Uniform Support in Concrete Pavement Structures

Due to the high level of strength provided by concrete pavements, uniformity trumps strength for subgrades and subbases.

The primary objective for building a roadbed or foundation for concrete pavement is to obtain a condition of uniform support for the pavement that will prevail throughout its service life. This mindset is somewhat contrary to the traditional thought that thickness and/or strength are the key objectives for building a long-lasting roadbed. The reasoning for this change in mindset is a better understanding of how concrete pavements distribute loads and what this means for the subgrades and/or subbases below them. This publication details how uniformity is more important than strength for subgrades and subbases used in concrete pavement structures, what this means in regards to design and construction, how to obtain a uniform support condition, and the importance of long-lasting uniformity. More on these topics is available in ACPA's **EB204P**, "*Subgrades and Subbases for Concrete Pavements*."

Strength versus Uniformity

Paving concrete typically has a specified 28-day flexural strength ranging from 550 to 750 psi (3.8 to 5.2 MPa), or greater, and a modulus of elasticity ranging from 4 to 6 million psi (28,000 to 41,000 MPa), helping provide a high degree of rigidity. This rigidity enables concrete pavements to distribute loads over large areas of the supporting layers (Figure 1), resulting in very low pressures and deflections in those layers.

However, while a uniform, good-quality, and properly-compacted subgrade and/or subbase will result in good performance of the pavement, it is not necessarily true that specifying a stronger subgrade and/or subbase will improve performance; most of the structural capacity of a concrete pavement structure is supplied by the concrete slab and not by the foundation (subgrade and/or subbase).

The magnitude of the increase in foundation support (often quantified as a k-value) from the inclusion of a subbase in the design of the pavement system depends on the subbase type and material. Regardless, normal variations in the field from an estimated composite k-value will not appreciably affect the design thickness of concrete pavement within typical k-value ranges, as shown in Figure 2. Thus, it is not economical to use an over-designed subbase system for the purpose of increasing the composite k-value.

The importance of uniformity of the subgrade and/or subbase is a much less intuitive idea and can best be explained by anomalies in pavement performance in the field. Performance surveys have been conducted over many miles of old concrete pavements that were constructed without proper subgrade compaction control and without subbases. Where the subgrade was naturally uniform, many of these old pavements are still in excellent condition. Distress is limited to cut-fill transitions and other locations where there are abrupt changes in subgrade materials and moisture conditions. Field tests show that low-strength but uniformly constructed soils performed better than stronger, non-uniform soils.

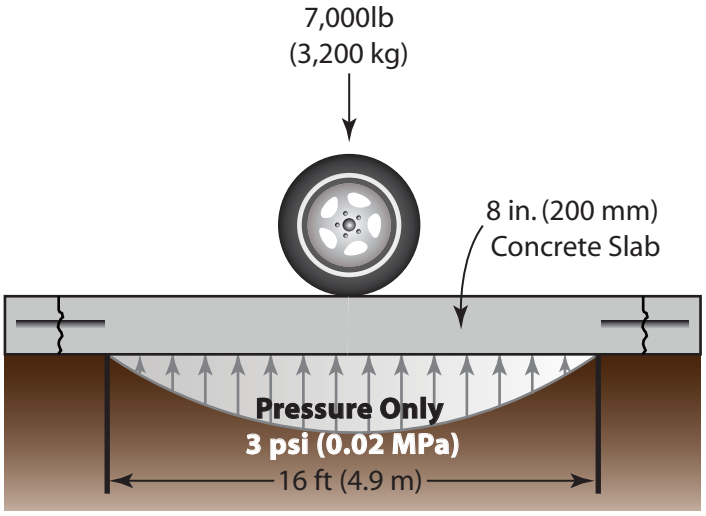

Figure 1. The rigidity of concrete helps a concrete pavement distribute wheel loads over large areas, keeping subbase/subgrade pressures low.

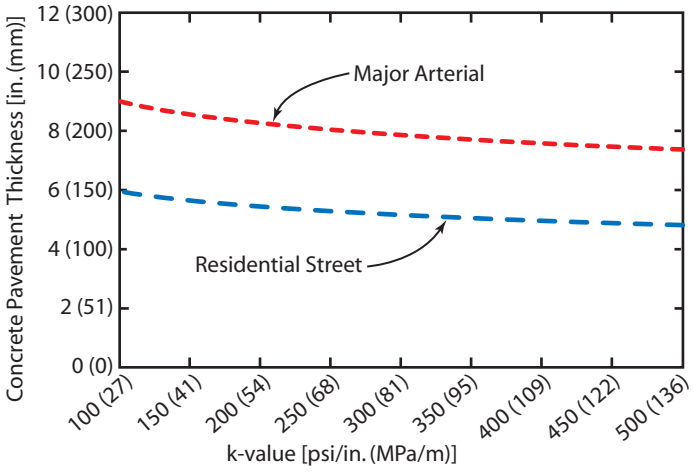

Figure 2. Sensitivity of k-value for a residential street and a major arterial. Assumptions for the residential street include: 12 ft (3.7 m) joint spacing, no dowel bars, 20 year design life, ADTT of 3, and a flexural strength of 600 psi (4.1 MPa). Assumptions for the major arterial include: 15 ft (4.6 m) joint spacing, 1.25 in. (32 mm) diameter dowel bars, 20 year design life, ADTT of 10,000, and a flexural strength of 600 psi (4.1 MPa).

Design and Construction Implications

Of all subgrade/subbase design characteristics, uniform support (support that is free from abrupt changes in character of the material) is of utmost importance. Providing uniformity is also one of the largest challenges in the design and construction of any pavement structure. Because every foundation design starts with the in-situ natural soils, the challenge always begins with the subgrade. In practical terms, the subgrade must, at least, provide a stable working platform for constructing the subsequent layers of the pavement structure, as any subbase must also have the in-place stability that is necessary for contractors to build consistently smooth pavements. Also, agencies must consider if specifying an unstabilized permeable subbase will limit the option to haul concrete to the paving site due to the high potential of rutting of the surface.

Perfect subgrade materials—those that would economically meet all design criteria—are rarely encountered in nature. This is particularly true of materials that would be used in heavily trafficked pavement. For this reason, a subbase layer provides an added measure of assurance that both uniform support and a non-erodible layer are provided for the concrete pavement slabs.

Obtaining Uniform Support

To obtain a subgrade that provides uniform support, the four major causes of non-uniformity must be addressed:

- Expansive soils.
- Frost-susceptible soils (frost heave).
- Pumping (from erodible layers underneath the pavement slabs).
- Wet soils.

Effective control of expansive soils and frost heave is most economically achieved through appropriate subgrade preparation techniques; the inclusion of thick subbase layers in an attempt to control expansive soils and frost heave is expensive and not as effective as proper subgrade preparation. In cases where the potential for pumping exists, a subbase layer is always required.

Where subgrade conditions are not reasonably uniform, correction is most economically and effectively achieved by selective grading, cross-hauling, mixing at soil-type and cut/fill transitions, and moisture-density control of subgrade compaction. No matter which techniques are applied, particular attention is necessary to control expansive soils and excessive differential frost heave.

A subbase layer also helps provide uniform support, but its primary purpose is to prevent pumping or erosion of the subgrade. Whether or not a subbase is used in a concrete pavement structure, proper subgrade preparation is the best means of obtaining uniform support.

Selection of an appropriate means to mitigate expansive soils, frost-susceptible soils and pumping is heavily dependent on the in-situ subgrade soil conditions, extent of improvement necessary, environmental concerns and construction requirements [MNDOT 2003]. Of particular concern, due to its difficulty to estimate prior to construction, is in-situ moisture content of the soil. If wet soils are encountered during construction, mitigation methods might not be as effective as planned.

Long-Lasting Uniformity

Sometimes, even when a uniform roadbed is provided during construction, this uniform support condition might not prevail throughout the entire service life of the pavement. Any time a non-uniform support condition is created for a concrete pavement structure, the risk of premature failures is increased.

One subbase type, in particular, seems to exhibit particularly poor performance in the field. Permeable (open-graded) subbases, subbases 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, do not appear to have the requisite stability necessary to provide long-lasting uniformity. In an attempt to increase permeability, the fines portion of the aggregate gradation is greatly reduced in permeable subbases. This can result in distresses ranging from a loss of support due to infiltration of the subgrade into the subbase to early age cracking due to penetration of mortar from the concrete pavement into the subbase. One of the documented distresses, loss of support due to breakdown of the aggregate, was observed on an asphalt-treated permeable subbase, again illustrating that uniformity is more important than strength because weaker free-draining subbases regularly outperform this particular asphalt-treated permeable subbase.

References

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