OFFICE OF STRUCTURES
MANUAL FOR HYDROLOGIC AND HYDRAULIC DESIGN

CHAPTER 12
BRIDGE DECK DRAINAGE SYSTEMS

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Chapter Table of Contents

CHAPTER 12
BRIDGE DECK DRAINAGE SYSTEMS

12.1 Policy

12.1.1 Table 1

The bridge deck and its highway approaches need to 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 the adjacent terrain, and maximizes the safety of passing vehicles. Bridge deck drainage systems are to be designed to accommodate runoff using the design criteria for rainfall intensities and spread of gutter flow set forth in Table 1.

12.1.2 Design Exceptions

Where it is not feasible to contain the gutter flow within the limits specified in Table 1, a request for a design exception needs to be submitted to and approved by the Director, Office of Structures. In no case should the design spread exceed a maximum width of the shoulder plus one-half driving lane.

12.1.3 Structure T.S. &L.

A preliminary evaluation of the adequacy of the bridge deck drainage system should be made prior to submission of the T S & L if one or more of the following conditions exist:

- There is a low point or sump within the limits of the bridge
- The elevation of the deck is less than one foot higher than the elevation of a sump or low point on the highway approach
- The bridge deck grades are less than 0.5% (except at crests).

This early review of problem areas should help to determine if the criteria in Table 1 can be met. If not, the engineer will need to decide whether to adjust the grade line or to seek a design exception.

TABLE 1
DESIGN CRITERIA FOR SPREAD OF GUTTER FLOW ON BRIDGES

1. BRIDGE DECKS ON GRADES OR ON CREST VERTICAL CURVES	
Rainfall Intensity (i): 6 inches per hour	
WIDTH OF SHOULDER	DESIGN SPREAD*
Greater than 6 feet	Limit spread to the shoulder.
6 feet or less	Limit spread to 6 feet*. (A narrower spread may be required for certain high speed expressway-type bridges where a six foot spread will extend well into the traveled way. This design condition should be discussed with the Office of Structures)
2. BRIDGE DECKS IN SAGS (SUMPS)	
•Meet the criteria in Item 1 above for bridge decks on grades. •In addition, for a 50 year/5 minute rainfall intensity of 8.7 inches per hour: - For shoulder widths greater than 6 feet, limit the gutter spread to 10 feet. - For shoulder widths or offsets of 6 feet or less, limit the gutter spread to 7 feet. - Where there is no shoulder or offset distance between the parapet and driving lane, limit the spread to the width of 1/2 driving lane. •Use flanker inlets next to the sump inlet (See Section 12.3.2)	

* In some cases (See Appendix D), it may be feasible to maintain a gutter spread less than the value indicated in Table 1 for high volume high speed facilities.

Where it is not feasible to meet the design values in Table 1, the engineer may request an exception to the design criteria following the procedure presented in Section 12.1.2 - Design Exceptions. Where justified, a design spread equal to the shoulder plus one-half driving lane may be used in the design of the bridge deck drainage system. Factors to consider in developing and evaluating requests for exceptions are included in Appendix D.

12.2.1 Design Standards

The Bridge Standards for the scuppers discussed in this chapter are available at:

> http://apps.roads.maryland.gov/businesswithsha/bizstdsspecs/obd/bridgestandards/Bridge_Standards/13_Super-Other2741/PDF/13_Super-Other.pdf

12.2.2 Design Guidance

To the extent practicable, bridge decks are to be designed in accordance with the following criteria in order to minimize maintenance problems and operating hazards such as corrosion, icing and the spread of water onto the traveled way:

- Where feasible in accordance with the criteria in this chapter, all runoff should be carried to drainage systems located off the bridge (See Standard No M (0.03)-80-123, Appendix B). Compression seal roadway joints and troughs shall be provided at all bridge joints in accordance with Bridge Standard No. BR-SS (7.02)-79-64 (Appendix B).

- Bridge scuppers should be used only when necessary to maintain the spread of the gutter flow onto the traveled way within the limits established in Table 1.

- Drains at bridge ends should have sufficient capacity to carry all contributing runoff from the bridge deck for the design storm. No consideration should be given to the flow intercepted by scuppers in the design of the bridge end drains.

- Water flowing downgrade in closed approach roadway sections should be intercepted so as to not run onto the bridge.

- Transverse drainage of the deck, including roadway and pedestrian walkways, should be achieved by providing cross slope or superelevation sufficient for positive drainage. The minimum cross slope for design is 2 percent.

- Where it is necessary to intercept deck drainage at intermediate points along the bridge, interceptors (scuppers) shall be designed and located so as to direct the outflow away from the bridge superstructure elements and the substructure. Consideration is to be given to controlling the discharge from scuppers in the following manner:

    - Utilize free drops from scuppers or slots in parapets, designed in accordance with the bridge standards to the extent permitted by environmental regulations. Free drops shall be avoided at locations where runoff creates problems with traffic, rail or shipping lanes. Provide riprap or other appropriate protection under free drops to prevent erosion unless the scupper outlet is more than 40 feet above the final ground elevation.

    - longitudinal runs of piping should not be used, and no drainage system shall be placed in any substructure unit or attached to any substructure unit unless such a design is approved by the Office of Structures.

- provide at least an 8.0 inch projection below the lowest adjacent superstructure component whenever water is discharged freely from scuppers.

- locate scuppers a minimum distance of 10 feet from the centerline of piers. For high bridges or for other conditions where scupper discharges are likely to be carried by the wind to substructure elements, this distance should be increased to twenty feet.

- dispose of runoff in a manner consistent with environmental and safety requirements.

•Selection of scupper type should be based on the following considerations:

- Scupper Types I and I-A serve effectively on both flat and steep grades, and are particularly useful in locations where scupper discharges must be controlled. Type I scuppers should be limited to bridge decks where the shoulder width is at least 6 feet, while Type I-A scuppers should be limited to bridge decks where the shoulder width is 4 feet or more. Where the shoulder is 6 feet or wider, give the contractor the option of using either scupper type unless there is a possibility that (1) the shoulder will be used in the future for maintenance of traffic or (2) the shoulder may be converted to a permanent traffic lane. If either of the above noted conditions is possible, specify Type IA scuppers (See STD NO. BR-SS (0.03)-80-112 or BR-SS (0.04)-81-130).

- Scupper Types II and III are effective in intercepting gutter flow on flat slopes, such as occurs near the crest of vertical curves. They are not recommended for use on grades exceeding 1 percent. Placement of these scuppers on the bridge fascia detracts from the appearance of the bridge. This may be a consideration for certain high visibility bridges. These scuppers should not be used at locations where the discharge from the scuppers must be controlled. The designer should check with the Office of Structures if there is a concern about discharging flows into environmentally sensitive areas. (See STD NO. BR-SS (0.05)-83-142 or BR-SS (0.06)-83-144).

- Scupper Types IV and V are most effective for bridge decks with shoulder widths less than 4 feet (Use of these scuppers may involve placement of the outlet pipe outside of the fascia beam). These scuppers are less efficient than Type 1, 1-A or VI Scuppers in capturing gutter flow for steep slopes and/or wide gutter spreads.

- Scupper Type VI is recommended for use on structures with a four foot shoulder, since it is more effective than scupper Type IV or V for such locations.

  The Bridge Standards for the above scuppers are available at:

  http://apps.roads.maryland.gov/businesswithsha/bizstdsspecs/obd/bridgestandards/Bridge_Standards/13_Super-Other2741/PDF/13_Super-Other.pdf

12.3 Design Procedure

12.3.1 Scuppers on Grades or on Crests

The design procedure for bridge deck drainage is based on research studies conducted by the FHWA and others as presented in References 2 and 5. The amount of runoff accumulated at any point on the bridge deck is calculated from the Rational Equation:

$$Q_t = \frac{CiWL}{43560} + Q_b \qquad (1)$$

Q_t = total runoff in the gutter
C = coefficient of runoff = 0.9
i = rainfall intensity (6 inches/hour)
W = total width of bridge deck contributing to gutter flow (ft.)
L = scupper spacing
Q_b = bypass flow from upgrade scupper as calculated by the computer program. (This value would be zero for the first scupper).

The quantity of flow that occurs in the gutter when the gutter spread is equal to the design spread is calculated from a variation of the Manning Equation:

$$Q_t = \frac{0.56}{n} S_x^{1.67} S^{0.5} T^{2.67} \qquad 2$$

where:
n = Manning's roughness coefficient = 0.016
S_x = cross-slope of deck (ft. /ft.)
S = longitudinal slope of deck (ft. /ft.)
T = design spread of gutter flow (ft.)

12.3.1.1 Design Procedure

The design procedure set forth in this chapter uses Equations 1 and 2 to locate the scupper at a point where the spread is close to but does not exceed the design spread (T). This is normally a trial and error process. Next, the flow intercepted by the scupper ($Q_{intercepted}$) is calculated using the procedures in Reference 4, and the flow by-passing the scupper ($Q_{by-pass}$) is calculated by Equation 3 below.

$$Q_{by-pass} = Q_{total} - Q_{intercepted} \qquad 3$$

This process is initiated on the high side of the bridge and repeated over and over again until an adequate number of scuppers have been located to maintain the gutter flow within the allowable spread (T).

12.3.1.2 Computer Software

Since manual computations to locate and design scuppers become time consuming and tedious, the software program MPADD (Maryland Pavement and Deck Design) has been developed to expedite such solutions. Please refer to Reference 6 and Appendix A in this chapter; and to the Software Chapter in the OOS Manual for Hydrologic and Hydraulic Design. We note that the MPADD Program is not recommended for pavement design.

12.3.2 Sumps

It is undesirable to locate the low point of a sag vertical curve on a bridge, and this type of design should be avoided whenever feasible to do so. If this type of design must be used, design calculations should be made to insure that the spread of the gutter flow for the 50 year rainfall does not exceed the allowable spread as described in Table 1.

A flanker inlet should be installed on either side of the sump inlet at the point on the vertical curve where the slope is 0.003 ft. /ft. This design provides for a safety factor against clogging of the sump inlet by debris (See discussion in Reference 4).

The computer program described in Appendix A can be used to evaluate the adequacy of scuppers in sumps, and to design the flanker inlets.

In some cases it may be necessary to locate the low point of a sag vertical curve immediately adjacent to the bridge limits. This type of design should also be checked for the 50 year rainfall to ensure that adequate roadway drains have been installed to limit ponding at the sump and to maintain the spread of gutter flow on the bridge within the limits set forth in Table 1. The computer program described in Appendix A can be used to evaluate this design condition.

12.3.3 Bridge Deck End Drains

Bridge deck end drains should normally be provided at the downslope end of bridge structures to remove any runoff from the bridge deck that is not intercepted by the scuppers. For short bridges, scuppers will not normally be provided, and the end drains must be designed to capture all runoff from the bridge. Bridge Standard No. M (0.03)-80-123 should be used for end drains. For bridges with scuppers, the use of this end drain is still recommended. It should be designed to capture all flow from the bridge deck without consideration of the flow captured by the scuppers. The hydraulic design procedure for end drains is presented in Appendix C

The Bridge Standards for this end drain are available at http://apps.roads.maryland.gov/businesswithsha/bizstdsspecs/obd/bridgestandards/Bridge_Standards/16_Miscellaneous2725/PDF/16_Miscellaneous.pdf

12.4 References

1. Design of Bridge Deck Drainage, Hydraulic Engineering Circular No. 21, Publication No. FHWASA-92-010, Federal Highway Administration, May, 1993

2. Maryland SHA Office of Structures Structural Standards Manual

3. Model Drainage Manual, American Association of State Transportation Officials, 1991.

4. Drainage of Highway Pavements, Hydraulic Engineering Circular No. 12, FHWA-TS-84-202, Federal Highway Administration, March, 1984.

5. Drainage of Highway Pavements, unpublished computer software prepared for the Federal Highway Administration by Fred Chang and Frank Johnson, 1980

6. Maryland Pavement and Deck Drainage Program – MPADD Program, In-house software used by the Office of Structures to design bridge deck drainage systems. (See the Software Chapter of the OOS Manual for Hydrologic and Hydraulic Design

APPENDIX 12-A
DESIGN PROCEDURE USING COMPUTER SOFTWARE

The Maryland SHA has developed a computer program entitled "Maryland Pavement and Deck Drainage Program" (MPADD) for use in evaluating the need for and in selecting the type and spacing of bridge deck scuppers (See reference 6). This program is contained in the software chapter of the OOS Manual for Hydrologic and Hydraulic Design. All information needed to run the program is contained within the help screens of the program itself. In addition, a User's Guide is included on the disk in the file entitled "MPADD.DOC". The MPADD Program is based on the design procedures recommended by the Federal Highway Administration in References 1 and 4.

PLEASE NOTE THAT THE MPADD PROGRAM IS NOT RECOMMENDED FOR HIGHWAY PAVEMENT DRAINAGE DESIGN AT THIS TIME.

APPENDIX 12-B
LIST OF DESIGN STANDARDS
(See Section 12.2.1)

INDEX

<u>List of Standards</u>

Type I Bridge Scupper-Sheets 1-4

Type IA Bridge Scupper-Sheets 1-4

Type II Bridge Scupper -Sheets 1-2

Type III Bridge Scupper-Sheets 1-2

Type IV Bridge Scupper-Sheets 1-4

Type V Bridge Scupper-Sheets 1-4

Type VI Bridge Scupper-Sheets 1-4

Drainage Inlet at End -Sheets 1-2
of Bridge Structure
(Open Approach Roadway)

Splash Blocks for-Sheet 1
Scupper Outlets

Scupper Downspout Support Bracket - for Short Cast Iron Scupper Downspout	Sheet 1-1
Scupper Downspout Support Bracket - for Long Cast Iron Scupper Downspout	Sheet 1-2

APPENDIX 12-C
DESIGN OF BRIDGE DECK END DRAINS

Bridge deck end drains are recommended for use on all bridges in accordance with the criteria set forth in Section 12.4. The standard end drain, M (0.03)-80-123, will accommodate runoff from bridge decks with an area of 47,000 square feet or less. For larger deck areas, the design charts in the FHWA Manual HEC-12 (Reference 4) can be used to evaluate the hydraulic performance of the end drain.

For locations where a drain other than the standard end drain is used, its performance should be evaluated using the procedures set forth in Reference 4. The computer program described in Appendix A can be used to make this analysis for a number of different types of installations.

APPENDIX 12-D
DISCUSSION OF DESIGN CRITERIA IN TABLE 1

The design values in Table 1 have been selected for the purpose of balancing the following objectives:

•Minimize or eliminate the need for bridge deck scuppers, where feasible.

•Provide a safe, efficient bridge deck drainage system.

These objectives are discussed below.

1. Minimize or eliminate the need for bridge deck scuppers

Bridge scuppers are high maintenance items because of their limited capacity to pass trash discarded from vehicles and sand deposited during winter maintenance activities. These materials cause scuppers to clog so that they no longer intercept gutter flow. Because of the added resistance to flow caused by a clogged scupper, the spread of the width of the gutter flow may increase onto the shoulder and driving lane. For these and other reasons regarding the structural design of the bridge, it is desirable to eliminate or minimize the use of scuppers on bridges. For relatively short bridges, it is feasible to eliminate scuppers entirely and still maintain the gutter spread within the limits of the criteria in Table 1. For longer bridges, especially those on flat grades of 1% or less, it will normally be necessary to provide scuppers in order to limit the gutter spread to tolerable limits.

2. Provide a safe, efficient bridge deck drainage system

Studies for the Federal Highway Administration (Reference 1) have reported that there is a rainfall intensity that windshield wipers cannot remove or that creates sufficient vision reduction so that a driver cannot see within a safe stopping distance, this intensity is estimated to be in the range of 4 to 5.6 inches per hour. Since a value of 6 inches per hour has been selected for the criteria in Table 1, it is expected that prudent drivers will pull over and stop or travel at a lower rate of speed for the combination of the proposed design conditions of rainfall intensity and spread.

The rainfall actually deposited on the bridge deck is expected to be less than that calculated from a rate of 6 inches per hour due to the disturbance to the natural wind patterns created by the bridge and the turbulence created by the vehicles on the bridge.

Bridge deck areas are small and well drained; consequently, the period of time that gutter flow will have a width equal to the design spread for most bridges will be extremely short (5 minutes or less).
Since almost all bridge decks are designed to avoid a sump condition, ponding of water on the deck area should not occur. In the rare event that such a design must be built, the design is to be

checked to ensure that ponding depths remain small in accordance with the criteria in Table 1. Bridges with shoulder widths of 7 feet or more are to be designed to carry the design gutter flow (Table 1) within the limits of the shoulder.

It will not be feasible, in most cases, to accommodate the design gutter flow within the shoulder limits for shoulder widths of 4 feet or less. Since it is desirable to minimize the spread of the gutter flow onto the driving lane for high volume high speed highways, an assessment should be made of the feasibility of reducing the design spread values in Table 1 for the following bridges:

•Long bridges on the National Highway System

•Bridges carrying four or more traffic lanes.

The Engineer must exercise judgment in making such an assessment to provide for a design that balances the two objectives listed above. The following factors are among those which may permit a reduction in the spread onto the traveled way:

•Short bridges

•Bridges on grades exceeding 1%

•Bridges where it is appropriate to use Scupper Types II or III to minimize the spread of the gutter flow.

The following factors should also be considered in evaluating the need to reduce the spread of gutter flow onto the traveled way:

•It is desirable to eliminate or at least minimize the use of scuppers, where feasible.

•A two or three foot encroachment of gutter flow onto the traveled lane provides the driver with about 9 or 10 feet of remaining pavement on which to drive without getting a wheel into the gutter flow. Information available from AASHTO (Reference 3) indicates that rainfall surface runoff (sheet flow) at the edge of a 24 foot wide bridge deck (two driving lanes) as computed for the SHA design criteria would be 25% of the depth of the gutter flow at the edge of the driving lane for a two foot spread onto the driving lane (0.01 ft and 0.04 ft respectively). Under these conditions of having a sheet of water across the entire pavement, a prudent driver would be expected to reduce speed to avoid hydroplaning on the bridge deck and approach road pavement.