to required sequencing of project.
5. Tracking man-hours associated with utility relocations for cost recovery, when appropriate.

Usually utilities will be accommodated by providing individual access openings for casings and sleeves to pass through. Access openings should be 2 inches larger than the diameter of the casings or sleeves and spaced as required by structural considerations.

For box girder bridges, access openings should be located as low as possible but no lower than 10 inches above the top of the bottom slab to allow for support brackets to be supported from the bottom slab. Where possible all utilities shall be supported from the bottom slab for box girder bridges.

For precast or steel girder bridges, the utilities shall not be placed in the exterior girder bay and they shall be supported from the deck slab, rather than from the diaphragms.

### ***Constructibility***

Bridges should be designed in a manner such that fabrication and erection can be performed without undue difficulty or distress and that locked-in construction force effects are within tolerable limits.

When the method of construction of a bridge is not self-evident or could induce unacceptable locked-in stresses, at least one feasible method shall be indicated in the contract documents. If the design requires some strengthening and/or temporary bracing or support during erection by the selected method, indication of the need thereof shall be indicated in the contract documents.

Details that require welding in restricted areas or placement of concrete through congested reinforcing should be avoided.

Climatic and hydraulic conditions that may affect the construction of the bridge shall be considered.

## ***Economy***

### **GENERAL**

Structural types, span lengths, and materials shall be selected with due consideration of projected cost. The cost of future expenditures during the projected service life of the bridge should be considered. Regional factors, such as availability of material, fabrication, location, shipping, and erection constraints, shall be considered.

If data for the trends in labor and material cost fluctuation is available, the effect of such trends should be projected to the time the bridge will likely be constructed.

Cost comparisons of structural alternatives should be based on long-range considerations, including inspection, maintenance, repair, and/or replacement. Lowest first cost does not necessarily lead to lowest total cost.

### **ALTERNATIVE PLANS**

In instances where economic studies do not indicate a clear choice, the State Bridge Engineer may require that alternative contract plans be prepared and bid competitively. Designs for alternative plans shall be of equal safety, serviceability, and aesthetic value.

Movable bridges over navigable waterways should be avoided to the extent feasible. Where movable bridges are proposed, at least one fixed bridge alternative should be included in the economic comparisons.

## *Bridge Aesthetics*

Bridges should complement their surroundings, be graceful in form, and present an appearance of adequate strength.

Significant improvements in appearance can often be made with small changes in shape or position of structural members at negligible cost. For prominent bridges, however, additional cost to achieve improved appearance is often justified, considering that the bridge will likely be a feature of the landscape for 75 or more years.

Engineers should seek more pleasant appearance by improving the shapes and relationships of the structural component themselves. The application of extraordinary and nonstructural embellishment should be avoided.

The following guidelines should be considered:

- Alternative bridge designs without piers or with few piers should be studied during the site selection and location stage and refined during the preliminary design stage.
- Pier form should be consistent in shape and detail with the superstructure.
- Abrupt changes in the form of components and structural type should be avoided. Where the interface of different structural types cannot be avoided, a smooth transition in appearance from one type to another should be attained.
- Attention to details, such as deck drain downspouts, should not be overlooked.
- The use of the bridge as a support for message or directional signing or lighting should be avoided wherever possible.
- Transverse web stiffeners, other than those located at bearing points, should not be visible in elevation.
- For spanning deep ravines, arch-type structures should be preferred.

The most admired modern structures are those that rely for their good appearance on the forms of the structural components themselves:

- Components are shaped to respond to the structural function. They are thick where the stresses are greatest and thin where the stresses are smaller.
- The function of each part and how the function is performed is visible.
- Components are slender and widely spaced, preserving views through the structure.

- The bridge is seen as a single whole, with all members consistent and contributing to that whole; for example, all elements should come from the same family of shapes, such as shapes with rounded edges.
- The bridge fulfills its function with a minimum of material and minimum number of elements.
- The size of each member compared with the others is clearly related to the overall structural concept and the job the component does, and
- The bridge as a whole has a clear and logical relationship to its surroundings.

## **HYDROLOGY AND HYDRAULICS**

### ***General***

Hydrologic and hydraulic studies and assessments of bridge sites for stream crossings shall be completed as part of the preliminary plan development. The detail of these studies should be commensurate with the importance of and risks associated with the structure.

Temporary structures for the Contractor's use or for accommodating traffic during construction shall be designed with regard to the safety of the traveling public and the adjacent property owners, as well as minimization of impact on floodplain natural resources. ADOT may permit revised design requirements consistent with the intended service period for, and flood hazard posed by, the temporary structure. Contract documents for temporary structures shall delineate the respective responsibilities and risks to be assumed by ADOT and the Contractor.

Evaluation of bridge design alternatives shall consider stream stability, backwater, flow distribution, stream velocities, scour potential, flood hazards, and consistency with established criteria for the National Flood Insurance Program.

### ***Site Data***

A site-specific data collection plan shall include consideration of:

- Collection of aerial and/or ground survey data for appropriate distances upstream and downstream from the bridge for the main stream channel and its floodplain;
- Estimation of roughness elements for the stream and the floodplain within the reach of the stream under study;

- Sampling of streambed material to a depth sufficient to ascertain material characteristics for scour analysis;
- Subsurface borings;
- Factors affecting water stages, including high water from streams, reservoirs, detention basins, and flood control structures and operating procedures;
- Existing studies and reports, including those conducted in accordance with the provisions of the National Flood Insurance Program or other flood control programs;
- Available historical information on the behavior of the stream and the performance of the structure during past floods, including observed scour, bank erosion, and structural damage due to debris or ice flows; and
- Possible geomorphic changes in channel flow.

### *Hydrologic Analysis*

The following flood flows should be investigated, as appropriate, in the hydrologic studies:

- For assessing flood hazards and meeting floodplain management requirements – the 100-year flood;
- For assessing risks to highway users and damage to the bridge and its roadway approaches – the overtopping flood and/or the design flood for bridge scour;
- For assessing catastrophic flood damage at high risk sites – a check flood of a magnitude selected by the Bridge Designer as appropriate for the site conditions and the perceived risk;
- For investigating the adequacy of bridge foundations to resist scour – the check flood for bridge scour;
- To satisfy ADOT design policies and criteria – design floods for waterway opening and bridge scour for the various functional classes of highways, as described in the ADOT Roadway Design Guidelines;
- To calibrate water surface profiles and to evaluate the performance of existing structures – historical floods, and
- To evaluate environmental conditions – low or base flow information

## *Hydraulic Analysis*

### **GENERAL**

The Bridge Designer shall utilize analytical models and techniques that have been approved by ADOT and that are consistent with the required level of analysis as described in the ADOT Roadway Design Guidelines.

### **STREAM STABILITY**

Studies shall be carried out to evaluate the stability of the waterway and to assess the impact of construction on the waterway. The following items shall be considered:

- Whether the stream reach is degrading, aggrading, or in equilibrium;
- For stream crossing near confluences, the effect of the main stream and the tributary on the flood stages, velocities, flow distribution, vertical and lateral movements of the stream, and the effect of the foregoing conditions on the hydraulic design of the bridge;
- Location of favorable stream crossing, taking into account whether the stream is straight, meandering, braided, or transitional, or control devices to protect the bridge from existing or anticipated future stream conditions;
- The effect of any proposed channel changes;
- The effect of aggregate mining or other operations in the channel;
- Potential changes in the rates or volumes of runoff due to land use changes;
- The effect of natural geomorphic stream pattern changes on the proposed structure; and
- The effect of geomorphic changes on existing structures in the vicinity of, and caused by, the proposed structure.

For unstable streams or flow conditions, special studies shall be carried out to assess the probable future changes to the plan form and profile of the stream and to determine countermeasures to be incorporated in the design, or at a future time, for the safety of the bridge and approach roadways.

## **BRIDGE WATERWAY**

The design process for sizing the bridge waterway shall include:

- The evaluation of flood flow patterns in the main channel and floodplain for existing conditions, and
- The evaluation of trial combinations of highway profiles, alignments, and bridge lengths for consistency with design objectives.

Where use is made of existing flood studies, their accuracy shall be determined.

## **BRIDGE FOUNDATIONS**

### **General**

The structural, hydraulic, and geotechnical aspects of foundation design shall be coordinated and differences resolved prior to approval of preliminary plans.

To reduce the vulnerability of the bridge to damage from scour and hydraulic loads, consideration should be given to the following general design concepts:

- Set deck elevations as high as practical for the given site conditions to minimize inundation, or overtopping of roadway approach sections, and streamline the superstructure to minimize the area subject to hydraulic loads and the collection of ice, debris, and drifts.
- Utilize relief bridges, guide banks, dikes, and other river training devices to reduce the turbulence and hydraulic forces acting at the bridge abutments.
- Utilize continuous span designs. Anchor superstructures to their substructures where subject to the effects of hydraulic loads, buoyancy, ice, or debris impacts or accumulations. Provide for venting and draining of the superstructure.
- Where practical, limit the number of piers in the channel, streamline pier shapes, and align pier columns with the direction of flood flows. Avoid pier types that collect ice and debris. Locate piers beyond the immediate vicinity of stream banks.
- Locate abutments back from the channel banks where significant problems with ice/debris buildup, scour, or channel stability are anticipated, or where special environmental or regulatory needs must be met, e.g., spanning wetlands.
- Design piers within floodplains as river piers. Locate their foundations at the appropriate depth if there is a likelihood that the stream channel will shift during the life of the structure or that channel cutoffs are likely to occur.

- Where practical, use debris racks to stop debris before it reaches the bridge. Where significant debris buildup is unavoidable, its effects should be accounted for in determining scour depths and hydraulic loads.
- A majority of bridge failures in the United States and elsewhere are the result of scour. The added cost of making a bridge less vulnerable to damage from scour is small in comparison to the total cost of a bridge failure.

### **Bridge Scour**

As required by Section 3, scour at bridge foundations is investigated for two conditions:

- For the design flood for scour, the streambed material in the scour prism above the scour line shall be assumed to have been removed for design conditions. The design flood storm surge, tide, or mixed population flood shall be the more severe of the 100-year events or from an overtopping flood of lesser recurrence interval.
- For the check flood for scour, the stability of the bridge foundation shall be investigated for scour conditions resulting from a designated flood storm surge, tide, or mixed population flood not to exceed the 500-year event or from an overtopping flood of lesser recurrence interval. Excess reserve beyond that required for stability under this condition is not necessary. The extreme event limit state shall apply.

If the site conditions, due to debris jams, and low tailwater conditions near stream confluences dictate the use of a more severe flood event for either the design or check flood for scour, the Bridge Designer may use such flood event.

Spread footings on soil or erodible rock shall be located beyond the scour potential of the waterway. Spread footings on scour-resistant rock shall be designed and constructed to maintain the integrity of the supporting rock.

Deep foundations with footings shall be designed to place the top of the footing below the estimated contraction scour depth where practical to minimize obstruction to flood flows and resulting local scour. Even lower elevations should be considered for pile-supported footings where the piles could be damaged by erosion and corrosion from exposure to stream currents. Where conditions dictate a need to construct the top of a footing to an elevation above the streambed, attention shall be given to the scour potential of the design.

When fendering or other pier protection systems are used, their effect on pier scour and collection of debris shall be taken into consideration in the design.

The design flood for scour shall be determined on the basis of the Bridge Designer's judgment of the hydrologic and hydraulic flow conditions at the site. The recommended procedure is to evaluate scour due to the specified flood flows and to design the foundation for the event expected to cause the deepest total scour.

The recommended procedure for determining the total scour depth at bridge foundations is as follows:

- Estimate the long-term channel profile aggradation or degradation over the service life of the bridge;
- Estimate the effects of gravel mining on the channel profile, if appropriate;
- Estimate the long-term channel plan form changes over the service life of the bridge;
- As a design check, adjust the existing channel and floodplain cross-sections upstream and downstream of bridge as necessary to reflect anticipated changes in the channel profile and plan form;
- Determine the combination of existing or likely future conditions and flood events that might be expected to result in the deepest scour for design conditions.;
- Determine water surface profiles for a stream reach that extends both upstream and downstream of the bridge site for the various combinations of conditions and events under consideration;
- Determine the magnitude of contraction scour and local scour at piers and abutments; and
- Evaluate the results of the scour analysis, taking into account the variables in the methods used, the available information on the behavior of the watercourse, and the performance of existing structures during past floods. Also consider present and anticipate future flow patterns and the effect of the flow on the bridge. Modify the bridge design where necessary to satisfy concerns raised by the scour analysis and the evaluation of the channel plan form.

Foundation designs should be based on the total scour depths estimated by the above procedure, taking into account appropriate geotechnical safety factors. Where necessary, bridge modifications may include:

- Relocation or redesign of piers or abutments to avoid areas of deep scour or overlapping scour holes from adjacent foundation elements,
- Addition of guide banks, dikes, or other river training works to provide for smoother flow transitions or to control lateral movement of the channel,
- Enlargement of the waterway area, or
- Relocation of the crossing to avoid an undesirable location.

Foundations should be designed to withstand the conditions of scour for the design flood and the check flood. In general, this will result in deep foundations. The design of the foundations of existing bridges that are being rehabilitated should consider underpinning if scour indicates the need. Riprap and other scour countermeasures may be appropriate if underpinning is not cost effective.

The stability of abutments in areas of turbulent flow shall be thoroughly investigated. Exposed embankment slopes should be protected with appropriate scour countermeasures.

## **ROADWAY APPROACHES TO BRIDGE**

The design of the bridge shall be coordinated with the design of the roadway approaches to the bridge on the floodplain so that the entire flood flow pattern is developed and analyzed as a single, interrelated entity. Where roadway approaches on the floodplain obstruct overbank flow, the highway segment within the floodplain limits shall be designed to minimize flood hazards.

Where diversion of flow to another watershed occurs as a result of backwater and obstruction of flood flows, an evaluation of the design shall be carried out to ensure compliance with legal requirements in regard to flood hazards in the watershed.

## ***Deck Drainage***

### **GENERAL**

The bridge deck and its highway approaches shall be designed to provide safe and efficient conveyance of surface runoff from the traveled way in a manner that minimizes damage to the bridge and maximizes the safety of passing vehicles. Transverse drainage of the deck, including roadway, bicycle paths, and pedestrian walkways, shall be achieved by providing a cross slope or superelevation sufficient for positive drainage. For wide bridges with more than three lanes in each direction, special design of bridge deck drainage and/or special rough road surfaces may be needed to reduce the potential for hydroplaning. Water flowing downgrade in the roadway gutter section shall be intercepted and not permitted to run into the bridge. Drains at bridge ends shall have sufficient capacity to carry all contributing runoff.

In those unique environmentally sensitive instances where it is not possible to discharge into the underlying water course, consideration should be given to conveying the water in a longitudinal storm drain affixed to the underside of the bridge and discharging it into appropriate facilities on natural ground at bridge end.

Where feasible, bridge decks should be watertight and all of the deck drainage should be carried to the ends of the bridge.

A longitudinal gradient on bridges should be maintained. Zero gradients and sag vertical curves should be avoided. Design of the bridge deck and the approach roadway drainage systems should be coordinated.

The “Storm Drainage” chapter of the AASHTO Model Drainage Manual contains guidance on recommended values for cross slopes.

### **DESIGN STORM**

The design storm for bridge deck drainage shall not be less than the storm used for design of the pavement drainage system of the adjacent roadway, unless otherwise specified.

### **TYPE, SIZE AND NUMBER OF DRAINS**

The number of deck drains should be kept to a minimum consistent with hydraulic requirements.

In the absence of other applicable guidance, for bridges where the highway design speed is less than 45 MPH, the size and number of deck drains should be such that the spread of deck drainage does not encroach on more than one-half the width of any designated traffic lane. For bridges where the highway design speed is not less than 45 MPH, the spread of deck drainage should not encroach on any portion of the designated traffic lanes. For bridges with adjacent pedestrian sidewalk, the spread of deck drainage should not encroach on any portion of the adjacent designated traffic lanes. Gutter flow should be intercepted at cross slope transitions to prevent flow across the bridge deck.

### **DISCHARGE FROM DECK DRAINS**

Deck drains shall be designed and located such that surface water from the bridge deck or road surface is directed away for the bridge superstructure elements and the substructure.

Consideration should be given to:

- A minimum 4.0-IN projection below the lowest adjacent superstructure component,
- Location of pipe outlets such that a 45-degree cone of splash will not touch structural components.
- Use of free drops or slots in parapets wherever practical and permissible,
- Use of bends not greater than 45 degrees, and
- Use of cleanouts.

Runoff from bridge decks and deck drains shall be disposed of in a manner consistent with environmental and safety requirements.

Consideration should be given to the effect of drainage systems on bridge aesthetics.

For bridges where free drops are not feasible, attention should be given to the design of the outlet piping system to:

- Minimize clogging and other maintenance problems, and
- Minimize the intrusive effect of the piping on the bridge symmetry and appearance.

Free drops should be avoided where runoff creates problems with traffic, rail, or shipping lanes. Riprap or pavement should be provided under the free drops to prevent erosion.

### **DRAINAGE OF STRUCTURES**

Cavities in structures where there is a likelihood for entrapment of water shall be drained at their lowest point. Decks and wearing surfaces shall be designed to prevent the ponding of water, especially at deck joints. For bridge decks with nonintegral wearing surfaces or stay-in-place forms, consideration shall be given to the evacuation of water that may accumulate at the interface.