must be compacted during construction to a high density. Unstabilized bases under concrete pavements should have a minimum of 100 percent of ASTM D 698 / AASHTO T 99 density. For high heavy traffic projects, density should be at least 105 percent of standard density or 98 to 100 percent of ASTM D 1557 / AASHTO T 180 density.

Achieving Proper Drainage

Poor drainage can lead to a failed pavement. Water trapped within the pavement system can lead to subgrade pumping and reduced subgrade and base support strengths, which result in pavement distresses. A drainable base layer daylighting to side ditches or drained through the use of a subdrain system can reduce the risk of trapped water, but increased permeability can have a direct effect on the material's stability. Drainage should be optimized without sacrificing stability.

Trimming

Unstabilized bases can be trimmed to grade. Cement-stabilized bases should be trimmed with caution, so as not to disturb the base surface.

National Concrete Pavement Technology Center

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This technical summary is based on chapter 7 of the IMCP Manual (Taylor, P.C., et al. 2006. *Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual*, Ames, Iowa, Iowa State University [FHWA HIF-07-004] [www.cptechcenter.org/publications/imcp/]) and was sponsored by the Federal Highway Administration. (References for any citations in this summary are at the end of the chapter.)

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the view of Federal Highway Administration or Iowa State University.

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A summary of chapter 7 (pages 191–202) of the *IMCP Manual* (reference information on page 4)

Preparation for Pavement Construction

This document is one of a set of technical summaries of chapters 1 through 10 of the *Integrated Materials and Construction Practices for Concrete Pavements: A State-of-the-Practice Manual* (IMCP manual). The summaries provide an overview of the manual and introduce its important concepts. To be useful for training, the summaries should be used in conjunction with the manual.

This document summarizes the importance of uniform subgrades and bases for maximizing pavement performance. Also described are problems associated with nonuniform subgrades and techniques for providing an adequate subgrade and base to ensure uniform, stable, adequate support.

Why is Preparation Important for Optimizing Concrete Pavement?

Proper subgrade and base preparation lays the foundation for the entire pavement structure. This support system is critical to the success of the construction process and the service life of a concrete pavement.

Preparing Subgrades

Subgrade is the natural ground, graded and compacted, on which a pavement is built. The subgrade must provide adequate and uniform support for a pavement throughout its design life. Subgrade preparation varies greatly and depends on soil types, environmental conditions, and anticipated traffic loadings during and after construction.

Obtaining Uniform Support

Concrete pavements can perform well on strong and not-so-strong foundations, but it is critical that the foundation be unifrom in order to evenly distribute the stresses of applied loads. Excessively hard or soft spots must be avoided (figure 1). Proof-rolling (driving a heavy, pneumatic-tired vehicle over the prepared grade) can help locate isolated soft areas before an unstabilized base is placed.

Factors that contribute to nonuniform support are as follows:

- Expansive soils.
- Frost action.
- Pumping.

Expansive soils

Shrinking and swelling (expansive) soils can make subgrade support nonuniform enough to distort pavements and impair ride quality. Several conditions can contribute to this problem:

- Expansive soils that are compacted when too dry or allowed to dry out before paving.
- Expansive soils with largely varying moisture contents (which affect subsequent shrinkage and swelling).
- Abrupt changes in soil type and expansive-contractive properties of materials used within a project.

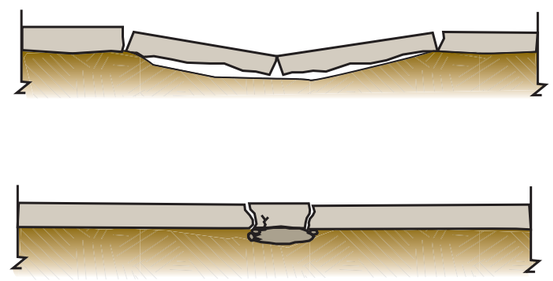

Figure 1. Nonuniform support of concrete slabs can lead to pavement distresses.

Frost action

Frost heave occurs when ice lenses form in the soil, which continue to attract water and expand further (figure 2). When this ice thaws, the subgrade softens, potentially resulting in differential settling of concrete slabs that can cause roughness and/or cracking.

Soils with high silt content are particularly sensitive to frost heave. Frost susceptibility is primarily affected by capillarity and permeability of the soil (figure 3). Clay soils have high capillary action but low permeability. Silty soils have moderate capillary action and are moderately permeable. Sandy soils have low capillary action but are highly permeable.

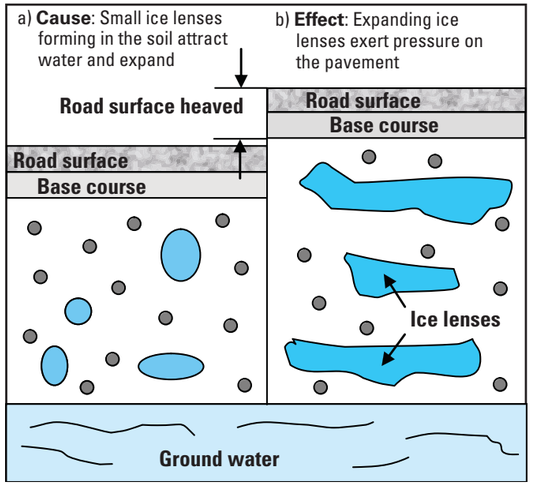

Figure 2. When ice lenses form in the concrete system, the road surface heaves at least as much as the combined lens thickness.

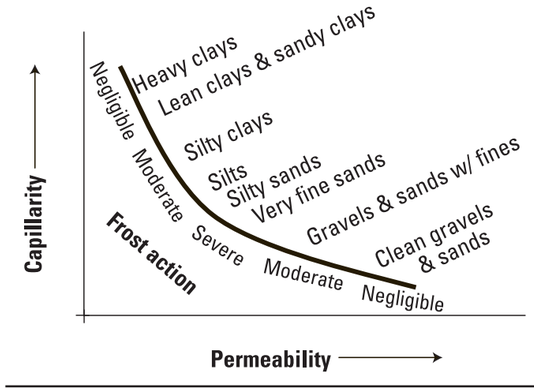

Figure 3. Frost action is influenced by the hydraulic properties of soils.

For frost heave to occur, all three of the following conditions must be present:

- A frost-susceptible soil.
- Freezing temperatures that penetrate the subgrade.
- A supply of water.

Pumping

Pumping is the forced displacement of mud from the subgrade when heavy loads are applied. With continued pumping, the subgrade is eroded and its uniformity destroyed, leading to potential cracking, faulting, and settling.

Controlling any one of these three necessary conditions with good pavement load transfer at the joints will dramatically reduce the potential for pumping damage:

- Susceptible materials beneath the slab that have pore sizes small enough to develop capillary potential and large enough to permit water movement (silty soil and silty clay).
- Free water between the pavement and subgrade/base.
- Large, rapid deflections of the slabs.

Improving Soil Characteristics

Pavement subgrades may need to be improved through the use of soil additives or binders for a number of reasons:

- To improve low-strength soil.
- To reduce swelling/shrinkage potential.
- To improve construction conditions.

Commonly used materials include cement, cement kiln dust, lime, lime kiln dust, and fly ash. Some techniques are more appropriate for soil stabilization (permanent support beneath pavement) and others are more appropriate for soil modification (temporary improvement during construction).

Trimming

Once the subgrade has been compacted to the desired density at the proper moisture level and/or treated to reduce expansion potential, it is trimmed to the proper grades, elevations, and cross-slopes per the design specifications (figure 4).

Preparing Bases

When heavy traffic is expected on a roadway, or when the roadway is built on poor soils, a base layer may be needed on top of the prepared subgrade and immediately below the pavement. The primary goal for a base is achieving balance between two opposing characteristics—stable support and adequate permeability (figure 5).

Selecting Base Type

Bases are categorized as unstabilized (granular) or stabilized (treated). The stabilized bases are sometimes referred to as subbases. The base type used will depend upon site-specific conditions, including soil type and potential traffic loading.

Unstabilized bases

Unstabilized bases are those made of compacted granular materials. This type of base provides a high degree of permeability, allowing potentially damaging water to drain out of the concrete pavement system.

A wide variety of materials and gradings have been used successfully for unstabilized bases. The following guidelines should be used to select appropriate materials:

- Limit amount of fines passing a 75-µm (#200) sieve.
- Avoid soft aggregates with more than 50 percent loss in the Los Angeles abrasion test (ASTM C 131/ AASHTO T 96).

Typical granular base materials include crushed stone, crushed concrete, bank-run sand-gravels, sands, soil-stabilized gravels, and local materials such as sand-shell mixtures and slag.

Figure 4. Autograder references the string line and trims the subgrade material (photo by American Concrete Pavement Association).

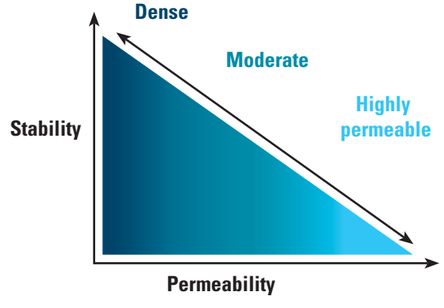

Figure 5. As base permeability increases, stability decreases (and vice versa).

Stabilized bases

Stabilized bases consist of granular materials treated with hydraulic cement or asphalt for a stabilizing effect. The consequent reduction in permeability can also minimize the potential for long-term durability problems.

Stabilized bases can provide the following benefits:

- Stable working platform to expedite construction operations (permits large daily production with minimum downtime for inclement weather).
- Firm support for slipform paver or side forms.
- Construction of smooth pavements due to stable trackline for slipform pavers.
- Prevention of base consolidation under traffic.
- Reduction in pavement deflections from vehicle loadings.
- Improved load transfer at pavement joints.
- Minimized intrusion of hard granular particles into the bottom of pavement joints.
- Increased base surface erosion resistance (compared to unstabilized bases).

Because there is a high potential for bonding of the concrete pavement to a stabilized base, it is important to consider this bond when timing the joint formation. A bond will increase the base's restriction of the concrete slab, increasing the tensile stress on the slab with shrinkage and, thus, increasing the cracking risk.

Achieving a Quality Base

When needed, an effective base can be achieved by following these guidelines:

- Select materials that meet minimum requirements for preventing pumping of subgrade soils.
- Specify controls that will ensure a reasonably constant base grading throughout a project.
- Specify a minimum base depth of 100 mm (4 in.).
- Design a cement- or asphalt-treated or lean concrete base that provides strong and uniform support for the pavement and joints, an all-weather working platform, and firm support for equipment during construction.
- Specify a permeable but stable base for pavements with heavy truck volumes when faulting and/or pumping are a consideration. Permeable and stable bases allow for proper long-term drainage and provide proper support for construction equipment during paving.

Achieving Proper Compaction

To prevent the consolidation of granular materials from heavy traffic once the pavement is in service, the base