SUBGRADE ENHANCEMENT GEOSYNTHETIC DESIGN AND CONSTRUCTION GUIDE

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Disclaimer

This guide presents an overview of subgrade enhancement geosynthetic design for efficient use of geotextile and geogrid for the subgrade enhancement. This guide is intended as guidance and is not a substitute for good engineering judgment. This guide is intended for the use of Caltrans personnel. Engineers and agencies outside of Caltrans may use this guide at their own discretion. Caltrans is not responsible for any work performed by non Caltrans personnel using this guide.

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1.0 Purpose

The purpose of this guide is to assist pavement design engineers in the selection of an appropriate Subgrade Enhancement Geosynthetic (SEG) including Geotextile (SEG_T) and Geogrid (SEG_G).

SEG is a geotextile or geogrid 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. Geotextiles and geogrids achieve mechanical stabilization through slightly different mechanisms:

- **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."
- **Subgrade Enhancement Geogrid (SEG_G).** A geogrid's primary stabilization mechanism 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.

SEG benefits 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;
- 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.

2.0 Application

2.1 Appropriate Applications

SEG can be applicable for a variety of following project conditions:

- 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: Cu < 2,000 psf, California R-value < 20, California Bearing Ratio (CBR) <3 or Resilient Modulus (M_R) < 4,500 psi;
- High water table and high soil sensitivity
- Shallow utilities or contaminated soils.

2.2 Conditions for Using SEG

- SEG_G is most applicable for R-values < 25 or CBR < 3.5 or 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 designer may consider utilizing a geogrid for base reinforcement.
- SEG_T is most applicable for R-value < 20 or CBR < 3 or M_R < 4,500 psi. For R-values between 20 and 40 or CBR between 3 and 6.5 or M_R between 4,500 and 9,500 psi, the designer 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), it may be necessary to place 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 (FHWA, 2008):
    - $D15_{Aggregate\ Base} / D85_{Subgrade} \leq 5$ and $D50_{Aggregate\ Base} / D50_{Subgrade} \leq 25$:
    - D15, D85, and D50 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. These requirements can be found in Table 1.
- Do not use geosynthetics for subgrade with R-value > 40 or CBR > 6500 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.

2.3 Required Tests

Geotechnical soil laboratory tests including following tests are required to evaluate subgrade for the geosynthetic applications:

- Atterberg Limit Tests: CT 204 or alternatively ASTM D 4318 or AASHTO T90

- R-value test: CT 301 or alternatively California Bearing Ratio (CBR) test (ASTM D1883) or AASHTO T 193
- Sieve Analysis: CT 202 or alternatively ASTM C136 or AASHTO T27

3.0 Selecting Geosynthetic Type and Design Parameters

3.1 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. Figure 1 shows a flowchart to aid in selecting the possible functions and types of geotextile and geogrid.

3.2 Selecting SEG

SEG can be selected based on the following criteria:

- For subgrade R-values less than 40 and greater than 25, SEG_T is recommended to use for its separator function. The property requirements for separator function can be found in Table 1.
- For subgrade R-value between 25 and 20, SEG_G should be used for its stabilization function. The property requirements for SEG_G can be found in Table 2.
- For subgrade R-value less than 20, a designer should choose either SEG_G or SEG_T. The property requirements can be found in Tables 1 and 2.

Before selecting SEG, the engineer should investigate the potential economic and intrinsic benefits of using it.

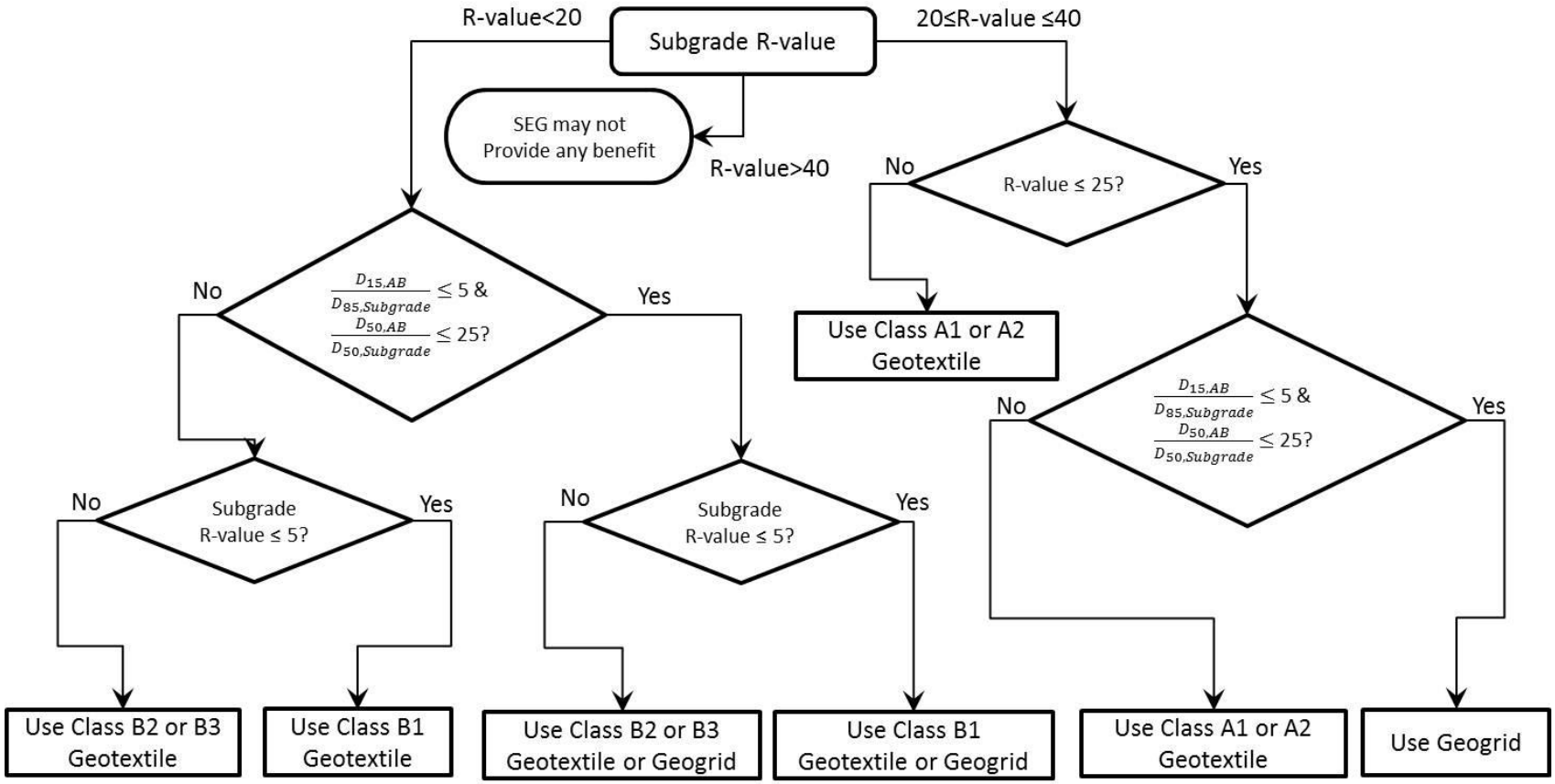

Figure 1. Flowchart for selecting an appropriate SEG

3.3 Property of Geosynthetics

Mechanical, physical, and other properties of geotextile (SEG_T) used for subgrade enhancement shall meet the requirements in Table 1.

Table 1. Property Requirements of Subgrade Enhancement Geotextile (SEG_T)

Property	Test Method	Separation Application		Stabilization Application		
		Caltrans Class A1 Woven	Caltrans Class A2 Nonwoven	Caltrans Class B1 Woven	Caltrans Class B2 Woven	Caltrans Class B3 Nonwoven
Elongation at break, %	ASTM D 4632	<50	≥50	<50	<50	≥50
Grab tensile strength (min), lb	ASTM D 4632	250	160	-	320	200
Wide width tensile strength (min) at 5% strain, lb/ft	ASTM D 4595	-	-	2,000		-
Wide width tensile strength (min) at ultimate strain, lb/ft	ASTM D 4595	-	-	4,800	-	-
Tear strength (min), lb	ASTM D 4533	90	60	-	120	80
Puncture strength (min), lb	ASTM D 6241	500	310	620	620	430
Permittivity (min), sec^{-1}	ASTM D 4491	0.05	0.05	0.20	0.20	0.20
Apparent opening size (max), inch	ASTM D 4751	0.012	0.012	0.024	0.012	0.012
Ultraviolet stability (retained strength after 500 hrs exposure) (min), %	ASTM D 4355	70	70	70	70	70

Notes:

(1) Values are based on MARV in the weaker principle direction except apparent opening size is based on maximum average roll value.

(2) Woven silt film geotextiles should not be used.

Property requirements for SEG_G are related to performance. Among the different property requirements of geogrid, the most important geogrid properties for subgrade enhancement related to the performance and survivability are tensile strength, junction strength, flexural rigidity, and aperture size.

Based on reviews and comparisons of property requirements, the property requirements for biaxial geogrid (SEG_G) in Table 2 are recommended.

Table 2. Property Requirements of Subgrade Enhancement Geogrid (SEG_G)

Property	Test	Value
Aperture size, inch[a] min and max	Calipered	0.8-1.3 x 1.0-1.6
Rib thickness, inch Min	Calipered	0.04
Junction thickness, inch Min	Calipered	0.150
Tensile strength, 2% strain, lb/ft[a] Min	ASTM D 6637	410 x 620
Tensile strength at ultimate, lb/ft[a] Min	ASTM D 6637	1,310 x 1,970
Ultraviolet resistance, percent min retained tensile strength, 500 hours	ASTM D 4355	100
Junction strength, lb/ft[a] Min	ASTM D 7737	1,220 x 1,830
Overall flexural rigidity, mg-cm Min	ASTM D 7748	750,000
Torsional rigidity at 20 cm-kg, mm-kg/deg[b] Min	GRI:GG9	0.65

[a]Machine direction x cross direction
[b]Geosynthetic Research Institute, Test Method GG9, *Torsional Behavior of Bidirectional Geogrids When Subjected to In-Plane Rotation*

Different types of geogrid can be used for SEG_G provided their stabilizing performance is equivalent to or greater than the specified SEG_G in Table 2. No additional credit is given for using different geogrid products.

3.4 Other Design Considerations

The following should also be considered by the pavement 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 table to provide access to construction equipment.
- For subgrade consisting of clay soils with plasticity index greater than 12, review Caltrans Highway Design Manual (HDM) Index 614.4 on how to mitigate for expansive soils.
- Consider using SEG for longer life pavement, if not otherwise specified.
- Perform a filter analysis if the soil material types described in Section 2.2 are on either side of SEG_G 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 an 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 must 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.

3.5 R-value Enhancement Using SEG

SEG_T: Subgrade with an R-value of less than 20, a design R-value of 20 can be used if subgrade enhancement geotextiles are utilized.

SEG_G: Based on published test results:

- Use a design R-value of 25 with use of SEG_G when existing subgrade has an R-value of below 25.
- Use additional geotextile separator unless the aggregate base material meets the natural filter criteria presented in Section 2.2.

4.0 Documenting on Plans, Specifications, and Estimates

4.1 Plans

For document use of SEG on project plans:

1. The typical cross sections should clearly show the location of SEG within the pavement or embankment section.
2. If separation geotextile is used with an SEG_G, the pavement cross section should show the location of separation geotextile which is typically placed at the subgrade interface (below the SEG_G).
3. Incorporate SEG as part of the Pavement Structure. Number to identify its limits on layouts and other plans.

4.2 Specifications

The specifications for SEG_T is provided in Caltrans Standard Specifications, Sections19-8 and 88-1.02O. The specifications for SEG_G is provided in SSP 19-10 Subgrade Enhancement Geogrid and RSS Section 88-1.02p. The specification Section 88 addresses material requirements and Section 19 addresses construction methods, inspection, acceptance requirements, measurement, and payment.

4.3 Estimating

The estimation process for the SEG sections must take into account furnishing geosynthetic materials and installation in addition to the standard estimating for conventional construction. The SEG is measured by the square yard of the covered area and does not include SEG required for overlaps.

4.4 Bid Item

SEG is measured and paid by the square yard of the surface area not including additional geogrid or geotextile required for overlaps.

5.0 Construction Consideration

SEG_T material can be damaged easily if mishandled during construction. SEG_G is somewhat more robust than SEG_T but it can also get damaged if mishandled during construction. Therefore, it is crucial that considerable attention be paid during placement of SEG to ensure that it will provide the expected benefits. SEG shall be placed directly on a cleared surface along the alignment to the limits shown on the plans. The surface to receive the geogrid or geotextile, immediately prior to placing, shall conform to the elevation tolerance and cross slopes as specified in the plans. Following are installation requirements:

- The subgrade to receive the SEG shall conform to the compaction and elevation tolerance specified in Section 25-1.03 and shall be free of loose or extraneous material and sharp objects that may damage the SEG during installation.
- SEG shall be positioned longitudinally along the alignment and pulled taut to form a wrinkle-free mat on the prepared surface.
- Adjacent borders of adjacent rolls of the geogrid or geotextile shall be overlapped a minimum of 2 feet. All roll ends shall be overlapped a minimum of 2 feet in the direction of the spreading of the aggregate subbase material. Overlap larger than 2 feet may be required for lower-strength subgrade (R-value $\leq$ 5).
- Thicker initial lift of subbase or aggregate base will require for a lower-strength subgrade (R-value < 10).
- Special care shall be taken in the handling of geogrids manufactured from polypropylene at temperatures at or below 0°F.
- Geotextile or geogrid damaged beyond repair during placement shall be replaced by placing a new geotextile or geogrid over the damaged area. The geotextile or geogrid overlap from the edge of the damaged area shall be a minimum of 3 feet

APPENDIX-A

Glossary of Terms:

The following is a list of definitions related to geosynthetics and their applications to be added in the new Subgrade Enhancement Geosynthetics (SEG) guide.

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.

D85: The particle (or grain) size represented by the "85 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.

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.

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

Resilient Modulus: The ratio of applied deviator stress to recoverable or resilient strain.

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.

APPENDIX-B

References:

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