Drainage in Concrete Pavement Structures

Proper drainage is crucial to the long-term performance of concrete pavement structures that will be exposed to moisture, but current recommendations vary from recent practice.

Drainage considerations are important in the proper design and construction of a roadbed or foundation for a concrete pavement structure. However, drainability and long-term durability of a subbase must be balanced when attempting to optimize performance of the overall concrete pavement structure. To design an appropriate roadbed system, pavement designers must first understand the sources of moisture and several of the drainage systems available to them. Where permeable (open-graded) subbases previously had been used with an edge drain system, it is now recommended that a daylighted free-draining subbase be used due to various problems encountered with permeable subbases. This publication briefly discusses these topics, but more more details are available in ACPA's **EB204P**, "*Subgrades and Subbases for Concrete Pavements.*"

Drainage as a Single Design Element

It is important not to build a roaded system that holds water underneath the pavement slabs because this can lead to poor field performance. It is equally important not to over design the permeability of a subbase layer. Overzealous engineering of a permeable subbase will most likely lead to a foundation that does not provide the requisite stability for long-term pavement performance. Where stability has been sacrificed for drainage, concrete pavements have performed poorly and have experienced unacceptable numbers of faulted joints and cracked slabs within a relatively short period (< 10 years).

Drainage also must be put into the proper perspective as just one element of many needed to optimize performance of a concrete pavement structure. Uniform support is the primary driver of good performance of a concrete pavement structure, making uniformity of the subgrade and/or subbase more important than stiffness, strength, or thickness of these layers.

In many respects, drainage should be addressed in preparing a subgrade and shaping the roadway template with ditches and adequate horizontal and vertical sloping; however, consideration of drainage in subbase layers is also important.

Sources of Moisture

The significance of the influence of moisture on the performance of pavements cannot be ignored. However, an engineer must also recognize that even though there may be some controls possible, drainage systems such as subsurface edge drains, edge ditches, and culverts are never an absolute control for preventing moisture from gaining access to the pavement. Instead, drainage systems are tools for minimizing moisture variations in the confines of a pavement structure to within reasonable limits. Extremes in moisture variation contribute more to pavement distresses and problems than the presence of moisture alone.

The sources of moisture to a pavement structure are shown in Figure 1. The water table beneath a pavement will rise and fall due to seasonal and annual differences in precipitation (i.e., number 5 is dependent on number 1). A higher water table will result in a greater driving force for capillary suction and vapor movement near the subgrade (i.e., numbers 2 and 4 are dependent on number 5). Thus, the design of the pavement structure must assume the highest water table expected during the life of the pavement, because that is when the subgrade and subbase will contain the most moisture and be the weakest. The highest water table during the life of a pavement should be expected around the most major precipitation event, making runoff from areas of higher elevation most detrimental to a local water table (so number 3 is related to number 1).

In an effort to minimize moisture levels in the pavement structure, roadway engineers often concentrate on sources of moisture easiest to isolate, which are numbers 1, 3, and 5. Often, highways are elevated with respect to their surroundings, a configuration that forces water to run downhill to ditches (mitigating numbers 1 and 3) while, at the same time, increasing the distance between the pavement structure and the water table (mitigating number 5 and, in turn, minimizing numbers 2 and 4). Since an elevated roadway typically is not possible for street or road applications, edge drains and sewers are used to collect any surface runoff (mitigating numbers 1, 3, and 5).

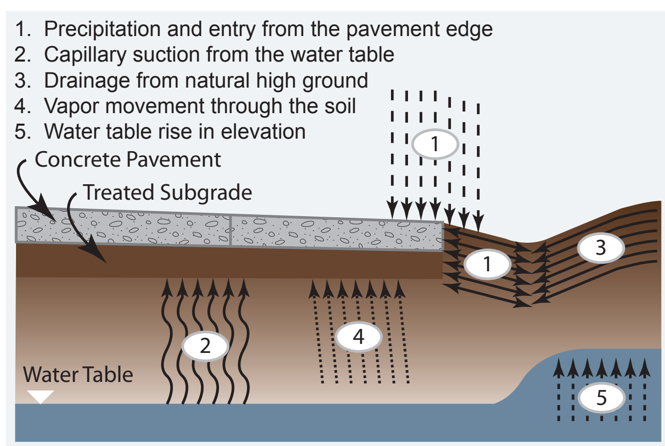

Figure 1. Sources of moisture to a typical concrete pavement structure.

Free-Draining Subbases

When it is a requirement that a subbase drain water from a concrete pavement structure, free-draining subbases often are specified. Free-draining subbases are preferred over permeable (open-graded) subbases because of their more durable, more stable nature. ACPA's recommended target permeability (k) for free-draining subbase materials is between 50 and 150 ft/day (15 and 46 m/day) in laboratory tests. Materials providing as much as 350 ft/day (107 m/day) in laboratory tests also may provide adequate long-term stability for a pavement foundation.

Older recommendations for unstabilized permeable subbases suggest a target permeability in the range of 500 to 3,000 ft/day (150 to 315 m/day) in laboratory tests. However, material with this high degree of permeability (above approximately 350 ft/day (107 m/day)) also has a high degree of void space, which decreases stability. Field reports from contractors indicate difficulty in constructing smooth pavements on these open-graded materials. Trucks, paving machines, and other heavy equipment displace unstabilized materials that are open in their gradation (consists of mostly one aggregate size). Contractors have used the description "it's like paving on marbles" to describe paving on a permeable subbase.

Though free-draining subbases drain slower than permeable subbases (because of the increased fines content) they drain more quickly than conventional, dense-graded subbases and will easily be able to drain away any amount of water that can usually be expected to be trapped under the pavement. Stability is enhanced by the use of aggregates that are angular and aggregates that do not degrade under repeated loading. Recycled concrete aggregate (either from an existing concrete pavement or another source) perform well in free-draining subbases; however, it should be noted that recycled aggregate subbase may have a lower permeability, strength, and resistance to particle degradation than limestone or gravel subbases.

Edge Drainage Systems

An edge drainage system typically consist of a collector pipe and outlet system with redundant outlets (Figure 2), or a daylighted subbase system (Figure 3) where the subbase extends and carries water to the side ditches. The common application for edge drainage systems is for high volume roadway or highway projects, such as major state roads and interstates. Even then, their use is not always required or recommended.

The use of edge drainage systems for low volume applications such as rural roads, county roads, etc. is not recommended. These types of pavements will provide excellent service with fundamental roadbed considerations, such as appropriate ditch and elevation design. Additionally, the loading on these

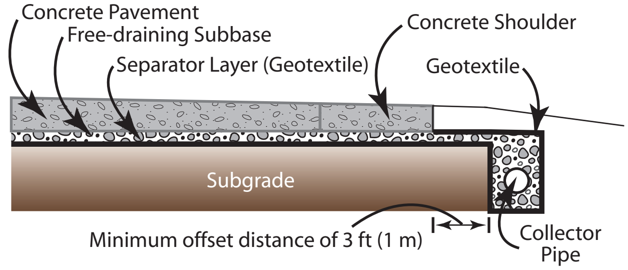

Figure 2. Detail for typical edge drain piping.

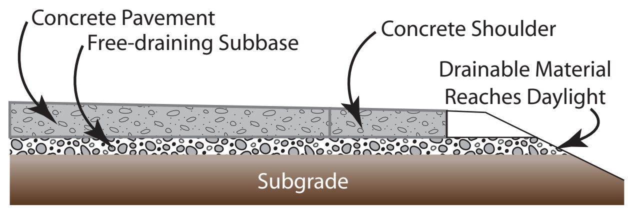

Figure 3. Detail for a typical daylighted subbase.

pavements is likely to be such that pumping is not a concern. In these situations, a dense-graded unstabilized (granular) subbase or construction on appropriately prepared subgrade will suffice.

Where edge drains are used, the hydraulic capacity of longitudinal edge drains and outlet laterals must be high enough to drain the free water within the pavement structure within 2 hours of rain cessation. The maintenance of edge drain systems is crucial to the long-term performance of such systems.

Though often disregarded in the past due to the mindset that overgrowth along the ditch line would clog the system, daylighted subbases have become preferred to edge drain systems because many DOT's have found that daylighted subbases perform better than the edge drain systems they can not afford to maintain.

Under Drainage Systems

Where elevating the pavement grade is impractical, underdrains may be used to lower groundwater tables. The drains must be placed so that the ground water level is lowered beyond the subgrade soil's capillary range since capillary water cannot be effectively drained. Where wet spots are encountered in the grade, due to seepage through a permeable stratum underlain by an impervious material, intercepting drains may be considered.

The backfill placed around and above pipe underdrains should be open-graded to permit rapid flow into the slotted pipe. Underdrain trenches should be wrapped with a geotextile fabric to prevent infiltration and clogging by adjacent soils.

References

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