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Tech Brief

Bases and Subbases for Concrete Pavements

This Tech Brief presents an overview of best practices for the design and construction of bases and subbases for concrete pavements and its effects on performance.

BACKGROUND

The need and use of bases and subbases for pavements has been well known for thousands of years. The Romans built over 53,000 miles of roads primarily to facilitate the movement of troops and supplies beginning in about 500 BC [Hays 2016]. The Romans recognized the benefits of "protecting" the natural earth subgrade from the impact of the repeated loading of their carts and chariots. Roads such as the Appian Way (Figure 1) were constructed of multiple layers of stones (subbase, base, and surface) and were sloped to drain water away from the road.

Figure 1. *Photo. Appian Way near Rome*

Early roads had fairly thick bases and subbases (Figure 2). In the early 1900s, with the use of asphalt- and cement-bound surface layers, base and subbase thicknesses were decreased.

U.S. Department of Transportation
Federal Highway Administration

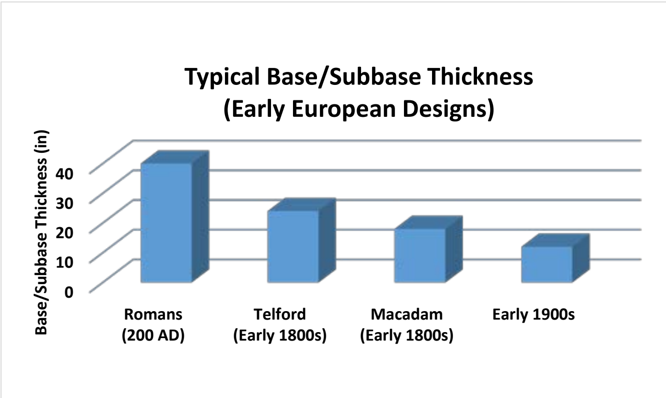

***Figure 2**. Graph. Base and subbase thickness for early roads.*

Portland cement concrete (PCC) was originally used as a base and was surfaced with wooden blocks, bricks, and cobblestones. The primary benefit of using PCC was its ability to spread load over a larger area than granular or bituminous bound materials, thereby allowing road builders to use less aggregate material. Issues for PCC included non-uniform and low compressive strength, inadequate mixture design, mixing, consolidation and curing, and jointing issues (orientation and spacing). PCC was first used as a wearing surface in North America beginning in 1891, in Bellefontaine, OH. Figure 3 shows early concrete pavement construction in Quebec, Canada.

***Figure 3**. Photo. Early concrete pavement construction in Québec.*

As shown in Figure 4, loads applied to a PCC-surfaced rigid pavement are spread over a large area of subgrade, compared to loads applied to an asphalt concrete-surfaced flexible pavement. This permits the use of thinner bases for rigid pavements than for flexible pavements.

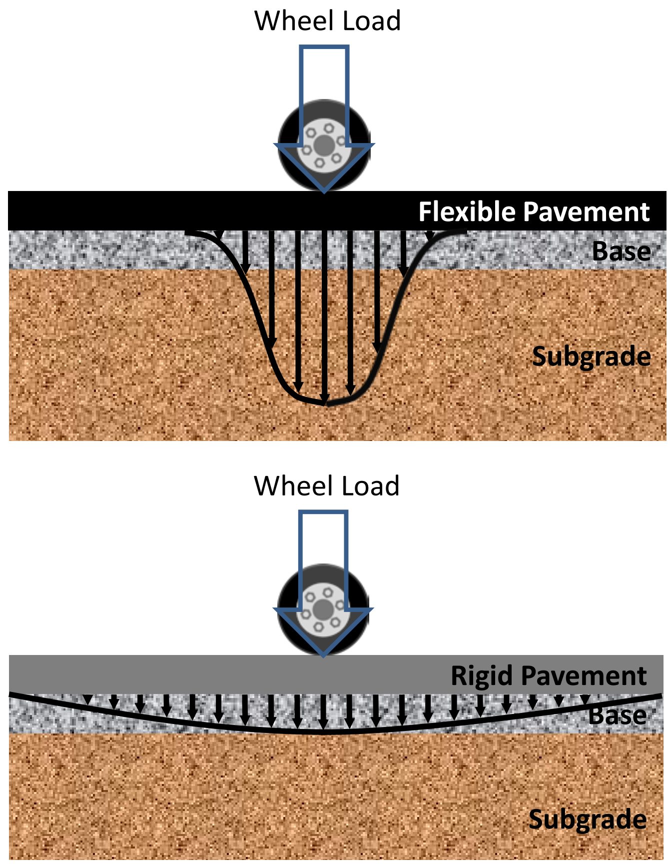

***Figure 4.** Illustrations. How rigid pavements and flexible pavements transfer applied loads to the layers beneath.*

RIGID PAVEMENT LAYER CONFIGURATION

Rigid pavements are typically constructed using a portland cement bound surface layer over one or more support layers over a prepared natural earth subgrade (Figure 5). The base layer is typically provided to support construction traffic and to provide uniformity of support to the PCC surface. The base layer may consist of unbound aggregate, bitumen-, or cement-bound aggregate. The bound layers may be conventional dense-graded asphalt, lean concrete, or cement-treated; or open-graded asphalt or concrete designed to promote lateral drainage within the pavement structure. The subbase layer is typically used to protect the pavement from the effects of frost heave and/or used to improve the constructability of the pavement layers above the subbase.

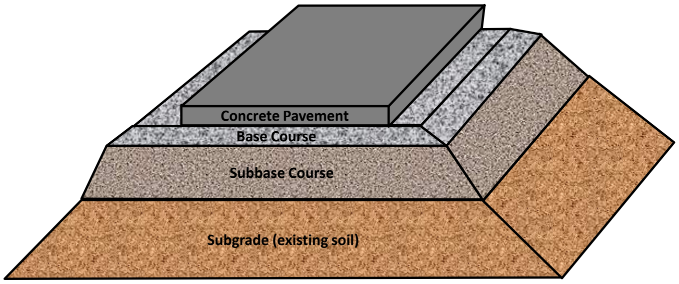

Figure 5. *Illustration. Definitions of base and subbase layers.*

DESIGN CONSIDERATIONS FOR BASE/SUBBASE

In 1940, the U.S. Army Corps of Engineers were assigned the responsibility for the design and construction of military airfields to support new heavy bomber aircraft such as the B-17 Flying Fortress. Pavement loading from these aircraft was three to five times heavier than any highway or aircraft loading designers had dealt with previously [Ahlvin 1991]. Based on a world-wide review of pavement design procedures, the Westergaard Design Method was chosen based on H.M. Westergaard's work with the Bureau of Public Roads and design method validation from the Arlington Road Tests.

In the early days of rigid pavement construction, concrete slabs were placed directly on top of the subgrade without any base/subbase layers. This pivotal work on rigid pavement design by the U.S. Army Corps of Engineers led to a much better understanding of the importance of the use of bases and subbases, their uniformity, and degree of compaction. One of the key findings during the implementation of the new design procedure was the importance of bases for concrete pavements. With an increase in traffic loads, volume, and speed, pumping of the subgrade material was observed through the joints and cracks in the PCC pavement. The loss of support due to pumping resulted in an increase in other distresses such as faulting, roughness, and corner breaks. Initially, a sand filter layer was specified to mitigate pumping of subgrade materials. With continued use, it became apparent that the filter layer also acted as a "subgrade improvement" layer, contributing not only to the reduction in pumping but also to the strength of the pavement and its constructability.

The key characteristic of a good quality rigid pavement foundation is not the strength of the support, but rather the provision of uniform support that is free of any abrupt spatial and material changes. Rigid pavement design relies on the structural carrying capacity of the PCC and on the uniformity of support provided by the base layers. As such, the pavement design engineer should not attempt to use the base/subbase layers simply to increase the overall structural capacity of a rigid pavement system or to reduce the thickness of the PCC layer. In most rigid pavement designs, the PCC design thickness is relatively insensitive to the foundation strength or stiffness and, therefore, slightly increasing the slab thickness is more economical than structurally increasing the thickness of the base layer to achieve the necessary structural capacity. A pavement design engineer should evaluate the potential causes of a non-uniform foundation and design the base or subbase layer to mitigate their effects. The three major causes of a non-uniform foundation are:

- Pumping of the fine particles.
- Frost heave.
- Soil expansion.

These factors must be controlled and limited over the life of a rigid pavement to ensure satisfactory performance. The conditions necessary to cause the above performance issues are summarized below:

- Pumping:
  - High-speed, heavy axles capable of deflecting the concrete slabs.
  - Joints with poor load transfer, especially undoweled joints.
  - Presence of water between pavement and subgrade.
  - Fine-grained subgrade or erodible base/subbase materials.
- Frost heave:
  - Frost-susceptible soil: Fine-grained soils with low plasticity and high percentage silts are most susceptible to frost heaving, while gravels and sands with fines and sandy/silty clays are prone to moderate frost action.
  - Source of water.
  - Freezing temperatures penetrating the soil.
- Soil Expansion:
  - Expansive soil: Soils sufficiently expansive to cause problems include the American Association of State Highway and Transportation Officials

(AASHTO) classification A-6 or A-7 soil groups or the Unified Soil Classification System CH, MH, and OH soils.
- Degree of moisture change within the soil.

Other factors responsible for non-uniform foundation include variability due to a number of reasons including, natural causes, excavation and fill, compaction during construction, and depth to bedrock. These sources of variability need to be properly considered in the design process.

DESIGN OF BASE/SUBBASE FOR RIGID PAVEMENTS

Strength and Stiffness Considerations

The pavement support, consisting of base, subbase and subgrade, is typically quantified by the modulus of subgrade reaction (also known as the k-value). One of the key assumptions in the design of concrete pavements is that the deflection of the support at any point under a concrete pavement is directly proportional to the vertical stress applied at that point. Conceptually, the concrete slabs are considered to be supported on a spring-like or dense liquid foundation. The k-value is determined by means of a plate load test in accordance with AASHTO T 122 and ASTM D 1996: Nonrepetitive Static Tests of Soils and Flexible Pavement Components, for Use in Evaluation and Design of Airport and Highway Pavements. The k-value is expressed in units of pounds per square inch per inch (psi/in) and is often stated as pounds per cubic inch (pci).

Placing a base or a subbase layer may provide improved protection of the subgrade, a stronger support to the PCC slabs, and result in an increased composite k-value. However, an exact k-value of the foundation is not typically required because the design thickness of the PCC is not significantly affected within the typical k-value ranges achieved by the subgrade and the base layers. The PCC slabs provide most of the structural capacity needed for the pavement.

Base and Subbase Types

The base and subbase types commonly used for rigid pavements include the following:

- Granular bases:
  - Dense-graded aggregate base.
  - Open-graded aggregate drainage layer.
- Stabilized bases:
  - Cement-stabilized bases:
    - Cement-treated base.
    - Lean concrete base.
    - Cement-treated open-graded drainage layer.
  - Asphalt-stabilized bases:
    - Asphalt dense-graded base.
    - Asphalt-treated base.
    - Asphalt-treated open-graded drainage layer.

Stabilized bases are typically constructed using concrete or asphalt paving equipment that can achieve a smooth surface. As such, the use of stabilized bases under a concrete pavement can contribute to achieving a high level of smoothness for concrete pavements. Figure 6 shows an example of an asphalt-treated base, and Figure 7 shows a cement-treated open-graded drainage layer.

Constructing a stiffer base layer does not guarantee good performance of a rigid pavement system and may even cause other problems [ACPA 1995, ACPA 2007]. A support system with reasonable stiffness provides several benefits, such as reduced strains in the pavement and improved load transfer across the joints. However, when the base becomes too stiff, it fails to conform to the changes in the shape of the slabs subjected to environmental loading (curling and warping). When this happens, the stresses and deflections increase within the slabs and this may eventually cause cracks to develop, especially when the concrete is relatively young. To avoid cracking of the concrete panels, the target compressive strength of cement-treated base should be within 300 to 800 psi, while lean concrete bases should have compressive strengths between 750 and 1,200 psi.

Figure 6. *Photo. Asphalt-treated base.*

Figure 7. *Photo. Cement-treated open-grade drainage layer.*

With respect to drainable base layers, the two most popular types are permeable base layers (granular or stabilized) with edge drains, and outlet pipes; and free-draining daylighted bases (Hall and Tayabji 2009). In the past (during the 1990s), the trend was to use drainable base layers with very high permeability—of the order of 8,000 to 10,000 ft/day. The current best practice is to use drainable base layers that are less permeable (500 to 800 ft/day) but more stable. There is no need to use drainable base layers with very high permeability because only a small amount of water actually infiltrates a well-maintained concrete pavement.

Thickness Requirements

The thickness of the subbase is usually governed by the extent of frost protection desired. This is governed by subgrade type, depth of frost penetration, and availability of water near the subgrade. The thickness of the base generally depends on the degree of support required for the construction equipment and type and condition of the underlying subgrade. Base thicknesses in the range of 4 to 6 inches are most common. Bases are typically extended 3 to 4 feet beyond the edge of pavement to accommodate the tracks of the paving equipment (Figure 8).

Figure 8. *Photo. Base extended beyond the concrete pavement to provide support for the paving equipment.*

MATERIALS FOR BASE AND SUBBASE

Base/Subbase Material Characteristics

Unstabilized bases, also frequently referred to as granular bases, are the most commonly used base types for concrete pavements. Adequately designed and properly constructed, unstabilized bases exhibit excellent field performance at a lower cost than stabilized bases. A wide variety of materials can be used as unstabilized bases, including crushed stone, sand-gravels, sands, and a variety of waste and byproducts. The materials for unstabilized base should meet the requirements of AASHTO M 147. In general, the materials for unstabilized base should meet the following criteria:

- Less than 10 percent passing No. 200 sieve.
- Plasticity index of 6 or less and liquid limit of 25 or less.
- Maximum particle size not exceeding one third of layer thickness.

- Los Angeles (L.A.) abrasion resistance (AASHTO T 96) of 50 percent or less.
- Permeability of approximately 150 ft/day and not exceeding 350 ft/day.

Limiting the amount of fines is the most important criterion for preventing pumping, base erosion, and frost action.

The AASHTO M 147 gradations shown in Table 1 were developed for both asphalt and concrete pavements, and the standard facilitates a rather wide range of gradations. All of the gradations except gradations A and C allow more than 15 percent passing the No. 200 sieve. Therefore, to utilize gradations B, D, E, and F, the requirement for percent passing the No. 200 sieve should be adjusted to limit the amount of fines.

Table 1. *Gradation requirements for soil-aggregate materials (AASHTO M 147).*

Sieve Designation	Percent Passing					
Inch	Gradation A*	Gradation B	Gradation C	Gradation D	Gradation E	Gradation F
2 in.	100	100	–	–	–	–
1 in.	–	75-95	100	100	100	100
¾ in.	30-65	40-75	50-85	60-100	–	–
No. 4	25-55	30-60	35-65	50-85	55-100	70-100
No. 10	15-40	20-45	25-50	40-70	40-100	55-100
No. 40	8-20	15-30	15-30	25-45	20-50	30-70
No. 200	2-8	5-20	5-15	5-20	6-20	8-25

The material requirements for cement-stabilized bases do not need to be as strict as those for unstabilized bases. As for cement-treated bases, which typically contain 2 to 5 percent cement, the material requirements may be relaxed to allow up to 35 percent passing the No. 200 sieve and a plasticity index of 10. All gradations specified in Table 1 without further modification work well for cement-treated bases. In addition, granular soils with plasticity index of 10 or less (more specifically, AASHTO classification A-1, A-3, A-2-4, and A-2-5 soils) may be used for these base types.

Lean concrete base, also known as econocrete, contains more cement than cement-treated base but less than conventional concrete. Due to the increased cement content, the material requirements may be further relaxed, allowing for the use of locally available, lower quality aggregates that do not meet the requirements for unstabilized base or conventional concrete.

Stabilized open-grade drainage layers have very little aggregate passing the No. 200 sieve. Asphalt cement contents typically range between 1.6 and 1.8 percent by mass of aggregates. Cement-treated open-graded drainage layers are typically produced with a water-to-cement ratio of 0.37 and a cement content of 185 to 220 lbs/yd^3.

The material requirements for the asphalt-treated bases should generally follow the agency's existing requirements for asphalt surfaces. Although a lower grade asphalt binder may be used for asphalt-treated bases, it is important to use durable aggregates to obtain satisfactory pavement performance.

Use of Recycled Materials

In addition to virgin aggregates, various recycled materials can be a good source of aggregate for base and subbase under a concrete pavement, especially when sustainability is of concern. Recycled concrete is the most frequently used recycled material (Figure 9) for use as unstabilized bases and as aggregates for cement-stabilized bases. The advantage of using recycled concrete is that almost any desired gradation can be achieved by crushing the recycled concrete, and most of the produced aggregates can easily meet the L.A. abrasion requirement of 50 percent or less. Some precautions that must be considered in using recycled concrete material include the following:

- Once crushed, recycled concrete material becomes very angular and may require more compaction effort than virgin aggregates.
- Unless the source of the recycled concrete is known, the material should be tested for contaminants such as soil, wood, plaster, gypsum, plastic, rubber, etc.

During crushing and sizing operations, a relatively small amount of fine particles may stick to the processed coarse aggregates. Although these fines do not create a serious problem, it is good practice to wash the processed aggregates to reduce potential for leaching and clogging of the drainage system. Use of these materials as aggregates for cement-treated base is also a good practice, if the material contains excessive fines or exhibits high plasticity for an unstabilized base.

Figure 9. *Photo. Reclaimed concrete crushed to be used as a base for concrete pavements.*

Other recycled materials frequently used as unstabilized bases for rigid pavements include waste materials such as reclaimed asphalt pavement, mill tailings, and other waste rock materials. These materials must be processed in an appropriate manner, may need to be blended with other materials to meet the gradation requirements, and should be free of any reactive chemical components.

CONSTRUCTION OF BASE AND SUBBASE

Construction of base and subbase layers largely depends on the type of base/subbase and the equipment available. It is not within the scope of this Tech Brief to provide an in-depth description of all available construction methods and procedures. In the following paragraphs, only the highlights of the best practices in constructing the base and subbase layers are provided for each base type.

Unstabilized Base

In general, the procedures for construction of unstabilized base involve mixing, placing, compacting, and grading the material. The keys to proper construction of unstabilized base are:

- Material should be blended so as to provide a homogeneous mixture.
- The material should be conditioned with water to maintain optimum moisture content before and during compaction.
- At a minimum, 95 percent of the standard proctor (AASHTO T 99) density should be achieved in the field. For projects designed to carry large volumes of heavy truck traffic, a minimum of 98 percent of modified proctor (AASHTO T 180) density is warranted.
- After compaction, the surface of the base should be trimmed to ± ½ inch of the design profile grade.
- Consistency in placing, compacting, and trimming operations should be ensured to avoid any segregation of aggregates.
- The unstabilized base must be wetted prior to paving of concrete to prevent the dry base material absorbing water from fresh concrete.

Cement-Treated Base

Similar to the unstabilized base, cement-treated base is typically placed using an asphalt or concrete spreader on the grade and compacted with rollers. The following summarizes best practices regarding construction of cement-treated bases:

- Due to the nature of the cement, the available time to placing, compacting, and trimming of the cement-treated base is limited to approximately 4 hours after the cement is mixed with water. Other factors, such as wind and heat, may further limit the available working time.
- The surface of the trimmed base should be within ± ½ inch of the design profile grade.
- After finishing, the base requires curing application with a light fog spray of water or a bituminous curing agent at a rate of 0.15 to 0.25 gal/yd^2.
- If trimming of cement-treated base is unavoidable just before paving of the PCC, the surface should be treated to prevent bonding of the base to the PCC. The applicable bond breakers include (1) reapplication of the bituminous curing agent with a thin layer of sand or (2) application of two coats of wax-based curing compound.

Lean Concrete Base

Lean concrete base is constructed in essentially the same manner as conventional concrete. The contractor can utilize the same equipment for construction of PCC and the base, thereby distributing the mobilization cost to a greater scope of work. In addition, it may eliminate the need to hire a subcontractor if a different type of base (e.g., asphalt-treated base) is to be constructed. The keys to achieving a successful lean concrete base material are as follows:

- For reasons explained earlier, the compressive strength of lean concrete base should be targeted to be between 750 and 1,200 psi. Lean concrete material meeting this requirement does not need joints. Shrinkage cracks will develop but will not reflect through the PCC slabs.
- Best control of surface grade is achieved by lean concrete base. The finished surface should be within ± ¼ inch of the design profile grade.
- The surface of lean concrete base should be left untextured to prevent bonding to the PCC slabs. Application of a bond breaker, such as two coats of wax-based curing compound, can further prevent bonding.
- Lean concrete base gains strength over time, similar to conventional concrete. As such, lean concrete base strength development must be factored in project sequencing, such that the lean concrete base does not become excessively stiff at the time of PCC placement.
- In situations where lean concrete base strength is estimated to be too high (not necessarily due to misapplication of the specification but due to elapsed time), the lean concrete base surface should be notched at the same locations where the joints will be cut in the PCC.
- Current practice in Germany is to place a 0.2-inch-thick polypropylene geotextile interlayer as a bond breaker between lean concrete base and PCC. The German experience has shown that this practice eliminates the need for notching of the lean concrete base [Germany 2012, Leykauf and Birmann 2006].

Asphalt-Treated Base

Construction procedures for asphalt-treated base are identical to those for a conventional asphalt surface, and all applicable agency specifications should apply. For best results, the following should be applied:

- Asphalt-treated base works better when constructed to yield a smooth surface. If the surface is constructed to be rough, it may induce excessive friction, which may need to be mitigated prior to PCC placement.
- Prior to PCC placement, the surface of asphalt-treated base may be sprayed with water, water-lime solution, or concrete curing compound to reduce the surface temperature, which may reach 140 °F or higher. Alternatively, night-time paving may be considered.
- Control of surface grade is also important for asphalt-treated base. The finished surface should be within ± ¼ inch of the design profile grade.

Asphalt and Cement-Treated Open-Graded Drainage Layer

Asphalt and cement-treated open-graded drainage layers are produced at asphalt or concrete plants and laid using an asphalt or concrete spreader. For best results, the following should be applied:

- Proper mixture design is essential to ensure the optimum asphalt or cement content for the chosen aggregate gradation.
- The finished surface should be within ± ¼ inch of the design profile grade.

COST CONSIDERATIONS

The base type should be selected while considering the purpose of the base, locally available materials, and their cost-effectiveness. Evaluating the cost-effectiveness is most appropriately carried out using life cycle cost analysis. Two of the crucial inputs needed for the analysis include the cost of materials and construction as well as the performance expected from various design features including the base types [Cole and Hall 1996]. The performance expectations should be based on an agency's past experience and data from previous projects, if available. However, the expected performance of a particular design feature, such as the base type, is often difficult to characterize, as the performance also depends on other design features [Hoerner et al. 2004, FHWA 1992, Hall et al. 2007].

Table 2 summarizes the cost comparisons of various base types relative to a cost of 100 assigned to a reference of dense-graded unstabilized base, which may be used as a general guide. As an alternative, considering the estimated construction cost may reveal insight into the cost-effectiveness of the various base types. The cost estimate should include all of the costs that are common to most projects as well as the additional costs and savings that may be achieved by using recycled materials and any incidental costs.

Table 2. *Relative cost for different types of base.*

Base Type	Relative Cost
No base/subbase	84
Dense-graded unstabilized base	100
Open-graded unstabilized base	114
Lean concrete base	122
Open-graded asphalt-treated base	123
Open-graded cement-treated base	124
Lean concrete base	122
Dense-graded asphalt base	135

EUROPEAN PRACTICES – A BRIEF SUMMARY

This section describes some of the current European practices that are relevant to base and subbase layers in rigid pavement systems. There is not a single practice representative of all of Europe, and the relevant practices vary from one country to another. As such, the summary provided herein is only for informational purposes and is by no means a comprehensive overview of the entire European practice.

European Rigid Pavement Design Methodologies

European countries use various methodologies for rigid pavement design, ranging from empirical approaches (e.g., United Kingdom) to mechanistic-empirical design methodologies (e.g., Netherlands and France) [FHWA 1992, Hall et al. 2007]. In addition, an empirical design method known as the "Catalogue Design" is used in countries such as Germany, Austria, and Belgium [Houben 2009, Rens 2016].

Unlike the U.S. rigid pavement design practice, in which the primary purpose of a base or a subbase layer is to prevent pumping, European designs generally emphasize the frost protection of subgrade and subsurface drainage, irrespective of the design methodology. As a result, the European designs typically use base and subbase layers that are substantially thicker than those in the U.S. Furthermore, some countries specify the total thickness of the pavement as the thickness of all layers that are not frost-susceptible.

As an example, Figure 10 shows the rigid pavement structures specified in the German catalogue for Class SV motorways, which have cumulative traffic of more than 32 million equivalent single axle loads (ESALs) during their design life. The total pavement thickness required for this roadway class is 33.5 inches, regardless of the base type. Once the type of base material is determined, the thicknesses of PCC, base, and subbase layers are read from the catalogue [Germany 2012].

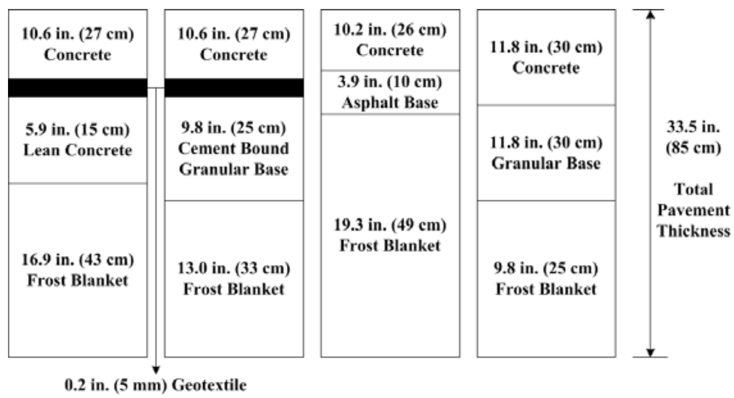

Figure 10. *Rigid pavement structures for motorways in German Design Catalogue RStO 12 [Germany 2012].*

Materials for European Base and Subbase

Similar to the materials used in the U.S., typical materials allowed for use in the design of European base include asphalt and cement-treated bases, lean concrete base, granular materials (mostly crushed stone), or a combination of these materials. The base is typically constructed on top of a thick subbase layer composed of dense-graded granular materials or lime-stabilized soil. Table 3 summarizes the base/subbase types and their thicknesses frequently used in the Europe.

Table 3. *Summary of European base/subbase materials [Sommer 2008].*

Base (Typical Thickness)	Subbase	Country
Asphalt-treated (2.5 in. to 4.0 in.)	Granular	All
Asphalt-treated (2.0 in.) + cement-treated or lean concrete (8.0 in.)	Granular	All
Asphalt-treated (2.0 in.) + cement-treated or lean concrete (8.0 in.)	Stabilized	Several
Geotextile (0.2 in.)* + lean concrete (8.0 in.)	Granular	Germany
Unstabilized (12.0 in.)	Granular	Germany

Many European countries use treated materials such as lean concrete or cement-treated base for the base on top of an aggregate subbase. In addition, to prevent the erosion problem frequently encountered in the base, a recent trend in countries such as France, Belgium, and Netherlands is to place an asphalt interlayer, 2.0 to 3.5 inches thick, between the PCC and the base layer consisting of lean concrete base or cement-treated base [Sommer 2008].

Construction of European Base/Subbase

The primary measures of construction acceptance adopted in the U.S. for subsurface layers are thickness and density. In many European countries, however, the specifications frequently include strength and/or stiffness measures, in addition to measures such as density and thickness. For example, in Germany and Belgium, plate load tests are conducted in the field, and the stiffness parameters must meet the requirements. If the stiffness requirement is not achieved in the field, contractors are required to take additional action (e.g., extra compaction, stabilization) before the next pavement layer is constructed. Similar practice is also found in Austria and Switzerland [Houben 2009, Rens 2016].

SUMMARY AND CONCLUSIONS

Because of the high strength, stiffness, and load distribution characteristics provided by the concrete surface, rigid pavements do not necessarily require a strong foundation. It is more important that the foundation provides uniform support to the concrete slabs.

Although the primary purpose of base/subbase layers in a rigid pavement system is to prevent pumping, these layers provide additional advantages, such as more uniform support to the concrete slabs compared to the subgrade, a more stable working platform for construction equipment, and improved control of soil expansion and differential frost heave. However, a rigid pavement system does not always require a base or a subbase layer; the engineer should study the available data and site conditions to decide whether a base layer is warranted. Furthermore, if a base layer is to be used, the engineer should consider the different base types while considering the available materials and their cost.

Irrespective of the type of base used, the best results are obtained by:

- Selecting a base (or a combination of base and subbase) material that is not prone to pumping.
- Selecting materials that will remain stable over time.
- Selecting a base type that does not exhibit excessive deflections under traffic loading.
- Treating the surface of the cementitious base to prevent bonding and reduce friction at the interface of the PCC and base.
- Specifying a gradation or other material controls that will ensure a consistent base along the length of the project.
- Specifying and constructing the base with grade controls that allow for consistent thickness and smoothness of concrete.

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