Chapter 660 – PAVEMENT FOUNDATIONS

Topic 661 - Engineering Considerations

Index 661.1 – Description

Pavement foundations are the layers below the surface material, typically asphalt concrete or portland cement concrete (PCC). Pavement foundations include various types of the following pavement layers:

- Base
- Subbase including stabilized subgrade soils
- Subgrade or basement soil

Depending on the type of pavement project and other design considerations, a pavement structure may include base and subbase layers, only base, or no base or subbase. The subbase generally consists of lower quality materials than the base, but better than the subgrade or basement soils. When needed, pavement foundation materials are stabilized to improve strength. Typically, there are two types of stabilization: mechanical and chemical stabilization. Stabilization should not be used to attempt to correct problems with poor drainage, as it will seldom be successful.

Mechanical stabilization by compaction to standards for subgrade soil is essential to improve the mechanical properties of the soil and its resistance to the effects of water. Structural design methods assume that base, subbase and subgrade layers will be mechanically stabilized by compaction to standards and the design must meet performance requirements. The only cases where subgrade compaction should not meet standard specifications are for pervious pavement (see Caltrans guidance for pervious pavements) or when recommended by the district materials engineers for site-specific reasons.

Additional mechanical stabilization can be obtained in appropriate applications by using geosynthetic interlayers. Interlayers are included in the pavement for specific purposes, such as filtration of fine particles, improving confinement of granular materials, and improving constructability on very wet subgrades. Specific interlayer types are used for each purpose.

The most common chemical stabilization is performed by using cement and/or lime.

661.2 Purpose

Pavement foundations provide support for the surface layer and help distribute the wheel loads to the subgrade material.

In addition to functioning as part of the pavement structure, bases and subbases serve the following functions:

- Low permeability will slow the upward pumping of fine particles from the subgrade soil into the pavement layers above.

- Minimize damage caused by frost by preventing frost heave and the effects of thawing; in areas of the state where frost penetration occurs, use materials that are not frost-susceptible at depths below the surface of the pavement reached by freezing temperatures.
- Prevent the accumulation of water within or below the pavement structure by draining laterally out of the shoulder of the pavement and leave the structure (known as "daylighting").
- Provide a working platform for construction equipment to prevent rutting in the subgrade during construction and to achieve optimal densities during compaction of subsequent layers.

Topic 662 - Types of Bases and Subbase

662.1 Aggregate Base

Aggregate bases consist of a combination of sand, gravel, crushed stone, and recycled material. They are classified in accordance with their particle size gradation, the plasticity of the fine materials, their resistance to shear stresses (stability) that causes rutting, and the durability of the particles to mechanical degradation. Caltrans uses two classes of aggregate base: Class-2 and Class-3. The quality of aggregate base material affects the extent of load distribution and drainage. The gradation of the aggregates can affect structural capacity, drainage, and frost susceptibility. A dense gradation is needed to provide structural capacity, without excessive fine materials that decrease structural capacity. The fine materials must not be susceptible to swelling and shrinking and loss of resilient modulus (stiffness) and rutting resistance when exposed to water. Aggregates, either blasted or from crushed alluvial deposits, must have sufficient angularity and rough surface texture to ensure good aggregate interlock that will provide the required structural capacity in terms of resilient modulus and rutting resistance.

662.2 Treated Base

(1) *Hot Mix Asphalt (HMA).* Dense-graded Type A Hot Mix Asphalt (HMA) is used as a base. Type A HMA is used as a base under concrete slabs for rigid pavement , and is part of the pavement surface layers for flexible surfaced pavement. .

(2) *Concrete Bases.* Concrete base (CB) and lean concrete base (LCB) are plant-mixed concrete products used as base. CB is essentially unreinforced concrete pavement, constructed with or without transverse joints, used primarily for widening rigid pavement structures that have been or will be surfaced with HMA. CB is finished in anticipation of being paved with HMA. LCB is produced with less cementitious material and allows lower quality aggregates than CB. LCB is only intended for jointed concrete pavement structures as a base beneath the PCC slabs. Concrete bases can utilize cements that develop strength and/or set faster than conventional cement. Rapid strength concrete base (RSCB) and lean concrete base rapid setting (LCBRS) have the same applications as CB and LCB but are usually specified for projects with short construction windows such as individual slab replacements. Concrete bases and lean concrete bases can be

sawcut to match the joints when used beneath JPCP. CB or LCB is not used as a base for continuously reinforced concrete pavement.

(3) Cement Treated Bases. Cement treated bases (CTB) are granular materials mixed with portland cement to increase their strength and stiffness. CTB can be plant-mixed or mixed on the site.

(4) Recycled Pavement Bases. Recycled pavement bases are materials that are constructed in place by in-place crack and seating or removing and crushing existing rigid pavement for use as an aggregate base, or pulverizing existing flexible pavement. Crushed rigid pavement is used as a granular base. Caltrans does not have a specification for in-place rubblization of rigid pavement. Pulverized existing flexible pavement can be used as a granular base or can be stabilized with a combination of foamed asphalt and cement, cement, lime, or other cementitious materials. The stabilization can be done as part of in-place recycling (IPR), or within or close to the construction site using cold central plant recycling (CCPR).

(5) Consideration of Treated Bases in Design.

(a) Rigid Pavement. Base type is a consideration in the design of new and rehabilitated rigid pavement, and the two alternatives considered in the JPCP design catalog are HMA Type A and LCB. HMA Type A is the only type of base used for continuously reinforced concrete pavement. CTB and treated permeable bases, particularly asphalt treated permeable base (ATPB) have been used in the past. CTB showed poor faulting and pumping performance under JPCP when the concrete transverse joints did not have dowels. ATPB was susceptible to moisture damage, and also had problems regarding early slab cracking and poor joint performance when used with shoulder edge drain systems.

(b) Flexible Pavement. Base type is a consideration in the design of new and rehabilitated flexible pavement. While combinations of aggregate base and subbase are common, treated bases are also used. Flexible pavements with cracked and seated rigid pavement below the HMA surface, chemically stabilized (cement, lime, or fly ash treated) bases below the asphalt surface layers, sometimes called semi-rigid pavement, should be designed using CalME and considering reflective cracking from shrinkage cracks in the stabilized base. Recycled pavement bases that are cement stabilized and not subjected to microcracking, appropriate curing and other practices described in the in-place recycling guidance should also be designed considering reflective cracking.

662.3 Treated Permeable Base

Treated permeable bases (TPB) provide a highly permeable drainage layer within the pavement structure. The binder material may be either asphalt (ATPB) or portland cement (CTPB). Either of these TPB layers will generally initially provide greater drainage capacity than is needed for most applications. The standard thickness is based primarily on constructability and consideration of construction variability.

TPB is not recommended for new pavement design or reconstruction unless it is needed to provide an outlet for existing TPB layers when widening. Where excess water needs to drain through the pavement, such as when the uphill side of pavement does not allow for drainage is use sub-surface drainage to carry water to the other side of the roadway, and a TPB layer just below the HMA to drain excess water through from the uphill side of the pavement to the downhill side should be avoided wherever possible.

Erosion in CTPB (water washing away cement paste and fines) can be an issue for TPB under both flexible and rigid pavement. Research conducted in the 1990s on flexible and rigid pavement by Caltrans and by the University of California Pavement Research Center (UCPRC) indicates that the use of ATPB is highly susceptible to stripping under both pavement types. Because of these problems with TPB, the Department recommends the use of standard aggregate base (AB), along with the use of a QC/QA specification for the HMA for new flexible pavement structures, instead of ATPB, to help minimize surface permeability and TPB is not included in the rigid pavement design catalog.

Where there is an issue of maintaining continuity of an ATPB/CTPB layer in existing lanes that will drain into a new lane or widening to provide drainage through the pavement structure, the site investigation should first determine by taking cores whether or not the TPB layer is capturing water and transmitting it to the conveyance system at the edge of the pavement. TPB that has been clogged with pumped fines may no longer be permeable.

Where the TPB can be determined in the site investigation to no longer be functioning as a drainage layer in the existing lanes, continuity of the TPB in the existing lanes through the new or widened lanes is not needed. Where the TPB in the existing lanes is still capturing and conveying water, a TPB should be included in the new or widened lane. The following features are recommended when using TPB:

(1) Daylight the edges or if that is not possible use edge drains (see Figure 651.2A in Chapter 650 for edge drain details).

(2) If using edge drains, be sure that Maintenance is informed and can budget funds for maintaining edge drains. Developing an estimate of maintenance costs to maintain edge drains and Budget Change Proposals may be required to assure edge drains can be maintained.

(3) Try to use permeable backfill in shoulders around edge drains to avoid the trapping of water under the pavement (referred to as the “bathtub effect”) if the edge drain becomes clogged.

662.4 Subbase and Stabilized Subgrade

Subbases may be aggregate subbase or stabilized subgrade.

Aggregate subbase is similar to aggregate base but with less restrictive quality requirements. Because of the continual depletion of quarry aggregates, most subbases typically consist of recycled pavement and/or demolition materials, or quarry products that cannot meet the criteria for aggregate base.

Excavated soil and low quality imported borrow material can be chemically treated with a stabilizing agent to increase strength and reduce expansiveness. The most common types of stabilized soils are lime stabilized soil (LSS) and cement stabilized soil (CSS). Other soil stabilization agents include asphalt binder and fly ash or kiln dust, but these are considered experimental alternatives and are not currently supported in the Department's Standard Specifications or guidelines.

Stabilizing the soil does not eliminate or reduce the required aggregate subbase for rigid or composite pavements in the rigid pavements catalog (see Topic 623). However, for flexible pavements, stabilized subgrade is a material considered in the design.

The Guidelines for the Stabilization of Subgrade Soils in California *(https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/f0016618-task-2201-pavement.pdf)* should be consulted to assist with the selection of the most appropriate method to stabilize soils for individual projects, and the District Materials Engineer should be contacted. The final decision as to which stabilization method to use rests with the District.

Topic 663 – Engineering Properties for Base and Subbase Materials

663.1 Selection Criteria

Different types of treated and untreated base and subbase materials have different capacities for resisting stresses and deformations imposed by traffic loads, which must be considered when determining the type and thickness of pavement foundation layers. Besides load carrying considerations, other factors should be considered, such as local availability of materials, costs, climate, and past performance of pavements on nearby projects with similar subgrades, climates and drainage conditions. The District Materials Engineer should be contacted for the latest guidance in base and subbase materials among other related engineering considerations.

Minimum aggregate base thicknesses to provide a working platform for the construction of rigid and flexible pavement are shown in Table 633.1.2. Subgrade stabilization (Topic 664) or Subgrade Enhancement Geosynthetics (Topic 665) may be used in place of the minimum thicknesses in the table.

663.2 Base and Subbase for Rigid Pavements

For rigid pavements, the capacity of base and subbase materials to resist traffic loads is considered in the design catalogs found in Topic 623. The base and subbase properties used in the development of the design catalog using the *Pavement ME* software are shown in the technical documentation for the catalog, available from the Office of Concrete Pavement.

663.3 Base and Subbase for Flexible Pavements

For flexible pavement mechanistic-empirical design, the capacity of treated and untreated base and subbase materials to resist traffic loads is considered by their resilient modulus and rutting properties, and if stabilized, by rutting and cracking-related properties. Base and subbase materials have default values for the design of new pavement using CalME shown in Table 663.3. Resilient modulus values for use in the design for rehabilitation or reconstruction of existing pavement should be determined following the Site Investigation Guide.

When stabilized soil is substituted for aggregate subbase for flexible pavements, as discussed in Index 662.4, the thickness of the stabilized soil layer is obtained from design using CalME. The resilient modulus (M_r) is determined based on unconfined compressive strength (UCS) of the stabilized material as follows:

M_r (ksi)= 0.124×UCS+9.98 for lime stabilized soil and ;

M_r (ksi)= 1.2 x UCS for cement stabilized soil

These equations are only valid for UCS of 300 psi or higher at 28 days of curing. For lime and cement stabilization, UCS is determined by different test methods, but in both cases the 28-day UCS is simulated by curing prepared samples in an oven for 7 days at 110±5°F. Refer to California Test Method 373 and ASTM D 1633 for lime and cement respectively. If test data are not available, default properties are available in CalME.

Because the stabilization of soil may be less expensive than importing and placing aggregate base material, the calculated base thickness can be reduced by increasing the stabilized soil thickness. The maximum thickness of lime and cement stabilized subgrade is 2 feet with a maximum lift thickness of 1 foot.

Topic 664 – Subgrade

Subgrade is defined as the roadbed portion on which pavement, surfacing, base, subbase, fill, or a layer of any other material is placed. It is the soil or rock material underlying the pavement structure, and unlike subbase, base and wearing course (surfacing) materials whose characteristics are relatively uniform, there is often substantial variability of engineering properties of subgrade soils over the length of a project. Since pavements are engineered to distribute stresses imposed by traffic to the subgrade, the subgrade conditions have a significant influence on the choice and thickness of pavement structure and the way it is designed. A thorough understanding of the nature and distribution of subgrade soils in any pavement project area is essential to appropriately engineer the construction, rehabilitation, or widening of a highway facility. Before beginning any project, a detailed site investigation should be performed to understand the subgrade soil conditions and engineering properties. For detailed site investigation information see the “Site Investigation Guide” and for soil characteristics refer to Topic 614 - Soils Characteristics.

664.1 Subgrade Improvement Overview

Depending on the existing soils and project design, it may be cost-effective to improve the properties of the subgrade either mechanically (in addition to compaction), chemically, or both. Subgrade improvement may also be a solution to constructability problems.

Table 663.3

Default Resilient Moduli for Bases and Subbases Used in Flexible Pavement Design

Type of Material	Abbreviation	Resilient Modulus, M_r (psi)	California R-value	Poison's Ratio, (**ν**)
Aggregate Base	AS-Class 2	30,000	50	0.35
	AS-Class 3	25,000	40	0.35
	AB-Class 2	45,000	78	0.35
	AB-Class 3	30,000	50	0.35
Asphalt Treated Permeable Base	ATPB	45,000	NA	NA
Cement Treated Base	CTB-Class A	1,508,000	NA	0.2
	CTB-Class B	1,140,000	80	0.2
Cement Treated Permeable Base	CTPB	1,100,000	NA	0.2
Lean Concrete Base	LCB	1508,000	NA	0.2
Lean Concrete Base Rapid Setting	LCBRS	1508,000	NA	0.2
Lime Stabilized Soil	LSS	0.124×UCS[1]+9.98	NA	0.2
Cement Stabilized Soil	CSS	1.2×UCS[2]	NA	0.2

NOTES:

(1) UCS is the unconfined compressive strength of the lime stabilized material in psi measured according to California Test Method 373 with the modification that samples are oven-cured at 110°F ± 5°F for 7 days.

(2) UCS of the cement stabilized materials in psi measured according to ASTM D 1633, oven-cured at 100±5°F for 7 days.

Legend:

NA = No default value available

UCS = Unconfined Compressive Strength in psi (minimum 300 psi)

664.2 Mechanical Stabilization

Improving strength and stiffness, and reducing permeability, are reasons for considering mechanical stabilization. Mechanical subgrade stabilization includes the following:

(1) *Compaction*. All materials, including those that are chemically stabilized, need to be compacted to required standards. Compaction increases strength and stiffness and reduces permeability. Chemically stabilized subgrades that are not well compacted will perform poorly. Subgrade soils should be ripped to a depth of one foot, moisture conditioned and compacted to required density..

(2) *Blending*. Blending involves the mixing of materials that have different properties, such as gradation and plasticity, to form a material with characteristics that improve upon the limitations of the source materials. In most instances, blending will involve adding coarse aggregates to the finer in situ material. Less common in California is the addition of fine material to in situ sandy or coarse aggregates to fill voids and obtain a denser gradation.

(3) *Subgrade Enhancement Geosynthetics.* Subgrade enhancement geosynthetics are typically geotextiles (also called fabric), geogrids, or geocomposites such as a combination of geogrid and geotextile interlayers placed between the pavement structure and the subgrade (the subgrade is usually untreated). Geosynthetics can be used for temporary improvement of subgrade to provide a platform for equipment during construction, and/or long-term enhancement to improve the ability to sustain traffic loads distributed to the subgrade. Detailed information on subgrade enhancement geosynthetics is provided in Topic 665.

664.3 Chemical Stabilization

The most common types of stabilized subgrade are lime stabilized soil (LSS) and cement stabilized soil (CSS). Other soil stabilization agents include asphalt binder and fly ash or kiln dust, but these are considered experimental alternatives and are not currently supported in the Department's Standard Specifications or guidelines.

The Guidelines for the Stabilization of Subgrade Soils in California should be consulted to assist with the selection of the most appropriate method to stabilize soils for individual projects, and the District Materials Engineer should be contacted. The District makes the final decision as to which subgrade stabilization method to use.

For rigid pavement design, low quality in-situ subgrade soil can be improved from Type III to Type II or Type I (see Table 623.1A) by chemical stabilization to a minimum depth of 0.65 foot using an approved stabilizing agent such as lime, cement, or fly ash (fly ash is not currently supported in the Department's Standard Specifications or guidelines). Chemically treated soil samples should be tested to determine the unconfined strength of the stabilized soil. To ensure long-term stability of the subgrade during the pavement design life, the stabilized soil should achieve an initial minimum unconfined compressive strength of 300 psi. For detailed information refer to "Guidelines for the Stabilization of Subgrade Soils in California": http://www.ucprc.ucdavis.edu/PDF/UCPRC-GL-2010-01.pdf.

Topic 665 - Subgrade Enhancement Geosynthetic

665.1 Purpose

Subgrade Enhancement Geosynthetic (SEG) can be either a Subgrade Enhancement Geotextile (SEG_T) or Subgrade Enhancement Geogrid (SEG_G) or a combination of SEG_T and SEG_G (a geocomposite) placed between the pavement structure and the subgrade (the subgrade is usually untreated). The placement of SEG below the pavement will provide subgrade enhancement by bridging soft areas.

Subgrade Enhancement Geogrids (SEG_G) are used to provide greater confinement to granular layers placed above a weak/soft subgrade that would otherwise be provided by the stiffness of the subgrade. SEG_G mobilize its tensile strength to reinforce the subgrade soil. Subgrade Enhancement Geotextiles (SEG_T) will provide a separation function between soft subgrade (with high fines content), susceptible to pumping, and high-quality subbase or base materials. On weak subgrade, the use of selected SEG_T also provides a stabilization function (i.e., the coincident function of separation and reinforcement). As the soft soil undergoes deformation, properly placed SEG will mobilize its tensile strength properties to provide increased strength to the subgrade. Typically, woven geotextile is used where improvement in tensile strength is desired by a geotextile. Check the standard specifications for different types of available geosynthetics for SEG.

Other benefits of using SEG include:

- Potential cost savings:
  - Reduced subbase or aggregate base thickness in some situations
  - Reduced, or elimination of, the amount of soft or unsuitable subgrade materials to be removed
- Preventing contamination of the base and subbase materials with plastic fines from clay subgrades (when using SEG_T)
- Reduced disturbance of soft or sensitive subgrade during construction
- Ability to install in a wide range of weather conditions.

665.2 Properties of Geosynthetics

(1) *Subgrade Enhancement Geotextile (SEG_T)*. Mechanical, physical, and other properties of geotextile (SEG_T) used for subgrade enhancement must meet the requirements in Section 96 of the Standard Specifications.

(2) *Subgrade Enhancement Geogrid (SEG_G)*. Property requirements for SEG_G are related to performance. The most important geogrid properties for subgrade enhancement related to performance and durability are tensile strength, junction strength, flexural rigidity, and aperture size.

Different types of geogrid can be used for SEG_G provided their stabilizing performance is equivalent to or greater than the values specified in Section 96 of the Standard Specifications.

665.3 Required Tests

The following geotechnical soil laboratory tests are required to evaluate subgrade for geosynthetic applications:

- Atterberg Limit Tests: CT 204 or alternatively ASTM D4318 or AASHTO T 90.
- Sieve Analysis: CT 202 or alternatively ASTM C136 or AASHTO T 27.
- Resilient Modulus Test: AASHTO T 307 or alternatively Dynamic Cone Penetrometer (DCP) (ASTM D6951), R-value test (CT 301) or California Bearing Ratio (CBR) test (ASTM D1883 or AASHTO T 193). Estimated values for resilient moduli based on DCP, R-value or CBR values can be found in the Site Investigation Guide.

665.4 Mechanical Stabilization Using SEG

Subgrade enhancement geosynthetics - SEGs (SEG_T and SEG_G) achieve mechanical stabilization through different mechanisms:

(1) *Subgrade Enhancement Geotextile (SEG_T).* A geotextile's primary stabilization mechanism is filtration and separation of a soft subgrade and the subbase or base materials. The sheet-like structure provides a physical barrier between these materials to prevent the aggregate and subgrade from mixing. It can also reduce excess pore water pressure through a mechanism of filtration and drainage. Secondary mechanisms of a geotextile are lateral restraint and reinforcement. Lateral restraint is achieved through friction between the surface of the geotextile and the subbase or base materials. The reinforcement mechanism requires deformation of the subgrade and stretching of the geotextile to engage the tensile strength and create a "tensioned membrane." Typically, woven geotextile is recommended for reinforcement mechanism, where subgrade enhancement is desired by tensile strength.

(2) *Subgrade Enhancement Geogrid (SEG_G).* The primary stabilization mechanism of a geogrid is lateral restraint of the subbase or base materials through a process of interlocking between the aggregate and the apertures of the geogrid. The level of lateral restraint that is achieved is a function of the type of geogrid and the quality and gradation of the base or subbase material placed on the geogrid. To maximize the performance of the geogrid, a well-graded granular base or subbase material should be selected that is sized appropriately for the aperture size of the geogrid. When aggregate is placed over a geogrid it quickly becomes confined within the apertures and is restrained from punching into the soft subgrade and shoving laterally. This results in a "stiffened" aggregate platform over the geogrid. Very little deformation of the geogrid is needed to achieve lateral restraint and reinforcement. Separation and filtration/vertical drainage are secondary mechanisms of a geogrid. Because the aggregate is confined within the apertures of the geogrid and cannot move under load, separation and filtration can be achieved. A layer of a geotextile can be used to prevent the migration of fines into base/subbase materials or for separation purposes along with the geogrid as a geocomposite.

665.5 Selecting Geosynthetic Type and Design Parameters

(1) *Determining SEG Functions* - Subgrade stabilization is the primary function for geogrids installed between an aggregate base or subbase and the subgrade. The primary functions of geotextiles are separation, stabilization, filtration, and drainage. Subgrade soils with resilient modulus <12 ksi (equivalent R-value <20) are considered poor or weak soils and may require SEG to provide reinforcement as the primary function and separation as the secondary function. However, depending on the type and treatment of the base layer, pavements constructed over subgrade soils with resilient modulus up to 23 ksi (equivalent R-value 40) can benefit from separation if the subgrade soil contains significant percentages of fines.

(2) *Conditions for Using SEG and Selecting SEG Type* - SEG is generally selected based on the following criteria:

- On soft subgrade conditions (4.0 ksi $\leq M_r < 6.5$ ksi), consider placing a thicker initial lift (minimum of 0.5 feet) of subbase or aggregate base material on top of the SEG to effectively bridge the soft soils and avoid bearing capacity failure under construction traffic loading.
- Use of SEG_G only is not recommended unless the aggregate material placed above the subgrade meets the following natural filter criteria: (D_{15}Aggregate Base/D_{85}Subgrade) ≤ 5 and (D_{50}Aggregate Base /D_{50}Subgrade) ≤ 25, where D_{15}, D_{85}, and D_{50} are grain sizes of the soil particles for which 15 percent, 85 percent, and 50 percent of the material is smaller than these sieve sizes. If the aggregate base material does not meet the above natural filter criteria, geotextiles that meet both separation and stabilization requirements are recommended, or a composite (combination of SEG_T and SEG_G) is recommended.
- For subgrade resilient modulus less than 15 ksi (equivalent R-value <25), SEG_G is most applicable, with or without geotextile, depending on the natural filter criteria.
- For subgrade resilient modulus between 12ksi and 15ksi (equivalent R-values between 20 and 25), SEG_G is generally selected for its stabilization function, depending on natural filter criteria. The stabilization requirements for SEG_G can be found in Section 96 of the Standard Specifications or SEG Design and Construction Guide.For subgrade resilient modulus greater than 15 ksi (equivalent R-values >25) but less than 23 ksi (equivalent R-value <40), the engineer may consider utilizing SEG_T as a separator.
- For subgrade resilient modulus greater than 15 ksi (equivalent R-values >25) but less than 23 ksi (equivalent R-value <40), the engineer may consider utilizing SEG_T as a separator.
- For subgrade resilient modulus greater than 23 ksi (equivalent R-value >40), the use of SEG may not provide any benefit.
- For very soft subgrade conditions, Mr < 4 ksi or R-value < 5 or CBR < 2.5, the subgrade should be treated as unsuitable materials. Remove and replace with

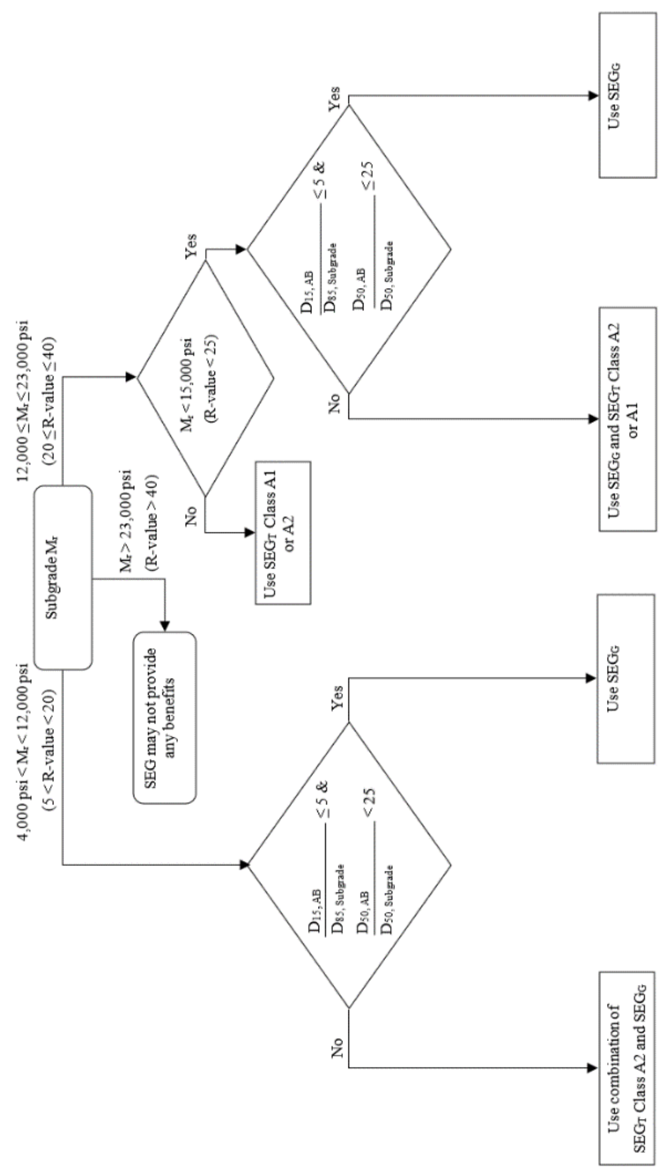
imported borrow materials or treat with lime or cement as specified in Standard Specification Section 24.

Use the flowchart shown in Figure 665.5 for the optimal selection of the most appropriate type of geotextile or geogrid based on subgrade resilient modulus, or estimated resilient modulus based on DCP, CBR, or R-value test results and gradation of the subgrade and aggregate base materials.

Before choosing to use SEG, the engineer should investigate the engineering and economic benefits of using SEG_G and/or SEG_T instead of designing the pavement for the existing subgrade resilient modulus.

Figure 665.5

Flowchart for SEG Selection



665.6 Appropriate Application of SEG

Where SEG may be the most cost-effective solution, include areas with the following soil characteristics:

- Poor (low strength) soils, which are classified in the Unified Soil Classification System (USCS) as clayey sand (SC), lean clay (CL), silty clay (ML-CL), high plastic clay or fat clay (CH), silt (ML), high plasticity or elastic silt (MH), organic soil (OL/OH), and peat (PT);
- Resilient Modulus (M_r) < 15 ksi (R-value 25), and/or other properties stated above in Index 665.5(2);
- High water table and high soil sensitivity.
- Shallow utilities or contaminated soils.

665.7 Other Design Considerations

The following should also be considered by the design engineer when designing pavements involving SEG:

- On soft subgrade soils, SEG may be used instead of stabilizing material such as lime or cement if the purpose of the treatment is solely a working platform to provide access to construction equipment. It may also be used with lime modified soil, where lime is used to modify the plasticity of the soil, but not result in permanent stabilization When placed with an aggregate subbase, SEG provides a working platform for access of construction equipment, typically on subgrade with resilient modulus 4.0ksi to 6.5ksi (equivalent R-values of 5 to 10).
- For information on how to mitigate for expansive clay subgrade with plasticity index (PI) greater than 12, see Index 614.5 Expansive Soils.
- Perform a filter analysis if the soil material types described in Index 665.5(2) are either above or below the limits shown in Figure 665.5 when SEG_G is considered to determine natural filter criteria are met, to control migration of fines into the subbase or aggregate base materials.
- For applications involving drainage and filtration, the design engineer should verify that the permeability of SEG_T is greater than the permeability of the soil.
- If SEG_T is to be placed in direct contact with recycled concrete material, SEG_T made of polyester should not be used. Otherwise, a separating layer (such as an aggregate base) with thickness greater than 0.33 feet (minimum of 4”) must be placed to separate the geotextile from the recycled concrete material.
- SEG is not necessary if chemical stabilization such as lime or cement treatment of the subgrade is planned.

665.8 Subgrade Stiffness Enhancement with SEG

The use of SEG on weak subgrade (with modulus < 15 ksi or equivalent R-value < 25) can increase the effective stiffness of such soils. Therefore, the benefit of using SEG on such weak soils can be realized by using thinner aggregate bases or subbases in flexible pavement design. Likewise, SEG can also affect the design of rigid pavements by providing a stronger subgrade foundation.

The following resilient modulus values are recommended for designing SEG per Figure 665.5 on subgrade with low modulus values (less than 15 ksi [equiv. R-value 25]):

- For subgrade with a resilient modulus of equal or greater than 4 ksi (equiv. R-value 5) and less than 12 ksi (equiv. R-value 20), a design modulus value of 12 ksi can be used if SEG_G is utilized.
- When subgrade has a modulus value equal to or greater than 12 ksi (equiv. R-value 20) and less than 15 ksi (equiv. R-value 25), a design modulus value of 15 ksi can be used if SEG_G is utilized. An additional geotextile separator (SEG_T) may be used above the SEG_G to provide for the function of filtration and separation unless the aggregate base material meets the natural filter criteria presented in Index 665.5(2).

665.9 SEG Abbreviations and Definitions

The following is a list of definitions related to subgrade enhancement geosynthetics and their applications:

Apparent Opening Size: A geotextile property that indicates the approximate diameter of the largest soil particle that would effectively pass through the geotextile. Commonly, 95 percent of the geotextile openings are required to have that diameter or smaller as measured using ASTM D4751.

Aperture Shape: Describes the shape of the geogrid opening.

Aperture Size: Dimension of the geogrid opening.

D_{15}: The particle (or grain) size represented by the "15 percent passing" point when conducting a sieve analysis of a soil sample.

D_{50}: The particle (or grain) size represented by the "50 percent passing" point when conducting a sieve analysis of a soil sample.

D_{85}: The particle (or grain) size represented by the "85 percent passing" point when conducting a sieve analysis of a soil sample.

Filtration: The process of allowing water out (perpendicular to plane of geotextile) of a soil mass while retaining the soil.

Geogrid: A geosynthetic formed by a regular network of integrally connected tensile elements with apertures of sufficient size to allow "strike-through" and interlocking with surrounding soil, rock, or earth to improve the performance of the soil structure.

Geosynthetic: A group of synthetic materials made from polymers that are used in many transportation and geotechnical engineering applications.

Geotextile: A permeable sheet-like geosynthetic which, when used in association with soil, has the ability to provide the functions of separation, filtration, reinforcement, and drainage to improve the performance of the soil structure.

Grab Tensile Strength: The maximum force applied parallel to the major axis of a geotextile test specimen of specified dimensions that is needed to tear that specimen using ASTM D4632.

Nonwoven Geotextile: A planar geotextile typically manufactured by putting small fibers together in the form of a sheet or web, and then binding them by mechanical, chemical and/or solvent means.

Woven Geotextile: Produced by interlacing two or more sets of yarns, fibers, or filaments where they pass each other at right angles.

Permeability: The permeability of soil or geotextile is the flow rate of water through a soil or geotextile. The permeability of a geotextile can be determined by permittivity, which can be measured using ASTM D4491, multiplied by its effective thickness and the permeability of soil can be measured using ASTM D2434 or 5084.

Permittivity: The volumetric flow rate of water per unit cross-section area of a geotextile, per unit head, in the normal direction through a material as measured using ASTM D4491.

Puncture Strength: The measure of a geotextile's resistance to puncture determined by forcing a probe through the geotextile at a fixed rate using ASTM D6241.10.

Reinforcement: The improvement of the soil system by introducing a geosynthetic to enhance lateral restraint, bearing capacity, and/or membrane support.

Separation: A geotextile function that prevents the intermixing between two adjacent dissimilar materials, so that the integrity of the materials on both sides of the geotextile remains intact.

Stabilization: The long-term modification of the soil by the coincident functions of separation, filtration, and reinforcement furnished by a geosynthetic.

Tear Strength: The maximum force required to start or to propagate a tear in a geotextile specimen of specified dimensions using ASTM D4533.

Ultraviolet Stability: The ability of a geosynthetic to resist deterioration from exposure to the sun’s ultraviolet rays as tested using ASTM D4355.

Topic 666 – Foundation Mechanistic-Empirical Parameters for Flexible Pavements

666.1 Layer Stiffness

(1) Use. The mechanistic-empirical (ME) method for flexible pavement design requires the stiffness and its variability for each layer. In CalME, different stiffness models are used for different layers depending on the material type:

- For cement bound materials, layer stiffness is affected by damage caused by traffic. This is the case for CTPB, CTB, CB, LCB, LSS, CSS, FDR-C, FDR-L, CCPR-C, and CCPR-L.
- For asphalt bound materials, layer stiffness is a function of layer temperature and traffic speed, and damage caused by traffic. The function is typically referred to as the stiffness master curve. This is the case for HMA, FDR-FA, PDR-FA, PDR-EA, CCPR-FA, and CCPR-EA. Although they use the same basic models in CalME, FDR and PDR have different coefficients than HMA reflecting that they are not as completely and continuously bound by the asphalt binder as HMA.
- For unbound materials, layer stiffness is a function of over-burden confinement and the magnitude of axle load. This is the case for aggregate base, aggregate subbase, FDR-N (no stabilization) and all subgrade.

For each stiffness model, there is a parameter called the reference stiffness that represents the typical loading condition and controls the overall magnitude of the stiffness.

In CalME, each material in the built-in Standard Materials Library has an applicable stiffness model. Each material has default values for the reference stiffness and its variability.

Table 614.3 provides default reference stiffnesses for subgrade soils based on their classification using the Unified Soils Classification System along with their Poisson's ratios (v). Refer to Table 614.2 for the Unified Soil Classification System.

Table 663.3 provides default reference stiffnesses of the bases and subbases typically encountered in constructing flexible pavements along with their Poisson's ratios (v), a parameter also required for design using the ME methods.

The default values should be overwritten by values determined through site investigation when applicable (refer to the Site Investigation Guide).

(2) Determination. The layer stiffness in a pavement can be determined by several means depending on project size, and whether the design is for new construction, reconstruction, or rehabilitation.

- In the laboratory, the resilient modulus of an unbound material is measured under a variety of conditions simulating the physical (e.g., moisture, density, etc.) and stress state conditions of the material subjected to moving wheel loads. Experimentally, it is determined from a relationship between stress and deformation of the material derived using a modified repeated load triaxial testing machine. The loading device in this specialized automated machine is capable of applying repeated cycles of haversine-shaped load pulses of 0.1 second duration followed by a rest period (0.9 seconds for hydraulic loading devices and 0.9-3.0 seconds for pneumatic loading devices) in accordance with the procedure described in AASHTO T 307, (Standard Method of Test for Determining the Resilient Modulus of Soils and Aggregate Materials). Numerically, it is calculated as the ratio of applied deviator stress (vertical stress less confining pressure) to recoverable or resilient strain. The resilient modulus determined using this procedure represents the elastic modulus of the tested materials which recognizes certain nonlinear characteristics. The resilient modulus derived from experiments conducted on material samples could be used in designing a flexible pavement using the ME design method.

- In the field, the following methods (when appropriate) can be used either independently or in combination to determine layer stiffness:
  - FWD deflection testing followed by the back-calculation analysis described in Index 635.4 can be used to determine layer stiffnesses for all materials. For detailed information refer to CT 357 and the "Site Investigation Guide" *Need to provide a link*
  - Dynamic cone penetrometer (DCP) tests can be used to estimate layer stiffness through the correlation between penetration rate and soil stiffness.
  - USCS classification of unbound materials can be used to estimate typical layer stiffness.

Refer to the Site Investigation Guide for more details.

666.2 Rutting Resistance

(1) Use. The mechanistic-empirical (ME) method for flexible pavement design requires rutting resistance model parameters. In CalME, different rutting models are used for different layers depending on the material type:

- For cement and lime stabilized materials, rutting is negligible. This is the case for CTPB, CTB, CB, LCB, FDR-C, FDR-L, CCPR-C, CCPR-L, LSS, and CSS.
- For asphalt bound materials, rutting is dependent on the shear stress caused by the traffic load. Rutting is only calculated in HMA layers that are within 0.33 ft of the pavement surface, where temperatures and shear stresses are high enough to cause rutting. This is the case for HMA, FDR-FA, PDR-FA, PDR-EA, CCPR-FA, and CCPR-EA.
- For unbound materials, rutting is dependent on the vertical strain at the top of the layer. This is the case for aggregate base, aggregate subbase, FDR-N, and all subgrades.

In CalME each material in the built-in Standard Materials Library has an applicable rutting model. Each material has corresponding rutting model parameters. It is important to select the appropriate material type for each layer. For subgrades, the material type is defined by the USCS classification.