CHAPTER 2 – REVIEW OF EXISTING NATIONAL GUIDELINES

In this chapter, national guidance for geosynthetic materials and applications as presented by AASHTO, FHWA, and Federal Lands Highway Divisions (FLHD) programs are reviewed. The documents summarized here range from standard construction specifications that define minimum properties for a particular product to be used on a given site, to manuals/guidelines and specifications giving step-by-step instructions for certain design and construction procedures.

AASHTO has a number of design and material specifications involving geosynthetics, mainly in the broader areas of pavement structures and retaining walls. Design guidelines are primarily for reinforcement of pavement subgrades and mechanically stabilized earth (MSE) walls. Material guidelines are wider ranging, specifying minimum survivability requirements for pavement overlays, filtration and separation geosynthetics, edge drains, erosion control and silt fences. These publications will be briefly reviewed here, focusing on applications within the scope of this study.

AASHTO Guide for Design of Pavement Structures

AASHTO (1993, 2002) contains no explicit guidelines for design of base course reinforcement with geosynthetics, subgrade stabilization, or for paving fabrics in rehabilitated asphalt overlays. However, this guide is often integral to the design procedures noted in the Federal Highway Documents discussed later in the "Pavement Overlays" chapter of the Geosynthetics Manual by Holtz et al. (1998). AASHTO's geosynthetic guidance for pavements seems only to be included in provisional standards or specifications.

AASHTO M 288-00

AASHTO M 288-00, "Geotextile Specification for Highway Applications" dictates target physical and material properties of a geotextile to be used on projects constructed using AASHTO specifications (AASHTO 2002). This document covers geotextiles for subsurface drainage (these are actually filtration specifications designed to prevent the migration of fines into a drainage media), separation, stabilization, permanent erosion control, silt fences, and paving fabrics. Drainage, erosion control and silt fences will not be covered in this report. The appendices of AASHTO M 288-00 include construction guidance which particularly cover thicknesses, required overlaps as a function of soil strength, and edge drain requirements.

AASHTO M 288-00 requires the geotextiles to be manufactured from long-chain synthetic polymers, and at least 95% by weight must be either polyesters or polyolefins (most likely polypropylene). The properties specified by AASHTO M 288-00 are all minimum average roll values (MARV) in the weakest direction. Apparent Opening Size (AOS) is the one exception, where the value specified is the maximum average roll value. The number of samples for quality control purposes of a geotextile is based on ASTM D

4759, and is usually determined by the smaller of a truckload or the entire shipment. ASTM D 4354 specifies how samples are collected for testing.

The AASHTO MARV values specified in AASHTO M 288-00 are reproduced in tabular form here for convenience. Table 1 shows the required properties relating to geotextile strength, as well as ASTM standards used for testing.

Table 1. AASHTO M 288-00 Geotextile Strength Property Requirements.

	Class 1		Class 2		Class 3	
	Elongation < 50%	Elongation ≥ 50%	Elongation < 50%	Elongation ≥ 50%	Elongation < 50%	Elongation ≥ 50%
Grab Strength	1400 N	900 N	1100 N	700 N	800 N	500 N
Sewn Seam Strength	1260 N	810 N	990 N	630 N	720 N	450 N
Tear Strength	500 N	350 N	400 N	250 N	300 N	180 N
Puncture Strength	500 N	350 N	400 N	250 N	300 N	180 N

For woven monofilament geotextiles, the minimum tear strength is 250 N.

Table 2 shows MARVs for the separation function, which is mainly to prevent mixing of subgrade and aggregate cover material. These values are applicable for soils with a California Bearing Ratio (CBR), a test used to determine subgrade strength in pavement applications, greater than three or undrained shear strength greater than 90 kPa in the field.

Table 2. AASHTO M 288-00 Separation Geotextile Property Requirements.

	Test Method	Requirements
Geotextile Class		Class 2 from Table 1
Permittivity	ASTM D 4491	0.02/s (greater than soil)
AOS	ASTM D 4751	0.60 mm max
UV Stability	ASTM D 4355	50% strength retained after 500 hrs exposure

Table 3 shows MARVs for the stabilization function. In wet, saturated soil conditions the geosynthetic may be used to provide filtration, separation, and in some cases reinforcement. Applicable soils are those with CBR between one and three and undrained shear strength ranges from 30 to 90 kPa. It is explicitly stated in the standard that these properties are not appropriate for embankment or pavement reinforcement, which are site specific design issues. Note that, other than requiring the strength based on geotextile class 1, there are no guidelines for selecting which strain level dictates or whether a particular modulus is required.

Table 3. AASHTO M 288-00 Stabilization Geotextile Property Requirements.

	Test Method	Requirements
Geotextile Class		Class 1 from Table 1
Permittivity	ASTM D 4491	0.05/s (greater than soil)
AOS	ASTM D 4751	0.43 mm max
UV Stability	ASTM D 4355	50% strength retained after 500 hrs exposure

Table 4 defines MARVs for paving fabrics, which act as waterproofing and a stress relief layer within the pavement structure. Specifications in Table 4 do not cover reinforcement applications such as reflective cracking, pavement joints and local or spot repairs.

Table 4. AASHTO M 288-00 Paving Fabric Requirements.

	Test Method	Requirements
Grab Strength	ASTM D 4632	450 N
Ultimate elongation	ASTM D 4632	≥ 50%
Mass per unit area	ASTM D 5261	140 gm/m^2
Asphalt Retention	ASTM D 6140	Manufacturer (1/m^2)
Melting Point	ASTM D 276	150^{o}C

These specifications exist to satisfy minimum survivability concerns. Guidelines for secondary functions related to burst strength, impact strength, and fatigue were not included as part of these specifications. If a particular design resulted in one or more of these functions as being critical, the engineering judgment clause would then govern.

AASHTO PROVISIONAL STANDARDS

AASHTO PP 46-01, (AASHTO, 2001) "Geosynthetic Reinforcement of the Aggregate Base Course for Flexible Pavement Structures" summarizes design considerations laid out by the Geosynthetics Materials Association (Berg et al. 2000) and in the Geosynthetics Design and Construction Guidelines (Holtz et al. 1998). AASHTO PP 46-01 warns that the methods outlined in the two publications are very empirical and that the practitioner should make an effort to identify documented field tests that are similar to the situation for which the design is being developed. Since AASHTO M 288-00 covers separation and filtration functions, AASHTO PP 46-01 only considers reinforcement applications.

The geosynthetics used in this application are intended to improve or extend the service life under traffic loads or to reduce the thickness of the structural section. The provisional standard recommends repeatedly that the designer check the design through field verification to ensure the engineering and economic benefits expected are being realized. The standard lays out steps for design. The design methodologies in the white paper (Berg et al., 2000) and in Holtz et al. (1998) will be summarized in Chapter 6. The design methodology in AASHTO PP 46-01 also includes recommendations for monitoring long term performance and preparation of annual performance assessments.

AASHTO STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES

Allowable Stress Design (ASD) (17th Edition, 2002)

Section 5.8 of the AASHTO ASD Specifications includes methods for designing MSE walls. External stability of the wall is calculated using as a factor of safety against sliding, overturning, bearing capacity and global stability. Internal stability depends on the extensibility of the reinforcement, and considers potential for geosynthetic reinforcement rupture or pullout at the wall facing and point of maximum stress. The geosynthetic's long term tensile strength for the internal stability calculations is reduced by a factor of safety and by reduction factors to prevent creep, to consider installation damage, and to account for degradation due to chemical and biological agents when applicable. The design factors of safety in the specifications are included in Table 5.

Table 5. AASHTO ASD Specifications: Design Factors of Safety for MSE walls (AASHTO 2002).

Wall Stability Concern	Minimum AASHTO Factor of Safety
Overturning	2.0
Sliding	1.5
Bearing Capacity	2.0 (with geotechnical analysis)
Reinforcement Pullout	1.5
Reinforcement Rupture	1.5 (global), plus reduction factors

The extensibility of the reinforcement used in the MSE wall dictates the shape of the active zone for internal stability analyses in the AASHTO (2002) specifications. For inextensible reinforcing elements (e.g., steel strips), the active zone is trapezoidal, while for extensible reinforcement (e.g., geosynthetics), a Rankine failure surface (triangular) is assumed. The shape of the active zone then partly determines the tension experienced by the reinforcement.

A chart used to estimate the lateral displacement of an MSE wall during construction is also included in AASHTO (2002). Considerations are given to surcharge loads due to hydraulic, traffic, and concentrated dead loads. Similarly, minimum reinforcement lengths are specified.

Load Resistance Factor Design (LRFD) (3rd Edition, 2006)

In the 2006 LRFD specifications, MSE walls are covered in Section 11.10. The methods of analysis of MSE walls in the AASHTO LRFD are similar to those in ASD. The major differences are related to load and resistance factor selections. For the initial LRFD specifications, the resistance factors required in LRFD section 11 were selected by calibrating the LRFD method to the same factors of safety in the ASD method. This should result in similar or slightly more conservative designs compared to those produced by ASD design methodologies. Once a larger database of tests and walls is compiled to better determine resistance and load factors, these factors may change in the future.

Unlike ASD, factors of safety against overturning are no longer calculated, otherwise, for external stability, the LRFD codes are largely unchanged.

The LRFD resistance factors in Table 6 for MSE walls show different resistance factors for metallic and geosynthetic reinforcement. The differences between metallic and geosynthetic resistance factors are historical: in previous ASD versions, the factor of safety required for metallic strips was higher than for geosynthetic strips. The calibration of resistance factors to the previous factors of safety then reflects this trend.

Table 6. Resistance Factors for Permanent MSE Walls (AASHTO LRFD Table 11.5.6-1, 2004).

DESIGN CONDITION		RESISTANCE FACTOR
Bearing resistance		0.45 to 0.55
Sliding		0.8 to 0.9
Tensile resistance of metallic reinforcement and connectors	Strip reinforcement: • Static loading • Combined static/earthquake loading Grid reinforcement: • Static loading • Combined static/earthquake loading	 0.75 1.00 0.65 0.85
Tensile resistance of geosynthetic reinforcement and connectors	Static loading Combined static/earthquake loading	0.90 1.20
Pullout resistance of tensile reinforcement	Static loading Combined static/earthquake loading	0.90 1.20

Similarly, the load factors applied to the vertical earth pressure load, EV, were determined assuming no inclusions (e.g. reinforcement strips) in the soil. The specifications note that the EV load factors should be considered "interim" until further studies are completed.

FEDERAL LANDS HIGHWAY PROGRAM SPECIFICATIONS

The current geosynthetic guidelines used and developed by the FLHD come solely in standard specifications and special contract requirements. All other design guidance comes from other agencies, such as AASHTO or National Highway Institute courses. This section summarizes the specifications currently in use from the Federal Lands Highway Division.

FP-03: Standard Specifications Addressing Geosynthetics

In the FP-03 specifications (FHWA 2003), Section 714 governs geocomposite drains and other geotextiles. This document provides no design guidance; instead, after a design is completed, the designer goes to Section 714 to require minimum properties for a geosynthetic. The material selected by the contractor must then meet or exceed these properties. In most cases, MARVs shown in FP-03 are the same as those laid out by AASHTO M 288-00. The applications for geotextiles are the same: subsurface drainage, which again, is actually filtration (Type I), separation (Type II), stabilization (Type III), permanent erosion control (Type IV), silt fences (Type V), and paving fabric (Type VI). The major differences are related to how geotextiles are classified.

Subclasses of Type I through VI depend mainly on the strength of the geotextile, as laid out in Table 1, combined with the other MARVs as presented in Table 2 through Table 4 for each particular application. For separation and stabilization, information from Table 1, Table 2 and Table 3 are used, with allowances for all strength classes in separation and Classes 1 and 2 for stabilization. Type VI Paving Fabric MARVs are the same as in Table 4, except for grab strength, which is 500 N (112 lbs) instead of the 450 N (101 lbs) noted in Table 4.

In FHWA Standard Specs (FP-03) Section 415, Paving Geotextiles are allowed as an overlay between existing and new pavement layers to form stress relieving and waterproofing layers. First, asphalt sealer is laid down, then geotextile fabric is placed atop the seal. After a tack coat, the top asphalt concrete layer is placed. The minimum average properties in the weakest direction for paving fabrics are summarized in Table 7. Note these results are similar to those from the AASHTO specifications in Table 4.

The standards in FP-03 are thus derived from AASHTO M 288-00, with some slight modifications. Like AASHTO M 288-00, these are predominantly minimum survivability properties, with other functions designed based on the responsible engineer's judgment.

Table 7. FP-03 Standard Specifications: Minimum Properties for Paving Applications.

Property	Specified Requirement
Grab Strength	500 N
Ultimate elongation	50% at break
Asphalt retention	0.90 L/m^2
Mass per unit area	140 g/m^2
Melting Point	150^o C

Special Contract Requirements

In the Western Federal Lands office, special specifications for geogrids have been created and added to the existing FP-03 specifications on a project specific basis (Alzamora, 2006). Otherwise, there are no official geogrid material specifications in FP-03.

NHI/FHWA PUBLICATIONS

In the last twenty years, a number of design manuals and guidelines have been introduced by contractors for the FHWA, often to develop materials for National Highway Institute (NHI) Courses. These include entire manuals on geosynthetic usage in designs and on MSE and reinforced soil slopes, as well as portions of other manuals, such as the column supported embankment and stone column sections in the Ground Improvement manual. A brief summary of some of the topics covered in each course manual follows, highlighting design methodologies used and other guidance given.

Geosynthetics Manual

The geosynthetics manual was last revised in 1998 by Holtz, et al. An update to the manual, reportedly, is to be completed prior the end of 2006. This document provides guidance for geosynthetic inclusion in design of subsurface drainage systems, erosion control systems, roadways and pavement reinforcement, pavement overlays, embankments, slopes, MSE walls and barriers. Each of these are briefly described below.

Roadway and Pavement Reinforcement

This section describes the typical use of geosynthetics in roadways as a separator, reinforcement, or as a filtration and drainage medium. The design methods for temporary and unpaved roads in the geosynthetics manual consider only the separation and filtration functions, since these have the longest history of successful implementation. The analysis method in this case is based on the work of Steward, et al. (1977), who quantified the improved drainage and segregation effects of the geosynthetic separator by suggesting an increased bearing capacity factor. Based on AASHTO (1993) design curves, this increased bearing capacity may lead to a reduced thickness of aggregate base course compared to the case without geosynthetics.

For permanent pavements, the geosynthetics are assumed to not provide any structural support or improvement. Any savings in overall thickness comes from the reduction of non-structural stabilizing layers in weak soils. By the methods noted here, the thickness of additional subbase, for stabilization using geosynthetics, is calculated using the same procedure as temporary road design. Again, this, however, does not reduce the height of the *structural* pavement system that will be placed atop the stabilization layer.

Pavement Overlays

This section of the manual deals with geosynthetics placed in asphalt or concrete overlays, primarily to prevent infiltration of water into the subbase or to relieve stresses transferred into the overlay by underlying reflective cracking. The main purpose of any overlay is to extend the life of the pavement, not to prevent cracks or fatigue indefinitely. Pavement overlay design without geosynthetics is covered in AASHTO (1993, 2002).

Holtz et al. (1998) stress the importance of comprehensive field studies both before and after overlay installation. This includes surveys of crack widths, structural strength, locations of base failure prior to the remediation with overlay and by installing a control section without geotextile overlay to monitor the relative performance of the geotextile. They recommend following the AASHTO (1993) guidelines, designing the thickness of the overlay as if the geotextile was not present. A method to allow reduction in thickness of the overlay is suggested in Holtz et al. (1998) by changing drainage coefficients in the equation to determine structural thickness. However, this guidance is not explicit, and selection of particular coefficients is left up to individual user of the manual.

Because correctly selected and installed pavement overlay geosynthetics are thought to increase the life of a roadway, Holtz et al (1998) suggest pavement overlays benefits should be justified by lower costs in maintenance, longer times between rehabilitation, and possibly an increased structural capacity. Based on the work of Barksdale (1991), this economic analysis could include historical cost and performance data available either locally, regionally or nationally, as well as analyses into the probability of success. Doing so, however, requires carefully controlled and documented field studies, some of which will be briefly discussed in PAVED ROADS: BOUND LAYERS section of Chapter 6.

Embankments

Design and construction of geosynthetic reinforced embankments is also covered in Holtz et al. (1998). In this case, the design method considers the selected geosynthetic to primarily perform a reinforcement function, although separation could also be a secondary function to prevent mixing of embankment soils with the subgrade. The design method first checks the need for additional reinforcement. Next, the required reinforcement strength for rotational stability and lateral spreading type failures is calculated. The reinforcement mechanism has no benefit on consolidation or secondary settlement.

Once the required geosynthetic strength is determined, the reinforcement deformation requirements are calculated depending on strain limits specified as a function of soil type. The recommended modulus is a secant tensile modulus between the strain limit and zero strain. Thus, the main reinforcement characteristics required for this design methodology are strength at a particular level of strain, the equivalent secant modulus, and the angle of the reinforcement force with respect to the critical failure surface.

Slopes and MSE Walls

While there is extensive coverage of MSE wall design in the Geosynthetics Manual, the information it contains has been updated and published in the “MSE Wall and Reinforced Soil Slope Design and Construction Guidelines” by Elias et al. (2001) described later in this chapter.

Barriers

Holtz et al. (1998) deals with basic design, specification and selection issues involved with selecting geosynthetics as moisture barriers. There is some mention of geosynthetic clay liners, mainly for flow mitigation applications such as tunnel and wall waterproofing, canal lining, or secondary containment of sensitive sites. Design considerations noted include installation conditions, Geosynthetic Clay Liner (GCL) durability, economics, and in-service conditions and performance.

Ground Improvement Manual

This manual (Elias, et al., 2006) summarizes a number of soil improvement design, and construction methodologies. Most of the topics in the manual do not use geosynthetics; however, the stone column section and the column supported embankment section do include some geosynthetics discussions. Lightweight fill materials, including expanded polystyrene (EPS) – also referred to as "geofoam," are addressed in this manual, as well. Lightweight fills are not within the scope of this report, but it is noted that such materials are often used in conjunction with embankment reinforcement applications.

Geotextile Encased Columns

One of the improvement approaches mentioned in Elias et al. (2006) is geotextile encased columns (GEC), a patented method developed in Europe. GEC are installed by replacing or displacing the *in situ* soil, and filling the resulting space with a tube of high strength, seamless geosynthetic. The empty tubes are then filled with sand. One possible advantage of such a column technology is their applicability in very soft soils and the ability to design them for vertical drainage. Unfortunately, they are still relatively new and are proprietary. Use of these columns in the U.S. has been very limited to date and, therefore, they should be considered as experimental features.

Column Supported Embankments with Geosynthetic Load Transfer Platforms

Elias et al. (2006) also contains a technical summary chapter on design, cost estimating, specification, and construction of Column Supported Embankments (CSE). In the last two decades, a load transfer platform constructed from layers of geosynthetics and soils has been added to help reduce the number of columns required. Elias et al. (2006) note that the main advantage of this technology is the speed of construction and elimination of post construction settlement. A major disadvantage of CSE is often initial construction cost when compared to other solutions. However, if the time savings are included in the economic analysis when using CSE technology, the cost may be far less than other solutions.

Another major disadvantage is lack of a widely accepted design procedure. There are many different design approaches, and they all give different results. Without some standardization of the load transfer platform design, the technology will be limited in its use and acceptance.

Current design methods of the geosynthetic load transfer platforms treat the composite soil-geosynthetic section as either a catenary or a beam. Catenary theory assumes that a single layer of reinforcement is deformed and soil arches form in the embankment soil. Beam theory (the Collin Method), assumes three or more layers of reinforcement spaced vertically 200 to 450 mm (8 to 18 inches) apart, that arching develops in the load transfer platform soil only, and that the platform is at least ½ the thickness of the span between the columns. In both the beam and catenary theory, the geosynthetic layer(s) must develop tension to withstand the weight of the soil (either embankment fill or load transfer fill for catenary and beam formulations, respectively). Design considerations for column design, lateral spreading, and global stability are similar to those discussed elsewhere.

Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design & Construction Guidelines

The FHWA guidelines on MSE walls and reinforced soil slopes were written by Elias et al. and published in 2001. These guidelines are consistent with those in AASHTO (2002). Reinforced soil structures involve placement of reinforcing strips or sheets, placement and compaction of reinforced fill, and construction of a facing system. The manual includes recommended, step-by-step design, construction and installation guidelines for both walls and slopes, using both hand and computer analysis methods.

MSE Walls

Elias et al. (2001)'s MSE wall design methodology consists of three analyses: working stress, equilibrium, and deformation. The working stress analysis examines tension and resistance to pullout in the reinforcement, and the spacing of the reinforcement layers. The limit equilibrium analysis checks the overall stability of the wall against sliding, bearing capacity, global stability and internal stability failures. The deformation analysis determines horizontal and vertical movements under assumed loadings.

In the design methods for internal stability outlined in Elias et al. (2001), the determination of the horizontal forces acting on the wall (and thus the required tensile resistance of the wall's reinforcement layers) depends on the type of reinforcement used. Similarly, the potential failure surface is determined by the reinforcement's extensibility. These also affect the length, spacing and required strength of the geosynthetic reinforcement. Calibrating and verifying these parts of the working stress analysis have received the most attention over the past two decades, in field tests and numerical studies. The manual suggests specific software, MSEW (ADAMA Engineering, Inc. 2006) that follows the design methodology laid out in Elias et al. (2001).

Another widely used national guideline for MSE walls is the National Concrete Masonry Association's (NCMA) Design Manual for Segmental Retaining Walls (1997). These guidelines are specifically for modular block unit (MBW) faced walls. However, FHWA (Elias et al., 2001) and AASHTO (2002) procedures also address MBW faced walls, and are different than the NCMA procedure. The use of the FHWA/AASHTO procedure is recommended to maintain a consistency in design and equitable bidding environment.

Reinforced Soil Slopes (RSS)

The design method for RSS involves calculating a factor of safety for the unreinforced slope for a series of possible failure surfaces. The required tensile resistance is then calculated based on the unbalanced driving moment, followed by distribution, spacing and length of the reinforcing members. Once the factor of safety against rotational failure is complete, the external and seismic stability of the reinforced structure must be checked. The slope face treatment to prevent erosion and promote vegetative growth, surface runoff, and subsurface water infiltration must also be considered. Elias et al. (2001) also suggests specific software for RSS analysis (ADAMA Engineering, Inc. 2006). A version of this software has been licensed to the FHWA.

Federally Sponsored Durability Studies

The FHWA oversaw a sizable pooled-fund study to determine the effects of a number of degradation mechanisms on the performance of geosynthetics (and steel reinforcements) used in geotechnical applications (Elias et al., 1998a, b, and c; Elias, 2000 and Elias 2001). The main purpose of these studies on geosynthetics was to better understand and quantify the effects of potential degradation due to stress cracking (Elias 1998a), chemical oxidation (Elias 1998c), ultraviolet and biological processes (Elias 2000). Elias (2001), in his study of geosynthetic material exhumed from 12 sites up to 20 years old, concluded that observed rates of degradation were consistent with laboratory tests, and that, in the cases examined, only low levels of strength loss were observed.

Elias (2000) also summarizes the soil types and groundwater environments that can lead to accelerated degradation of geosynthetics manufactured from certain types of polymer materials. This report also compiles a range of reduction factors for geosynthetic tensile strengths that considers both the geosynthetic type and polymer for installation damage and durability. Methods to monitor and test installation damage are also suggested in this document.

Degradation mechanisms, environmental factors, and degradation rates of geosynthetics are well documented as a result of this study. Specific environmental limits and design property reduction values were defined, and can actively be used for design of geosynthetic structures.

Shallow Foundations Reference Manual

Munfakh et al. (2001) summarized guidelines for design of shallow foundations. The discussion includes a short section on reinforced soil foundations. Reinforced soil foundations involve placing one or more layers of geosynthetics beneath the shallow foundation to act as a stiffener. The design formulation for shallow foundations over geosynthetic reinforced soils is for settlement calculation only, and models the geosynthetics as a series of stiff layers using Westergaard's theory. The geosynthetic spacing, horizontal extent and total depth are recommended in these guidelines based on empirical small scale and field scale laboratory tests. The design method does not consider improvements to limit state bearing capacity calculations, nor does it discuss the geosynthetic properties such as tensile strength, stiffness or creep characteristics that should be considered when specifying a design. Use of geosynthetics for reinforcement beneath shallow foundations has been very limited to date and, therefore, such applications should considered experimental in nature.

OTHER RELATED PUBLICATIONS

In an attempt to speed acceptance of new earth retaining system technologies and to help reduce redundant system evaluations by multiple organizations (DOTs), a set of guidelines to evaluate proprietary earth retaining systems was developed in 1998 (HITEC, 1998). The evaluations are set in motion by the manufacturers of the retaining systems. The application process for evaluating a system includes summarizing the materials used, the suggested design procedures, the methods of construction, and documented performance histories. Once a manufacturer submits an application, an advisory panel then suggests further testing (if required) and creates a technical evaluation report for the product. The distributed reports are then used by DOTs as a tool for system evaluation. These guidelines spawned a series of other reports that evaluated various geosynthetic reinforced wall systems (for an example, HITEC, 2003).

Another noteworthy publication (relevant to FLHD mission) is the one by Fannin (2001b) in which he describes applications of geosynthetics specifically for forest engineering. In 2000, Fannin compiled a "best practices" document geared specifically toward projects that affected forestry projects. Describing Canadian practices, this document included a review of ten forestry projects in which geosynthetics were used.

A review of several international documents was also conducted .These were Queensland Department of Main Roads (2001), Queensland Department of Main Roads (1999), Vic Roads (Undated), Miki (2005), and Palmeira (2005) led to the conclusion that information related to international practice is rather similar to US literature with slight variation that are mainly in response to local issue

SUMMARY

When considering existing national design guidelines and specifications involving geosynthetics, it is clear that some applications have been studied and developed extensively, while others require more calibration and development. For example, MSE walls, reinforced soil slopes, and geosynthetic reinforced embankments have reached a level of acceptance in practice that is related to the completeness of their design methods. While these applications still have some outstanding development issues to consider, it is our assessment that these applications are relatively mature.

Pavement applications and ground improvement techniques (geosynthetic plus column supported embankments, for example) have some information on usable design methodologies but still require considerable calibration, additional validation and possibly some improvements through carefully designed and instrumented laboratory and field studies. While case studies exist, more are required before a design model is widely accepted.

Other applications have little or no coverage in the national or AASHTO design guidelines. Reinforced shallow footings and geosynthetic encased columns are mentioned, but the suggested design methods are either nonexistent or still largely based on a few empirical studies. Geosynthetics for bridging subsurface voids and for capillary barriers to control frost heave are not mentioned at all.

The existing specifications (FP-03 and AASHTO) are used to determine acceptability of a product suggested by a contractor and were written with roadway applications in mind. As such, geosynthetics are mainly grouped by their ability to provide filtration and separation when one type of soil material is placed adjacent to another. Both FP-03 and AASHTO M 288-00 do not include specifications for applications for reinforcement.

In the next chapter, the results of a survey of FLHD and U.S. Forest Service (USFS) engineers will be presented. The survey will provide information on types of applications in which the engineers are involved and the process and methods the engineers use to design projects that include geosynthetics. The perceived challenges, benefits and problems with geosynthetics will also be summarized.