11.6 Pavement Drainage

11.6.1 Introduction

Highway storm drainage facilities collect stormwater runoff and convey it through the roadway right-of-way in a manner which adequately drains the roadway and minimizes the potential for flooding and erosion to properties adjacent to the right-of-way. Storm drainage facilities consist of curbs, gutters, storm drains, channels and culverts. The placement and hydraulic capacities of storm drainage facilities should be designed to take into consideration damage to adjacent property and to secure as low a degree of risk of traffic interruption by flooding as is consistent with the importance of the road, the design traffic service requirements and available funds.

Following are the procedures which should be followed for storm drain design and analysis. For a general discussion of policies and guidelines for storm drainage, the designer is referred to the publication, "A Policy on Geometric Design of Highways and Streets," published by the American Association of State Highway and Transportation Officials. For more design and engineering guidance, refer to AASHTO, Highway Drainage Guidelines, Volume 9, or the FHWA publications HEC 12 and HEC 21.

Roadway features considered during gutter, inlet and pavement drainage calculations include:

- longitudinal and cross slopes
- curb and gutter sections
- roadside and median ditches
- bridge decks

The pavement width, cross slope and profile control the time it takes for storm water to drain to the gutter section. The gutter cross section and longitudinal slope control the quantity of flow which can be carried in the gutter section.

11.6.2 Longitudinal Slope

A minimum longitudinal gradient is more important for a curbed pavement, since it is susceptible to stormwater spread. Flat gradients on uncurbed pavements can also lead to a spread problem if vegetation is allowed to build up along the pavement edge.

Gutter grades should not be less than 0.5 percent. Minimum grades can be maintained in very flat terrain by use of a sawtooth profile.

11.6.3 Cross Slope

The ConnDOT "Highway Design Manual" establishes the cross slopes for highways. Median areas should not be drained across traveled lanes. A careful check should be made of designs to minimize the number and length of flat pavement sections in cross slope transition areas.

Shoulders should generally be sloped to drain away from the pavement.

11.6.4 Roadside And Median Channels

Roadside channels are commonly used with uncurbed roadway sections to convey runoff from the highway pavement and from areas which drain toward the highway. Due to right-of-way limitations, roadside channels cannot be used on most urban arterials. They can be used in cut sections, depressed sections, and other locations where sufficient right-of-way is available and driveways or intersections are infrequent.

Curbed highway sections are relatively inefficient at conveying water, and the area tributary to the gutter section should be kept to a minimum to reduce the hazard from water on the pavement. Where practicable, the flow from major areas draining toward curbed highway pavements should be intercepted by channels as appropriate.

It is preferable to slope median areas and inside shoulders to a center swale, to prevent drainage from the median area running across the pavement. This is particularly important for high-speed facilities, and for facilities with more than two lanes of traffic in each direction.

11.6.5 Bridge Decks

Drainage of bridge decks is similar to other curbed roadway sections. It is often less efficient, since parapets collect large amounts of debris, and drainage inlets have a higher potential for clogging by debris, therefore the designer should consider the type of inlet and piping system being proposed. The frequent gutter flow from roadways should be intercepted before it reaches a bridge. In many cases, deck drainage must be carried several spans to the bridge end for disposal.

Zero gradients and sag vertical curves should be avoided on bridges. The minimum desirable longitudinal slope for bridge deck drainage should be 0.5 percent. When bridges are placed at a vertical curve and the longitudinal slope is less than 0.5 percent, the gutter spread should be checked to ensure a safe, reasonable design. Inlets are the recommended method of deck drainage. Inlets should not be outletted over embankments, slope pavement, slope protection, navigation channels, driving lanes, or railroad tracks. Runoff collected and transported to the end of the bridge should generally be collected by inlets and down drains.

Grates for bridge inlets should be the same as for catch basins. If they are different then a separate analysis may be required using HEC 12 or HEC 21 to determine their interception characteristics including splashover.

Short, continuous span bridges, particularly over-passes, may be built without inlets. The water from the bridge roadway should be intercepted by an inlet beyond the end of the bridge structure. Some type of bridge end drainage must be provided at all bridges.

11.6.6 Hydroplaning

NCHRP research project 1-29, "Improved Surface Drainage of Pavements," suggests that hydroplaning conditions can develop for relatively low vehicle speeds and at low rainfall intensities for storms that frequently occur each year. Analysis methods developed through this research effort provide guidance in identifying potential hydroplaning conditions. Unfortunately, it is virtually impossible to prevent water from exceeding a depth that would be identified through this analysis procedure as a potential hydroplaning condition for wide pavement during high intensity rainfall and under some relationship of the primary controlling factors of:

- vehicle speed
- tire conditions (pressure and tire tread)
- pavement type
- roadway geometrics (pavement width, cross slope, grade)
- pavement conditions (rutting, depressions, roughness)

Speed appears as a significant factor in the occurrence of hydroplaning, therefore, it is considered to be the driver's responsibility to exercise prudence and caution when driving during wet conditions (Highway Drainage Guidelines, Volume 9, Storm Drain Systems). In many respects hydroplaning conditions are analogous to ice or snow on the roadway.

Designers do not have control over all of the factors involved in hydroplaning. However, many remedial measures can be included in development of a project to reduce hydroplaning potential. The following is provided as guidance for the designer as practical measures to consider in accordance with the AASHTO Policy on Geometric Design of Highways:

Pavement Sheet Flow

- maximize transverse slope
- maximize pavement roughness

Gutter Flow

- limit street spread (adequate inlet spacing)
- maximize interception of gutter flow on the high side of superelevation transitions

Sag Areas

- limit pond duration and depth

Overtopping

- limit depth and duration of overtopping flow

In the event that suitable measures cannot be implemented to address an area of high potential for hydroplaning, or an identified existing problem area, consideration should be given to installing advance warning signs.

11.6.7 Underdrains

In certain areas ground water can be a significant problem as it attacks foundations, substructures, subgrades and other aspects of highway components. In most soils where ground water is a problem, a system of underdrains, installed for the removal of excess moisture, can be a very useful feature in the overall roadway design. Underdrains may take the form of networks of perforated (or otherwise permeable) pipe, French drains, or collector fields. Where such appurtenances are needed, the additional expense in their installation is usually fully justified in terms of future savings in roadway and structure maintenance costs.

Percolation rates for ground water may be obtained from Natural Resource Conservation Service offices, measured, or simply estimated. Collector pipe sizes and networks may then be established for the removal of that water. French drains can be very useful where the unwanted ground water percolation rates are relatively high. Collector fields may be useful where reasonable outfalls for ground water are not available. All of the above appurtenances may be enhanced by the use of some type of geotextile filter material.