Permeable Subbases: Reasons to Avoid Their Use

The inclusion of permeable (open-graded) subbases in concrete pavement structures is no longer recommended for many of the reasons discussed herein.

The use of highly open-graded and permeable subbase layers (stabilized or unstabilized) with a permeability coefficient of more than about 350 ft/day (107 m/day) in laboratory tests are no longer recommended as a design element in concrete pavement structures. This conclusion was reached through experiences in the field and it is supported by a national performance evaluation study. Furthermore, concrete pavement structures that include permeable systems can cost as much as twenty-five percent more than conventional concrete pavement structures, substantially increasing project costs without a proportionate increase in performance. This publication details these and several other reasons to avoid the use of permeable subbases. More on the topic of permeable subbases is available in ACPA's **EB204P**, "*Subgrades and Subbases for Concrete Pavements*."

Permeable Subbases Background

Permeable subbases, also known as "drainable" or "open-graded" subbases, became a very popular design element for concrete highway pavements in the 1990's. These subbase are generally characterized as a crushed aggregate (often stabilized with cement or asphalt) with a reduced amount of fines to increase the permeability of the subbase to greater than about 350 ft/day (107 m/day) in laboratory tests. Despite the intuitive advantage of an ability of the permeable subbase to remove excess water from the pavement rapidly, permeable subbases have had a problematic history.

Permeable subbases are no longer considered a cost effective design element for concrete pavement. This conclusion was reached through experiences with poorly performing pavements built on permeable subbase layers. It is further supported by several performance evaluation studies that concluded that these systems do not have a significant positive influence on concrete pavement performance for many design conditions. This publications discusses the mechanism behind several of the common problems with permeable subbases, as well as results from the most comprehensive review of the performance of concrete pavement structures that included permeable subbases and a relative cost comparison of various subbase alternatives.

Loss of Support Due to Breakdown of the Aggregate

Starting in 1996, cracks started to appear in pavements placed on some unstabilized permeable subbases. The cracking was determined to be due to break down of subbase material at the joints, which created a non-uniform support condition between the ends of the slab (joints) and the center of the slab. The mechanism for the deterioration is crushing of the aggregate in the subbase below pavement joints because of high deflections and high point-to-point contact pressure between the particles of the unstabilized permeable subbase (Figure 1).

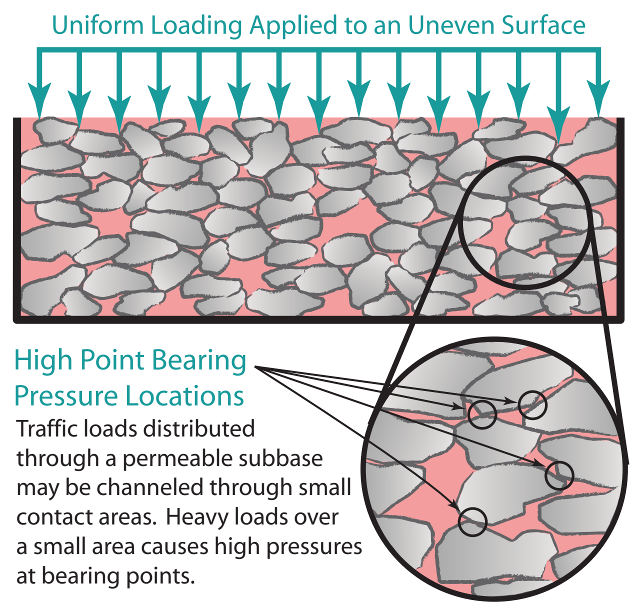

Figure 1. Schematic of unstabilized permeable subbase and potential for high bearing stress.

When this occurs, the crushed aggregate particles fall into the open void structure of the permeable subbase and, after enough repetitions, the subbase at the joint consolidates, leaving the ends of the slab unsupported.

Loss of Support Due to Infiltration of the Subgrade into the Subbase

Loss of support due to infiltration of the subgrade into the subbase occurs because the subbase under the entire slab consolidates, causing the entire slab to settle (Figure 2). The most common reason for this is having a poor or no filter-separator layer to prevent the migration of fines (minus No. 200 (75 µm) sieve material) into the permeable subbase from the subgrade. When this infiltration occurs, the pavement may undergo a secondary consolidation to a degree that matches the infiltration. Though this can occur with both unstabilized and stabilized permeable subbases, stabilized subbases can worsen the effect by working themselves into the subgrade material as the pavement system expands and contracts due to temperature changes throughout the year.

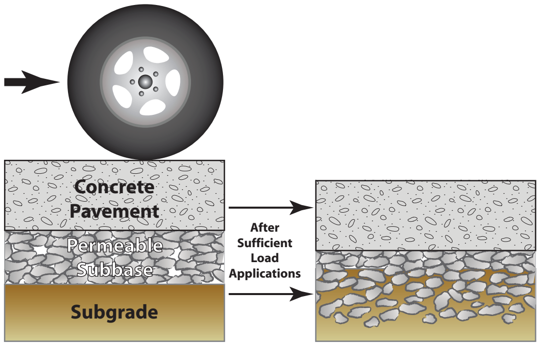

Figure 2. Infiltration of the subgrade into the subbase due to a poor performing, or lack of a, filter-separator layer. Note the infiltration and resultant settlement of the pavement.

Early Age Cracking Due to Penetration of Mortar from the Concrete Pavement into the Subbase

Early age cracking due to penetration of mortar from the concrete pavement into the subbase is another problem that can occur on permeable subbases. Because of the openness of the permeable subbase structure, mortar works its way into the voids during plavement as the concrete is vibrated and consolidated. This penetration into the subbase restricts slab movement, increasing the risk of both early-age and long-term cracking in the pavement.

Instability as a Construction Platform

Subbase material stability is another important consideration. Dense-graded or free-draining granular materials and materials stabilized with cement or asphalt create firm support for construction equipment. Unstabilized permeable layers, however, have caused some placement problems.

The hydraulic systems that control a slipform paving machine's profile pan cannot effectively adjust to significant variations in the machine's vertical position caused by settlement of an unstable subbase or track line. An unstable track line causes the profile pan to continually attempt to adjust its position relative to the machine's frame. If too abrupt or frequent, these types of mechanical adjustments are known to cause bumps or dips in the pavement surface.

Unstabilized layers with high permeability coefficients generally do not have the in-place stability necessary to enable contractors to build consistently smooth surfaces. Also, agencies must consider whether specifying an unstabilized permeable subbase will limit the option to haul concrete to the paving site on the subbase due to the high potential of rutting of the surface.

Overall Field Performance

The most comprehensive study ever conducted of the performance of permeable subbases and concrete pavement drainage systems concluded the following:

- For properly designed, doweled, jointed concrete pavements, joint faulting in general is fairly low and a permeable subbase has a relatively small effect on reducing joint faulting further. Dowel bars greatly minimize differential deflections across joints, thus reducing the potential for pumping and erosion.
- For non-doweled, jointed concrete pavements, joint faulting in general is much higher and a permeable subbase has a significant effect in reducing joint faulting. However, the permeable subbase must be well designed or it can become contaminated by fines, allowing faulting to develop.

Cost Effectiveness

The final consideration is the cost of permeable subbases versus the incremental improvement in pavement performance. Figure 3 shows the relative cost comparisons for different types of subbases that are used under concrete pavements. On average, unstabilized permeable subbases add approximately 15% to the cost of concrete pavement relative to a traditional dense-graded unstabilized subbase. Other studies estimate the cost differential at over 30%. A cost benefit analysis shows that permeable subbases would need to extend pavement life between 8 and 15 years in a life cycle cost analysis to be considered cost effective. Experience over the past two decades indicates that permeable subbases do not provide that level of impact, and the positive impacts of drainage can be provided more effectively with a free-draining subbase layer. Therefore, installation of a permeable subbase design carries with it a substantial risk that the system will not function properly over the life of the pavement and even it if does, it will not extend pavement life enough to be considered cost effective, negating any other potential benefits.

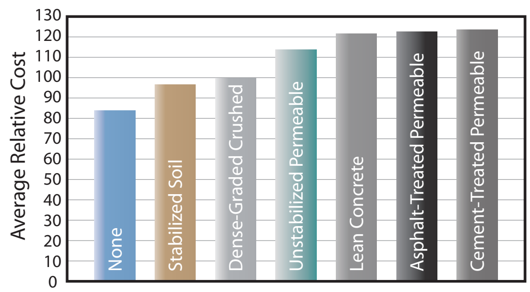

Figure 3. Effects subbase type have on total construction cost, with dense-graded crushed aggregate subbase assigned the relative cost of 100 percent.

References

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