

CHAPTER 660 PAVEMENT FOUNDATIONS

Topic 661 - Engineering Considerations

Index 661.1 – Description

Pavement foundations typically consist of the following pavement structure layers:

- Base,
- Subbase including stabilized soils, and
- Subgrade or basement soil.

Depending on the type of pavement project and other design considerations, a pavement structure may or may not include base, subbase, or both base and subbase layers. 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 treated to improve strength. The most common treatment materials are cement, lime, asphalt, and geosynthetics.

661.2 Purpose

Pavement foundations serve as a support for the surface layer and distribute the wheel loads to subgrade material.

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

- Slow down the intrusion of fines through upward pumping from the subgrade soil into pavement surface structural layer.
- Minimize the damage caused by frost action.
- Prevent the accumulation of free water within or below the pavement structure.
- Provide a working platform for construction equipment.

Topic 662 - Types of Bases

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 gradation and the amount of fines. There are two classes of aggregate bases: Class-1 and Class-2. The gradation of the aggregates can affect structural capacity, drainage, and frost susceptibility. The quality of aggregate base material affects the rate of load distribution and drainage.

662.2 Treated Base

(1) *Hot Mix Asphalt Base (HMAB)*. Depending on the quality of aggregate, HMAB is classified as dense-graded Type A or Type B Hot Mix Asphalt, (HMA). Type A is primarily a crushed aggregate, which provides greater stability than Type B. When used with HMA pavement, the HMAB is to be considered as part of the pavement layer. The HMAB will be assigned the same gravel factor, G_r , as the remainder of the HMA in the pavement structure.

(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 reduced 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 primarily intended for concrete pavement structures. Concrete bases can utilize materials that develop strength and/or set quickly. 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 replacement.

(3) *Treated Bases*. Treated bases are granular materials mixed with asphalt or portland cement to improve the strength or stiffness. Treated bases include cement treated base (CTB) and asphalt treated base (ATB). CTB has shown poor performance under rigid pavement in the past. CTB exhibits excessive pumping, faulting, and cracking. This is most likely due to impervious nature of the base, which traps moisture and yet can break down

and contribute to the movement of fines beneath the slab.

662.3 Treated Permeable Base

Treated permeable bases (TPB) provide a strong, 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 provide greater drainage capacity than is needed. The standard thickness is based primarily on constructability with an added allowance to compensate for construction tolerances. If material other than ATPB and CTPB with a different permeability is used, it is necessary to check the permeability and structural adequacy of the layer thickness. TPB must be used in accordance with a positive sub-drainage system per Index 651.2.

Erosion (water washing away cement paste, and fines) and stripping (water damaging the bond between the asphalt binder and aggregate) can be an issue for TPB. Research conducted in the 1990s at the University of California Pavement Research Center (UCPRC) indicates that the use of ATPB is highly susceptible to stripping. Because of this, the Department recommends use of standard aggregate base (AB), with a compaction of the HMA layer of at least 93 percent of theoretical Rice maximum, instead of ATPB for new pavement structures. When ATPB is needed, such as to ensure continuity of existing ATPB/CTPB layer and/or provide drainage through the pavement structure, special provisions should be made to ensure that it is not subjected to conditions that will lead to premature structural failure. The following guidelines should be followed when using ATPB on State highway pavement projects.

- (1) *Considerations for using ATPB.* The following two conditions warrant consideration to use ATPB layer in the pavement structure:
 - (a) When widening or adding lanes adjacent to an existing ATPB layer to ensure continuity of existing ATPB layer.
 - (b) Where there is need to drain excess water through the pavement, such as when the uphill side of pavement does not allow for drainage. However, when practical, it is better in such cases to use sub-surface drainage to carry water to the other side of

the roadway rather than drain excess water through an ATPB layer just below the HMA.

- (2) *Added features when using ATPB.* The following features are recommended when using ATPB:
 - (a) Use edge drains or daylight the edges (see Figure 651.2A in Chapter 650).
 - (b) 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.
 - (c) Try to use permeable backfill in shoulders on sides of edge drain to avoid bathtub effect if edge drain becomes clogged.
 - (d) Increase binder content to 3 percent (maybe higher).
 - (e) Tack coat each layer.
 - (f) Perform moisture sensitivity testing on ATPB.
 - (g) Compaction of the HMA layer should be at least 93 percent of theoretical Rice maximum.

662.4 Subbase

Aggregate subbase is similar to aggregate base but with less restrictive quality requirements. Because of continual depletion of quarry aggregates, most subbases typically consist of recycled pavement 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 cementitious binder to improve 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 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 soil can be used as a substitute for all or part of the required subbase.

The District Materials Engineer should be contacted to assist with the selection of the most appropriate method to stabilize soils for individual projects. 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

Because different types of treated and untreated base or subbase materials have different capacities for resisting forces imposed by traffic loads, this factor must be considered when determining the thickness of pavement elements. Besides load carrying consideration, the final selection of the bases or subbases for a given project depends on several other factors such as available materials, terrain, climate, economics, and past performance of the pavement under similar project or climate conditions and travel patterns. The District Materials Engineer should be contacted for the latest guidance in base and subbase materials among other related engineering considerations.

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. Table 663.2 provides the properties for base and subbase materials used for the Rigid Pavements design catalogs.

663.3 Base and Subbase for Flexible Pavements

For flexible pavements, the capacity of treated or untreated base and subbase materials to resist traffic loads is considered by use of the California R-value and the gravel factor, G_f , which expresses the relative stiffness of various materials when compared to gravel. Table 663.3 provides the

California R-value and G_f for base and subbase materials used in the design of flexible pavements using the empirical procedure outlined in Chapter 630.

When the stabilized soil is substituted for aggregate subbase for flexible pavements, as discussed in Index 662.4, the actual thickness of the stabilized soil layer is obtained by dividing the GE by the appropriate G_f . The gravel factor G_f is determined based on unconfined compressive strength (UCS) of the stabilized material as follows:

$$G_f = 0.9 + \frac{UCS(psi)}{1000}$$

This equation is only valid for UCS of 300 psi or higher at 28 days cure. For cement and lime 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. Refer to the Department Test Method 373. The gravel factor G_f allowed using this equation should range from a minimum of 1.2 to a maximum of 1.7.

Because the stabilization of soil may be less expensive than the base material, the calculated base thickness can be reduced and the stabilized soil thickness increased. The base thickness is reduced by the corresponding gravel equivalency provided by the cement or lime stabilized soil. The maximum thickness of lime and cement treated subgrade is limited to 2 feet.

For flexible pavement design with the mechanistic-Empirical (ME) method, the strength of base and subbase materials (as well as subgrade soils) is expressed in terms of the resilient modulus. Refer to Topic 666 for discussion and proposed values of resilient modulus to be used in the ME method.

Topic 664 - Subgrade Enhancement

664.1 Overview

Properties of low quality subgrade can be improved to provide a platform for the construction of subsequent layers and to provide adequate support for the pavement over its design life. The most common methods used in the Department for subgrade improvement include:

Table 663.2

Base and Subbase Material Properties for Rigid Pavement Catalog

HMA Type A Properties	
Aggregate gradation	0% retained on $\frac{3}{4}$ inch sieve 32% retained on $\frac{3}{8}$ inch sieve 52% retained on No. 4 sieve 5.5% passing No. 200 sieve
Asphalt binder type	See Index 632.1(2) and Table 632.1
Reference temperature	70 °F
Poisson's ratio	0.35
Effective binder content	11.662%
Air voids	8%
Total unit weight	149 lb/ft ³
Thermal conductivity	0.657 Btu/hr ft °F
Heat capacity	0.23 Btu/lbm-°F
Base erodibility index ⁽¹⁾	2
LCB / LCBRS ⁽¹⁾ Properties	
Unit weight	150 lb/ft ³
Poisson's ratio	0.20
Elastic modulus	2.00 × 10 ⁶ psi
Thermal conductivity	15 Btu-in/h-ft ² -°F
Heat capacity	0.28 Btu/lbm-°F
Base erodibility index ⁽¹⁾	1
AB / AS Properties	
Poisson's ratio	0.40
Coefficient of lateral pressure, K ₀	0.5
Resilient modulus for AB	43,500 psi
Resilient modulus for AS	29,000 psi
Plasticity Index	1
Passing No. 200	3%
Passing No. 4	20%
D ₆₀ ⁽²⁾	0.315 inch
Base erodibility index ⁽³⁾	4

NOTES:

- (1) LCB / LCBRS = Lean Concrete Base / Lean Concrete Base Rapid Setting
- (2) D₆₀ = Particle diameter at which 60 percent of the material sample is finer than or would pass a sieve size of that diameter.
- (3) Base erodibility index is classified as a number from 1 to 5 as follows:
- 1 = Extremely erosion resistant material
 - 2 = Very erosion resistant material
 - 3 = Erosion resistant material
 - 4 = Fairly erodible material
 - 5 = Very erodible material

Table 663.3**Gravel Factor and California R-value for Bases and Subbases Used in Flexible Pavement Design**

Type of Material	Abbreviation	California R-value	Gravel Factor (G_f)
Aggregate Subbase	AS-Class 1	60	1.0
	AS-Class 2	50	1.0
	AS-Class 3	40	1.0
	AS-Class 4	specify	1.0
	AS-Class 5	specify	1.0
Aggregate Base	AB-Class 2	78	1.1
	AB-Class 3	specify	1.1 ⁽¹⁾
Asphalt Treated Permeable Base	ATPB	NA	1.4
Cement Treated Base	CTB-Class A	<u>NA</u>	1.7
	CTB-Class B	80	1.2
Cement Treated Permeable Base	CTPB	NA	1.7
Lean Concrete Base	LCB	NA	1.9
Lean Concrete Base Rapid Setting	LCBRS	NA	1.9
Hot Mix Asphalt Base	HMAB	NA	⁽²⁾
Lime Stabilized Soil	LSS	NA	$0.9+(UCS/1,000)$
Cement Stabilized Soil	CSS	NA	$0.9+(UCS/1,000)$

NOTES:

- (1) Must conform to the quality requirements of AB-Class 2.
- (2) When used with HMA, the HMAB is to be considered as part of the pavement layer. The HMAB will be assigned the same G_f as the remainder of the HMA in the pavement structure.

Legend:

NA = Not Applicable

UCS = Unconfined Compressive Strength in psi (minimum 300 psi per California Test 373) for lime and ASTM D 1633 (modified) for cement

- Mechanical stabilization;
- Chemical stabilization; or
- Subgrade enhancement geosynthetics, see Topic 665.

664.2 Mechanical Subgrade Enhancement

Improving strength is usually the primary reason for implementing mechanical stabilization. Mechanical subgrade enhancement includes the following:

- (1) *Compaction.* Sufficient strength can often be achieved on certain subgrade materials that do not quite meet the design requirements by additional compaction usually with a heavier or different type of roller than is normally used. Compaction improves aggregate interlock, and reduces air-void content, pore connectivity, and consequent susceptibility to moisture ingress.
- (2) *Blending.* Blending involves the mixing of materials that have different properties (typically particle size distribution) 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.

664.3 Chemical Stabilization

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, asphalt, or fly ash (asphalt and fly ash are not currently supported in the Department's Standard Specifications or guidelines). Chemically treated soil samples should be tested to determine the unconfined strength for 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 strength of 300 psi.

664.4 Subgrade Enhancement Geosynthetics

Subgrade enhancement geosynthetics are geotextile (also called fabric) or geogrid 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.

Topic 665 - Subgrade Enhancement Geosynthetic Fabrics

665.1 Purpose

Subgrade Enhancement Geosynthetic (SEG) can be either a Subgrade Enhancement Geotextile (SEG_T) or Subgrade Enhancement Geogrid (SEG_G) 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 and, when using SEG_T, provides a separation function between soft subgrade (with a high amount of fines) susceptible to pumping and high quality subbase or base materials. On weak subgrade, the use of SEG_T can also provide a stabilization function (i.e., the coincident function of separation and reinforcement). As the soft soil undergoes deformation, properly placed SEG when stretched will mobilize its tensile strength properties necessary for providing its benefits. Other benefits of using SEG include:

- Prevent premature failure and reduce long-term maintenance costs;
- Potential cost savings:
 - Reduce subbase or aggregate base thickness in some situations,
 - Reduce or eliminate the amount of soft or unsuitable subgrade materials to be removed,
- Increased performance life and reliability of the pavement;
- Prevent contamination of the base materials (when using SEG_T);

- Better performance of a pavement over soils subject to freeze/thaw cycles;
- Reduced disturbance of soft or sensitive subgrade during construction; and
- 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 shall 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 the geosynthetic applications:

- Atterberg Limits Tests: CT 204 or alternatively ASTM D 4318 or AASHTO T90.
- R-value Test: CT 301 or alternatively California Bearing Ratio (CBR) test (ASTM D 1883) or AASHTO T 193.
- Sieve Analysis: CT 202 or alternatively ASTM C 136 or AASHTO T27.

665.4 Mechanical Stabilization Using SEG

SEGs (SEG_T and SEG_G) achieve mechanical stabilization through slightly 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

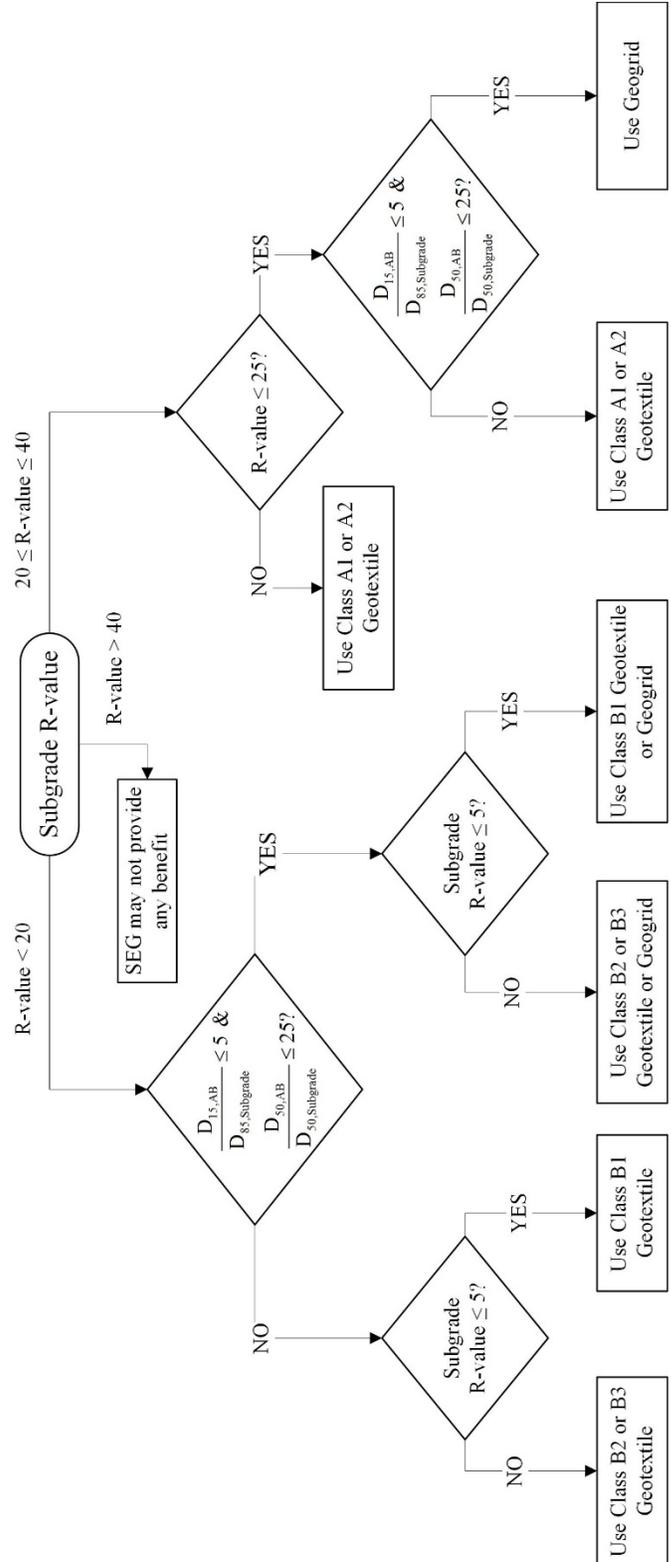
these materials to prevent the aggregate and subgrade from mixing. It can also reduce excess pore water pressure through a mechanism of filtration and drainage. Secondary mechanisms of a geotextile are lateral restraint and reinforcement. Lateral restraint is achieved through friction between the surface of the geotextile and the subbase or base materials. Reinforcement mechanism requires deformation of the subgrade and stretching of the geotextile to engage the tensile strength and create a "tensioned membrane."

- (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 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 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 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 the 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.

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 and subgrade layer. The primary functions of geotextiles are separation, stabilization, filtration, reinforcement, and drainage.
- (2) *Selecting SEG*. SEG can be generally selected based on the following criteria:

Figure 665.5
Flowchart for SEG Selection



- For subgrade R-values greater than 25 but less than 40, SEG_T is recommended to use for its separation function. The requirements for separation function can be found in Section 96 of the Standard Specifications.
- For subgrade R-value between 20 and 25, generally an SEG_G is 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.
- For subgrade R-value less than 20, a designer may choose either SEG_G or SEG_T .
- For subgrade R-value greater than 40, the use of any SEG type may not provide any benefit.

Use the flowchart shown in Figure 665.5 for the optimal selection of the most appropriate type of geotextile or geogrid based on subgrade R-value and gradation of the subgrade and aggregate base materials.

Before selecting SEG, the engineer should investigate the potential engineering and economic benefits of using SEG_T or SEG_G .

665.6 Application of SEG

(1) *Appropriate Applications.* Locations that may require placement of SEG 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 (CH), silt (ML), high plasticity or micaceous silt (MH), organic soil (OL/OH), and peat (PT);
- Low undrained shear strength: $C_u < 2,000$ psf, and/or other properties stated below in Index 665.6(2);
- High water table and high soil sensitivity
- Shallow utilities or contaminated soils.

(2) *Conditions for Using SEG.*

- SEG_G is most applicable for subgrade R-values < 25 or $CBR < 3.5$ or resilient modulus $M_r < 5,000$ psi. For R-value between 25 and 40 or CBR between 3.5 and 6.5 or M_r between 5,000 and 9,500 psi the engineer may consider utilizing a geogrid for base reinforcement. Refer to Topic 666 for additional information on resilient modulus.
- SEG_T is most applicable for subgrade R-value < 20 or $CBR < 3$ or $M_r < 4,500$ psi. For subgrade R-values between 20 and 40 or CBR between 3 and 6.5 or M_r between 4,500 and 9,500 psi, the engineer may consider utilizing a SEG_T as a separator.
- On very soft subgrade conditions (R-value < 10 or $CBR < 2$ or $M_r < 3,000$ psi), consider placing a thicker initial lift (minimum of 6 inches) of subbase or aggregate base material on top of SEG to effectively bridge the soft soils and avoid bearing capacity failure under construction traffic loading.
- Use of geogrid is not recommended unless the aggregate material meets the following natural filter criteria:
 - $(D_{15} \text{Aggregate Base} / D_{85} \text{Subgrade}) \leq 5$ and $(D_{50} \text{Aggregate Base} / D_{50} \text{Subgrade}) \leq 25$, 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.
- Do not use geosynthetics for subgrade with R-value > 40 or $CBR > 6.5$ or $M_r > 9,500$ psi, because stabilization of subgrade is not required and application of geosynthetics will not impart significant benefit to the pavement.

665.7 Other Design Considerations

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

- On soft subgrade soils, the SEG may replace some or all stabilizing material such as lime or cement used solely as a working platform to provide access to construction equipment.
- For information on how to mitigate for expansive subgrade consisting of clay soils with plasticity index (PI) greater than 12, see Index 614.4.
- Consider using SEG for longer life pavement, if not otherwise specified.
- Perform a filter analysis if the soil material types described in Index 665.6(1) are either above or below limits shown in Figure 665.5 when SEG_G is considered to determine whether 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 the SEG_T is greater than the permeability of the soil.
- If a 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 of thickness greater than 0.3 feet (such as aggregate base) must be placed to separate the geotextile from the recycled concrete material.
- SEG is not necessary if the subgrade is planned for chemical stabilization such as lime or cement treatment.

665.8 Subgrade R-value Enhancement with SEG

Subgrade soils with R-value < 20 are considered poor or weak soils and require SEG to provide reinforcement as the primary function and separation as the secondary function. However, depending on type and treatment of the base layer, pavements constructed over subgrade soils with R-value up to 40 can benefit from separation if the subgrade soil contains an appreciable amount of

fines. The SEG when placed with aggregate subbase provides a working platform for access of construction equipment, mainly on subgrade with R-values of 5 to 10.

The use of SEG on weak subgrade (with R-value < 20) can increase the effective R-value of such soils. Therefore, the benefit of using SEG on such weak soils can be realized though 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 R-values are recommended when SEG is used on subgrade with low R-value less than 25:

- For subgrade with an R-value of less than 20, a design R-value of 20 can be used if SEG_T is utilized.
- When subgrade has an R-value of less than 25, a design R-value of 25 can be used if SEG_G is utilized. An additional geotextile separator (SEG_T) may be used beneath 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 665.6(2).

Additional information on the use of SEG and the selection of the appropriate properties of the SEG based on project specifics are explained in the “Subgrade Enhancement Geosynthetic Design and Construction Guide” available on the Department Pavement website.

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 D 4751.

Aperture Shape: Describes the shape of the geogrid opening.

Aperture Size: Dimension of the geogrid opening.

D₁₅: The particle (or grain) size represented by the "15 percent passing" point when conducting a sieve analysis of a soil sample.

D₅₀: The particle (or grain) size represented by the "50 percent passing" point when conducting a sieve analysis of a soil sample.

D₈₅: 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 D 4632.

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.

Permeability: The permeability of soil or geotextile is the flow rate of water through a soil or geotextile. The permeability of geotextile can be determined by permittivity, which can be measured using ASTM D 4491, multiplied by its effective thickness and the permeability of soil can be measured using ASTM D 2434 or 5084.

Permittivity: It is 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 D 4491.

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 D 6241. 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 D 4533.

Ultraviolet Stability: The ability of a geosynthetic to resist deterioration from exposure to the ultraviolet rays of the sun as tested using ASTM D 4355.

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

Topic 666 – Foundation Strength Parameters for Mechanistic-Empirical Design of New Construction and Rehabilitation of Flexible Pavements

666.1 Resilient Modulus

(1) *Use*. Unlike the empirical procedure for flexible pavement design which is based on gravel factors (G_r) and/or R-value of the subgrade, bases, and subbase materials, the mechanistic-empirical (ME) methods for flexible pavement design and rehabilitation require the strength for these foundation materials to be expressed in terms of the resilient modulus, M_r . The resilient modulus is both (1) the input strength parameter in the

Department's flexible pavement design methods encoded into the CalME program, and (2) output strength parameter obtained from the back-calculation procedure encoded into CalBack for existing pavement rehabilitation. In the ME method, all layers except the HMA and RHMA-G layers are assigned resilient modulus (different strength parameter is assigned for asphaltic materials that must be derived from advanced laboratory testing). For rehabilitation, the back-calculated resilient moduli of all layers including asphaltic layers are obtained and used in the ME rehabilitation method. Refer to Index 635 for additional information.

(2) *Determination.* The resilient modulus of a material may be found in a number of ways depending on need, whether the material is standard or nonstandard, and whether the design is for new construction or rehabilitation.

- In the laboratory, the resilient modulus of a material (e.g., nonstandard 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 repetitive triaxial testing machine. The loading device in this specialized automated machine is capable of applying repeated cycles of haversine-shaped load pulse of 0.1 second duration followed by a rest period (0.9 seconds for hydraulic loading device and 0.9-3.0 seconds for pneumatic loading device) 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 recognizing certain nonlinear characteristics. The resilient modulus derived from laboratory experiments

conducted on material samples could be used in designing a new flexible pavement using the ME design method.

- For new flexible pavement design using the Department's ME method, the resilient modulus of bases, subbases, and subgrade soils are obtained from the standard materials library currently available in CalME.

Table 666.1A provides representative resilient moduli of most standard bases and subbases typically encountered in constructing new pavements along with their Poisson's ratios (ν); a parameter also required for design using the ME methods.

Table 666.1B provides typical resilient modulus values for subgrade soils based on their classification using the Unified Soils Classification System along with their Poisson's ratios (ν). Refer to Table 614.2 for soil classification.

For nonstandard materials, the resilient modulus must be determined experimentally using the AASHTO T 307 test procedure as described above.

For rehabilitation of an existing flexible pavement using the Department's ME method, FWD deflection testing followed by back-calculation analysis described in Index 635.4 are necessary for the determination of in-situ resilient modulus of each layer. The obtained in-situ modulus values must be used in the ME-based rehabilitation method.

Table 666.1A

**Typical Resilient Modulus and
Poisson's Ratio for Standard
Base and Subbase Materials
Used in ME-Based Flexible
Pavement Design**

Material ⁽¹⁾	Resilient modulus, M_r (psi)	Poisson's Ratio, (ν)
AB-Class 2	45,000	0.35
CTB-Class A	1,400,000	0.20
CTB-Class B	1,100,000	0.20
CTPB	1,100,000	0.20
LCB	870,000	0.20
AS-Class 1	35,000	0.35
AS-Class 2	30,000	0.35
AS-Class 3	25,000	0.35
Lime or cement stabilized soil ⁽²⁾	$0.124 \times \text{UCS} + 9.98$	0.20

NOTES:

- (1) For definition, see Table 663.3.
- (2) UCS is the unconfined compressive strength of the stabilized material in psi measured according to California Test Method 373 with the modification that samples are oven-cured at 105° F for 5 days.

Table 666.1B

**Typical Resilient Modulus and
Poisson's Ratio for Subgrade
Soils Used in ME-Based Flexible
Pavement Design**

Soil Classification	Resilient Modulus, M_r (psi)	Poisson's ratio, (ν)
CH	4,000	0.35
CL	9,000	0.35
GC	20,000	0.35
GM	30,000	0.35
GP	29,000	0.35
GW	38,000	0.35
MH	6,000	0.35
ML	11,000	0.35
SC	14,000	0.35
SM	21,000	0.35
SP	17,000	0.35
SW	21,000	0.35