R&T UPDATE
Concrete Pavement Research & Technology

Making the Grade

Grade Preparation is Important in Achieving Pavement Performance

A reasonably uniform subgrade or subbase, with no abrupt changes in support, is ideal for any concrete pavement. The actions required to attain uniformity may vary considerably depending on the subgrade soil type, environmental conditions, desired performance, and amount of heavy truck or bus traffic.

In reconstruction projects, achieving uniformity after pavement removal operations will require some effort, particularly in relatively confined work areas such as urban roadway reconstruction. For new alignment or rural reconstruction projects, subgrade preparation and subbase construction are usually easier, as the extra room allows additional working space.

Subgrade Preparation

Regardless of project type, the first step is to examine existing soils and determine potential problems such as swelling (expansive soils) and frost action (heaving).

The key in dealing with expansive soils is to first identify the expansive characteristics of the soil and then determine the most appropriate treatment. Most soils sufficiently expansive to cause pavement distortion are in the AASHTO A-6 or A-7 groups. By the Unified Soil Classification System, soils classified as CH, MH, and OH are considered expansive(1). Soils with plasticity index (PI) greater than 15 or 20 are considered expansive and need to be treated accordingly.

Expansive soils can be addressed by:

1. *Proper Grading* – Put highly expansive soils in the bottom of fills. Surcharge loads greatly reduce the potential for expansion.
2. *Moisture-Density Control* – Compact expansive soils slightly wet of optimum moisture content.
3. *Non-Expansive Cover* – Install a layer of non-expansive cover such as a 4- to 6-inch compacted aggregate subbase.
4. *Chemical Modification* – Use cement, cement kiln dust, fly ash, lime, or other chemical agent to stabilize the soil and reduce swelling potential.

Subgrades that are particularly susceptible to frost action and subsequent heaving are low-plasticity, fine-grained soils with a high percentage of silt-size particles. These soils have pore sizes small enough to develop capillary potential yet large enough to permit travel of water to the frozen zone. Coarser soils could accommodate higher rates of flow but do not have the capillary potential to lift enough moisture for heaving. More cohesive soils have high capillarity but low permeability, and water moves too slowly for growth of thick ice lenses.

Control of frost heave is accomplished by:

1. *Grade and Water Table* – Set grade lines high and ditches low, so that the grade remains 4 to 5 feet (1.2 - 1.5 m) above the bottom of the ditch.
2. *Mixing and Grading* – Place frost-susceptible soils in the bottom of fill sections, and cross-haul and mix marginal soils with better subgrades on the project. Transition and blend soils where the roadway cross-section changes from cut to fill (and vice-versa).
3. *Removing Silt Pockets* – Excavate and backfill these areas with soil similar to surrounding subgrade.
4. *Moisture-Density Control* – Compact frost-susceptible soils slightly wet of optimum moisture content.
5. *Drainage* – If high grades are impractical, install drain tiles to lower the water table.
6. *Frost-Free Layer* – Aggregate subbase layers will help reduce frost heave, although subbase

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thicknesses greater than 8 inches (200 mm) are neither recommended, due to potential for consolidation, nor cost-effective, as they do not dramatically improve pavement performance or load-carrying capacity.

The second step in subgrade preparation is to ensure that the subgrade soils are relatively uniform and compacted to the proper density. Uniformity will usually be achieved during remediation of expansive and frost-susceptible soils. However, if subgrade remediation techniques are not necessary, some cross-hauling or mixing of soils may be required to achieve consistent properties.

Compacting the subgrade surface adequately requires a compactor heavy enough to achieve a minimum of 95 percent of AASHTO T99 (ASTM D 698, or standard proctor) density. For confined areas, smaller equipment may require more time or passes to achieve similar density.

The soil moisture content should be reasonably uniform during compaction; excessively wet or dry spots typically require correction to produce uniformity. For most soils, compaction should be done at moisture contents at or slightly above optimum.

Soft spots in the subgrade often become visible after removing an old pavement. Shattered slabs or heavily faulted joints may be an indication of poor support and should be noted during removal of the existing pavement. For most heavily-trafficked pavements, it is not acceptable to merely place a granular layer over these soft areas; excavation is usually necessary to remove the suspect soils. Ideally, the replacement soil should be of the same type and similar support as in the surrounding subgrade to develop uniform support.

Pay particular attention to sections of the subgrade overlying any utility installations such as sewers, drainage structures, water mains, telecommunication lines, and power conduits. Careless compaction of fill materials in these trenches often causes soft spots in the subgrade. Controlled low-strength material (flowable fill) is an economical alternative for backfill in these areas.

Flowable-fill materials are self-leveling and do not require compaction. The mixtures generally contain portland cement, sand, fly ash and water, and will typically develop 28-day compressive strengths of about 50-100 psi (0.35-0.70 MPa). Correctly proportioned flowable-fill materials provide enough strength to prevent settlement, but are easy to remove using a backhoe or front-end loader if excavation is necessary for utility repair.

Flowable fill should not be used as a base course under the entire pavement, however, because loss of support may result from consolidation under heavy loads and the potential for erosion and mud-pumping of the fines in the material.

Subbase Construction

A subbase is a thin layer of granular material placed on top of the prepared subgrade. Subbases provide uniform support to the pavement and a stable platform for construction equipment. Subbases also help prevent mud-pumping of fine-grained subgrade soils at transverse pavement joints in roads subject to a large volume of unidirectional truck traffic. Parking lots, low-volume roadways, and even some streets that may carry a small amount of heavy vehicles usually do not require a subbase, but one may be specified to ensure uniformity and give the contractor a working platform.

Where used, the granular subbase thickness generally should not exceed 4 to 6 in. (100 to 150 mm). A thicker subbase is not necessary or economical under most conditions. Good dense-graded, granular-subbase materials have a plasticity index (PI) of 6 or less, and contain a maximum of 15 percent fine particles that pass the No. 200 (75 μm) sieve. For stability, granular (unbound or unstabilized aggregate) subbases require compaction to 95 percent of AASHTO T99 (standard proctor or ASTM D 698) density.

Eighteen state agencies use the standard proctor density test for subbase compaction, and the majority (ten) of those require 95 percent of standard proctor density (see Figure 1). Of the nine states that specify modified proctor, the majority (three) also require 95 percent compaction (see Figure 2).[2]

The gradation of aggregate subbases is critical, because open-graded material will not be able to achieve desired density without crushing the material during compaction, thereby changing the gradation in-situ. This is especially true for softer aggregates. In this case, the contractor cannot be held responsible for changes in gradation of the material. Otherwise, increasing the water content over the optimum will make the measurement seem to be

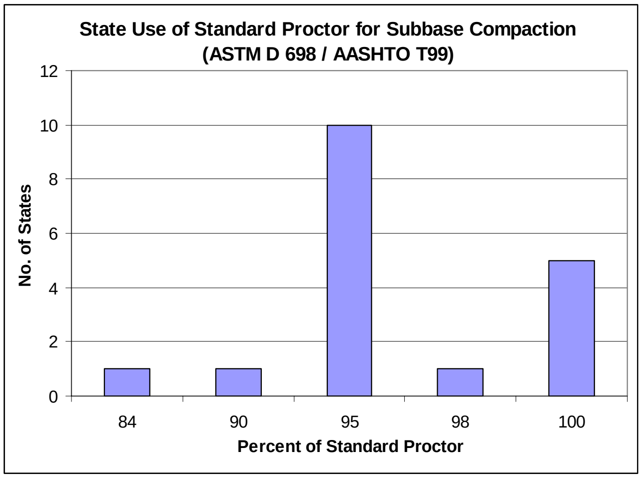

Figure 1. State agency use of standard proctor for subbase compaction and percent compaction required.

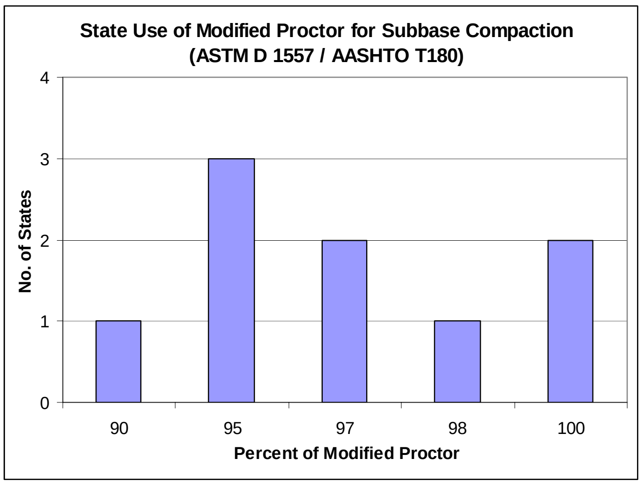

Figure 2. State agency use of modified proctor for subbase compaction and percent compaction required.

at the desired level of density, but the open-graded nature of the material would still exist. The extra water fills the voids that should instead be filled with coarse sandy material. ACPA recommends requiring only 95% of standard proctor density, particularly for subbases that use a stone gradation with a significant amount of voids. A typical aggregate subbase gradation is shown in Table 1.

Permeable subbases with drainage systems are generally unnecessary for urban pavements, because in many cases, the presence of curbs and gutters with inlets to a municipal storm sewer system will adequately remove surface water.

Table 1. Typical Gradation of Aggregate Subbase *

Sieve Size		**Percent Passing**	
mm	in.	**Spec**	**Typical**
25	1	100	100
12.5	½	60-90	85
4.75	#4	35-60	55
600 μm	#30	10-35	20
75 μm	#200	0-15	9

* Note: These gradations are not necessarily recommended.

Permeable subbases are, however, quite popular among state highway departments and airport agencies for draining surface-infiltrated water from concrete pavement structures. These subbases can be untreated, but most are stabilized with portland cement or asphalt. To be effective, a permeable subbase requires a collector pipe and outlet system with redundant outlets to discharge water away from the pavement. An effective alternate to edge drains and outlet pipes is daylighting the drainable subbase, which entails designing and constructing the width of the permeable subbase such that it extends out and allows water to drain directly into the side ditches. The daylighted area must be maintained and graded periodically to prevent clogging.

The key to making drainable bases work is finding the right gradation. The base needs to be open-graded enough so that it allows water to drain from the pavement structure, but if the gradation is too open, the base becomes unstable, even when stabilized with cement or asphalt. Many open-graded drainable bases utilize only one aggregate, such as an AASHTO #57 gradation, along with the binder. Unfortunately, a #57 stone usually has minimal material passing the #8 (2.36 mm) sieve (see Table 2), which often results in a base that is susceptible to consolidation under repeated heavy traffic loadings, causing the pavement to deflect excessively and leading to premature cracking. The surface of the base is also open enough to allow penetration of the concrete mortar during paving, contributing to problems such as uncontrolled cracking soon after construction.

Material used for treated permeable bases should have a gradation that allows a permeability of only 150 to 500 ft/day (45 - 150 m/day). This may mean

Table 2. Typical Gradation of Permeable (Drainable) Subbase Material *

Sieve Size		Percent Passing	
mm	in.	**#57**	**Typical**
37.5	1½	100	100
25	1	95-100	97
19	¾		75
12.5	½	25-60	45
9.5	3/8		25
4.75	#4	0-10	5
2.36	#8	0-5	2

* Note: These gradations are not necessarily recommended.

using another aggregate in combination with a #57 stone, or another gradation altogether.

Uniformity of the subbase is the goal for subbase design and construction, and differential consolidation results in non-uniformity. **ACPA does not recommend sacrificing the stability of the base material for the sake of drainage. Stability should be the primary consideration, and drainage secondary.**

Trimming

The method for trimming or shaping the grade varies by project and typically depends upon the project's size. Typical specifications[3] require:

1. A subgrade surface that does not vary from the design elevation by more than 0.5 in. (12 mm).
2. A granular subbase surface with deviations that do not exceed 0.5 in. (12 mm), longitudinal or transverse, by a 10-ft (3-m) straightedge.

On large projects, contractors may use automatic trimming equipment to shape the subbase or subgrade and deposit any excess material outside the paving area. For fixed-form paving, the automatic trimming machine rides on the forms after they are fastened into place. For slipform paving, the trimming machine references the same stringline(s) used for the slipform paving machine.

On small projects and in confined work zones, it may not be practical to use automatic trimming equipment. In these cases, the contractor will typically trim the grade with a motor grader or small loader. Because final trimming disturbs the subbase surface slightly, additional compaction or rolling is usually necessary.

Summary

Careful attention to the design and construction of subgrades and subbases is essential to ensure the structural capacity and ride quality of all types of pavements. For concrete pavements, the requirements may vary considerably depending on subgrade soil type, environmental conditions, and amount of heavy traffic. In any case, the objective is to obtain a condition of uniform support for the pavement that will prevail throughout its service life.

The ability to compact granular subbases is highly dependent on the gradation of the material. Density is not the measure of quality in regard to granular subbases – instead, stability should be the goal, regardless of compactive effort. Treated permeable subbases should be designed and constructed with long-term stability in mind, and the permeability of the material as a secondary concern.

References

1. *Subgrades and Subbases for Concrete Pavements*, Concrete Paving Technology, TB011P, American Concrete Pavement Association, Skokie, IL, 1995.

2. *Survey of State DOT Concrete Pavement Practices,* http://www.pavement.com/pavtech/tech/stpract/main.html, American Concrete Pavement Association, Skokie, IL, 1999, accessed 4/20/05.

3. *Guide Specifications for Highway Construction,* American Association of Highway and Transportation Officials, Washington, DC, 1993.

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