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LITERATURE REVIEW ON GEOTEXTILES TO IMPROVE PAVEMENTS FOR GENERAL AVIATION AIRPORTS

by

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13. ABSTRACT *(Maximum 200 words)*

This report covers a literature search and review to obtain information on geotextile applications related to pavement construction. Applicable information from this study, if sufficient, would then be used to prepare guidelines on design application, material specifications, performance criteria, and construction procedures for improving subgrade support with geotextiles in general aviation airport pavements.

The study revealed that there are numerous design procedures available for using geotextiles in aggregate surfaced pavements and flexible pavement road construction. However, there is no generally accepted procedure for either type construction. The state-of-the-art has not advanced to the point where design procedures for using geotextiles in paved airport construction are available. Construction/installation procedures are available for using
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geotextiles in aggregate surfaced pavements and flexible pavements for roads, and these may be used as an aid in recommending procedures for airport construction.

Results of comprehensive tests by researchers indicate that geogrids have more potential than geotextiles for reinforcement of flexible pavements. Until design procedures for flexible pavements for airports incorporating geotextiles are developed, current standard airport pavement design procedures should continue to be used, and if geotextiles are included in the structure, no structural support should be attributed to geotextiles. Further research on the use of geotextiles to improve subgrade support for general aviation airports should be delayed until the laboratory grid study and field grid tests are completed.

PREFACE

The information reported herein was sponsored by the US Department of Transportation, Federal Aviation Administration (FAA) under Interagency Agreement No. DTFA01-89-Z-02029, "Grid Reinforced Aggregate Base Courses for General Aviation Airports." This report completes Phase I, Task 3, "Report on Geotextiles for Improved Subgrade Support" of the agreement. Technical Monitor for this study was Mr. Hisao Tomita.

Personnel of the US Army Engineer Waterways Experiment Station (WES) Geotechnical Laboratory (GL) who were actively engaged in this study during the period November 1989 to March 1990 were Messrs. Steve L. Webster and Dewey W. White, Jr., Pavement Systems Division (PSD), GL. This report was prepared by Mr. White. The report was edited by Ms. Odell F. Allen, Visual Production Center, Information Technology Laboratory (ITL). Mrs. Jimmie Perry, Information Management Division, ITL, provided assistance in conducting the literature search. This study was conducted under the general supervision of Dr. W. F. Marcuson III, Chief, GL, WES. Direct supervision was provided by Mr. H. H. Ulery, Jr., Chief, PSD, Dr. R. R. Rollings, former Chief, Materials Research and Construction Technology Branch (MR&CTB), and Messrs. L. N. Godwin and T. W. Vollor, Acting Chiefs, MR&CTB, PSD.

COL Larry B. Fulton, EN, was the Commander and Director of WES. Dr. Robert W. Whalin was the Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
degrees	0.01745329	radians
feet	0.3048	metres
inches	2.54	centimetres
miles per hour (international)	0.1609344	kilometres per hour
pounds (force)	4.448222	newtons
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
square feet	0.09290304	square metres
tons (2,000 pounds, mass)	907.1847	kilograms

LITERATURE REVIEW ON GEOTEXTILES TO IMPROVE PAVEMENTS FOR GENERAL AVIATION AIRPORTS

PART I: INTRODUCTION

1. Airport pavement base courses must be composed of good quality material in order to resist shear forces and protect the subgrade from excessive deformation under aircraft wheel loads. The Federal Aviation Administration (FAA) Advisory Circulars which specify acceptable types of aggregate material are provided to airport owners and operators. Such materials are rapidly being depleted, and in many cases, suitable aggregates must be transported considerable distances to reach airport pavement construction sites at high costs.

2. Research has been accomplished on the use of aggregate filled cells to improve the shearing resistance of base courses. Studies on the effectiveness of grid- and lattice-type reinforcement to reduce vertical deformation of pavement structures over subgrades of various strengths have been pursued in laboratories. However, results have not been verified under field conditions. A laboratory grid study (Phase I, Task 4) and field grid tests (Phase I, Task 5) will be conducted as part of the overall interagency agreement with a separate report to be prepared on that work.

3. A less expensive alternative may be the use of geotextiles to increase subgrade support. Design guidelines, standardized specifications, and test methods are needed by the FAA field and design engineers to permit them to make decisions regarding the use of geotextiles in general aviation airport pavement construction.

4. The objective of this study was to conduct a literature search and review to obtain information on geotextile applications related to pavement construction. The information obtained, if sufficient, could then be used to prepare guidelines on design application, material specifications, performance criteria, and construction procedures for improving subgrade support with geotextiles in general aviation airport pavements.

PART II: LITERATURE REVIEW SOURCES

5. Several searches of literature databases were conducted through the US Army Engineer Waterways Experiment Station (WES) Information Technology Laboratory. These included:

- a. COMPENDEX PLUS. Engineering Information, Inc. New York, NY.
- b. CONFERENCE PAPERS INDEX. Cambridge Scientific Abstracts, Bethesda, MD.
- c. GEOARCHIVE. Geosystems, Oxon, England.
- d. GEOBASE. Geo Abstracts Ltd, Norwich, UK.
- e. GEOREF. American Geological Institute, Alexandria, VA.
- f. NTIS. National Technical Information Service, US Department of Commerce, Springfield, VA.
- g. TRIS. US Department of Transportation and Transportation Research Board, Washington, DC.

6. Other references were obtained from a search of the WES technical library and from written and verbal communications with people associated with geotextiles. Two valuable sources that contained additional references and information on geotextile usage were the "Geotextile Engineering Manual" (Christopher and Holtz 1985) and the "1990 Specifier's Guide" issue of the Geotechnical Fabrics Report (1990 Specifier's Guide 1989). Twenty-one firms listed in the applications section of the Specifier's Guide under "Geotextile, Reinforcing" and "Geotextile, Separating" and one consulting firm listed in the "Consultant" section were contacted by written communication requesting data and information on geotextile use in pavement construction.* Personal conversations by telephone were also made for information related to geotextile usage.*

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* Appendix B.

PART III: LITERATURE SEARCH RESULTS

7. The results of this search revealed considerable references to published information on the use of geotextiles in aggregate surfaced pavement construction. However, only limited references are available to published information on geotextile usage in flexible pavement road construction, and very little is related to usage in airport pavement construction. This published information includes design guidelines, important properties, functions, and construction/installation procedures prepared by researchers, designers, and manufactures/suppliers.

8. A total of 104 different reports, magazine articles, periodicals, books, and technical papers were reviewed. Responses were received from 9 of 22 written communications for data/information mentioned under the section titled "Literature Review Sources". Five of the responses contained, in addition to product information, design guidelines and construction/installation information for aggregate surfaced pavements and flexible pavements for roads. One source provided information on one of its products used in conjunction with airport pavement construction. However, no design guideline information on geotextile use specifically for airport pavement construction was included with any of the responses. Further information relative to the manufacturer's product in airport pavement will be given in the section entitled, "Flexible Pavements for Airports". A review of the agenda for the 4th International Conference on Geotextiles, Geomembranes and Related Products held May 28-June 1, 1990 at The Hague, the Netherlands (Fourth International Conference on Geotextiles 1990), revealed that papers of direct interest to this study were on geotextiles related to aggregate surfaced pavements. A complete bibliography is contained in Appendix A. Personal and written communications that were made are included in Appendix B.

9. Details on the composition, materials, types, and manufacturing processing for geotextiles are not contained in this report. This information can be obtained from publications such as "Geotextile Engineering Manual," (Christopher and Holtz 1985) Designing with Geosynthetics," (Koerner 1990) "Construction and Geotechnical Engineering Using Synthetic Fabrics," (Koerner and Welsh 1980a) "Geotextile Design and Construction Guidelines," (US Department of Transportation 1989) and manufacturers' product literature. Suggested test methods for determining properties and parameters for geotextile

selection can be obtained from "Geotextile Engineering Manual" (Christopher and Holtz 1985) and "Geotextile Design and Construction Guidelines." (US Department of Transportation 1989).

10. The results of this study revealed that a complex structural situation exists when geotextiles are used in the layered system of aggregate surfaced pavements (Hausmann 1987, Robnett and Lai 1982b) and flexible pavement construction (Barksdale, Brown, and Chan 1989). In the "Aggregate Surfaced Pavements" and "Flexible Pavements for Roads" sections of this report, various design procedures by manufacturers, and researchers will be mentioned. Design procedures for aggregate surfaced pavements cannot be used for flexible pavements for roads (US Department of Transportation 1989). The major difference being the performance requirements. Aggregate surfaced pavement design usually allows some rutting to occur over the life of the structure. However, a paving surface (concrete or asphalt) cannot be placed on a structure that yields or ruts under load since the surfaces would crack and deteriorate after a few load applications. Long-term field installations are needed to further verify these procedures and for determining the long-term effects on geotextile properties (Anderson and Killeavy 1989; Barksdale, Brown, and Chan 1989; Haliburton, Lawmaster, and King 1980; Hausmann 1987; and Jorenby and Hicks 1986). Guideline specifications for various geotextile applications and functions are needed along with a uniform set of test standards for verifying the specified properties (Giroud 1986; Headquarters, Department of the Army 1990; Jorenby and Hicks 1986; Koerner 1990; Lawson 1989; Robnett and Lai 1982b; Sowers, Collins, and Miller 1982). Federal Highway Administration Task Force 25, which is composed of the American Association of State Highway and Transportation Officials, Associated General Contractors of America, and the American Road and Transportation Builders Association, is currently working on guidelines for mechanical and physical properties for silt fences, drainage erosion, separation, and paving fabrics.

PART IV: AGGREGATE SURFACED PAVEMENTS

11. This study revealed that a considerable amount of research has been conducted by various individuals and groups on the use of geotextiles in road construction. From this research, a number of design procedures for aggregate surfaced pavements are available. There are several factors to be considered in selecting a particular procedure for a certain application. The factors include experience of designer with geotextile use, site conditions, amount of allowable rutting, material availability, load conditions, and expected road service life. Some of these procedures will be mentioned; however, details are not given in this report but can be found in the respective references. A brief summary of some full-scale traffic tests conducted by Webster (unpublished b) is given below. Other items related to geotextile usage that are considered to be important are also discussed.

Full-Scale Traffic Tests

12. Full-scale traffic tests on geogrid and geotextile reinforced aggregate layers over a sand (SP) subgrade were conducted by Webster (unpblished b) These tests were conducted using a truck, tank, and simulated C-130 aircraft tire traffic. The tests included a 4-in.* aggregate base layer with and without reinforcement placed at the top of the subgrade. Reinforcement materials were as follows:

Test Item	Reinforcement	Wide Width Strength/ Elongation ASTM D 4595-86 lb/in. at 5% Strain	Grab Strength/ Elongation ASTM D 4632-86 lb/%
1	None	--	--
2	Geotextile	--	130/60
3	Geogrid	47.4	--
4	Geotextile	--	250/20
5	Geotextile	--	475/25
6	Geotextile	--	1,000/25

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

Test traffic loads were as follows:

Truck	C-130	Tank
5 ton military	Single tire	70 ton
Payload at 20,000 lb	Load at 35,000 lb	--
Gross weight at 41,900 lb	--	--
Tire pressure at 70 psi	Tire pressure at 100 psi	--

Traffic test results are shown in Figures 1 through 3 (Webster unpublished b). Under truck traffic (Figure 1), only the geogrid item (Item 3) performed better than the control item (Item 1). For a 2-in. rut depth, the control item had 2,600 passes versus 5,200 passes for the geogrid item. Three geotextile items (Items 2,5, and 6) performed significantly worse than the control item, indicating aggregate slippage on the geotextiles. Under the C-130 tire traffic (Figure 2), all reinforcement items performed much worse than the control item. For a 3-in. rut, the reinforcement items handled only 100 to 200 passes, and the control item had 600 passes. Under tank traffic (Figure 3), performance was mixed. The geogrid (Item 3) performed best, followed by the two strongest geotextiles (Items 6 and 5), the control (Item 1), and then the two weaker geotextiles (Items 4 and 2). For all three types of traffic, test results showed that geogrids performed better than geotextiles. Results also showed that reinforcement material friction properties are critical to performance and that more work needs to be done regarding placement depths of reinforcement materials.

Geotextile Functions

13. Geotextiles that are used in aggregate surfaced pavements on soft subgrades usually fulfill one or more of the functions of separation, filtration, drainage, and reinforcement (Christopher and Holtz 1985, Hausmann 1987, Stabilization Design Guide 1987, US Department of Transportation 1989b). Information on these functions are given in the following paragraphs.

Separation

14. The separation function, which is considered by many (Barsvary and Korgemagi 1979, Christopher and Holtz 1985, Puffer 1987, US Department of Transportation 1989b) to be the primary function of geotextiles in road construction, prevents contamination of the coarse aggregate by intermixing with the subgrade soil, thus preserving the design. This intermixing occurs by

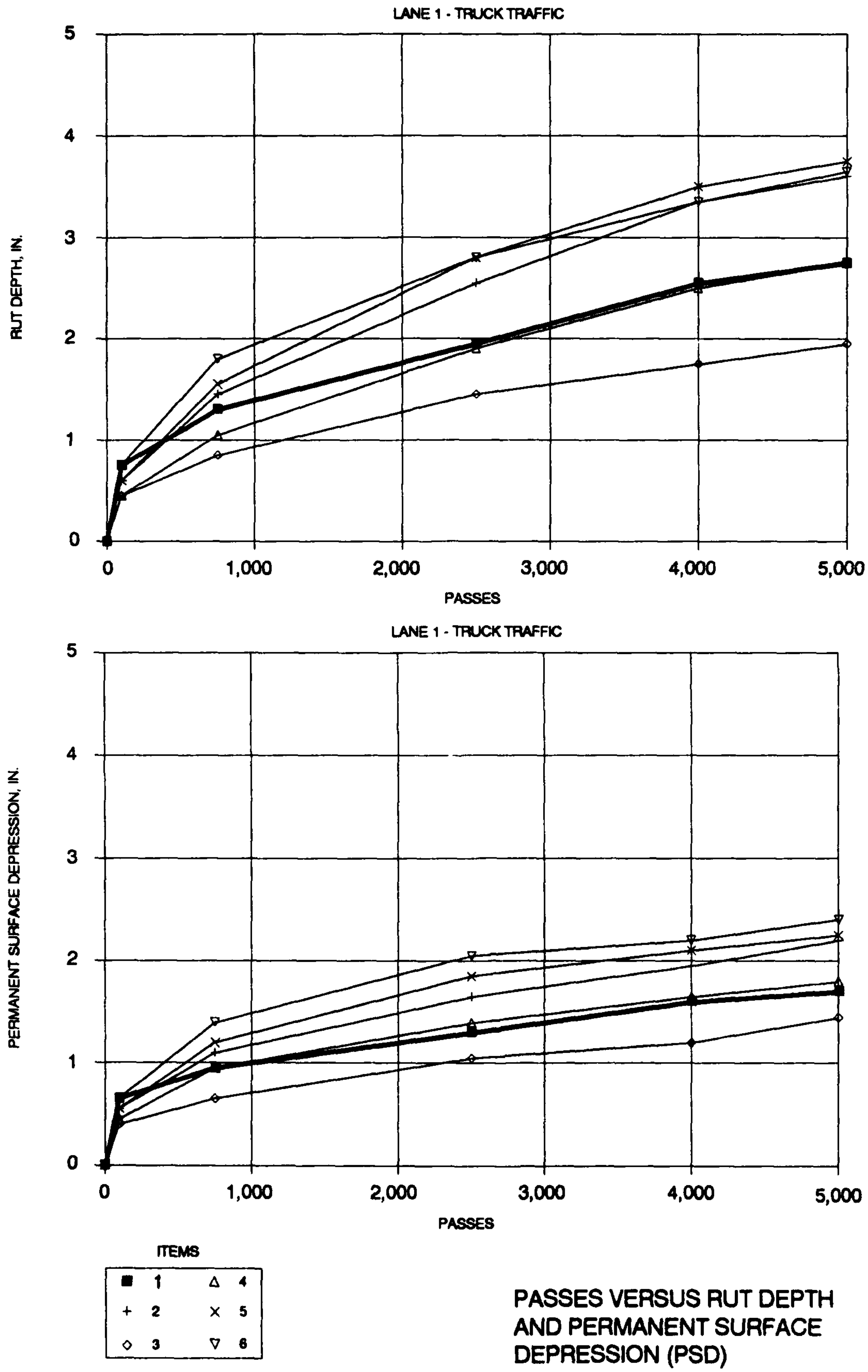


Figure 1. Truck traffic

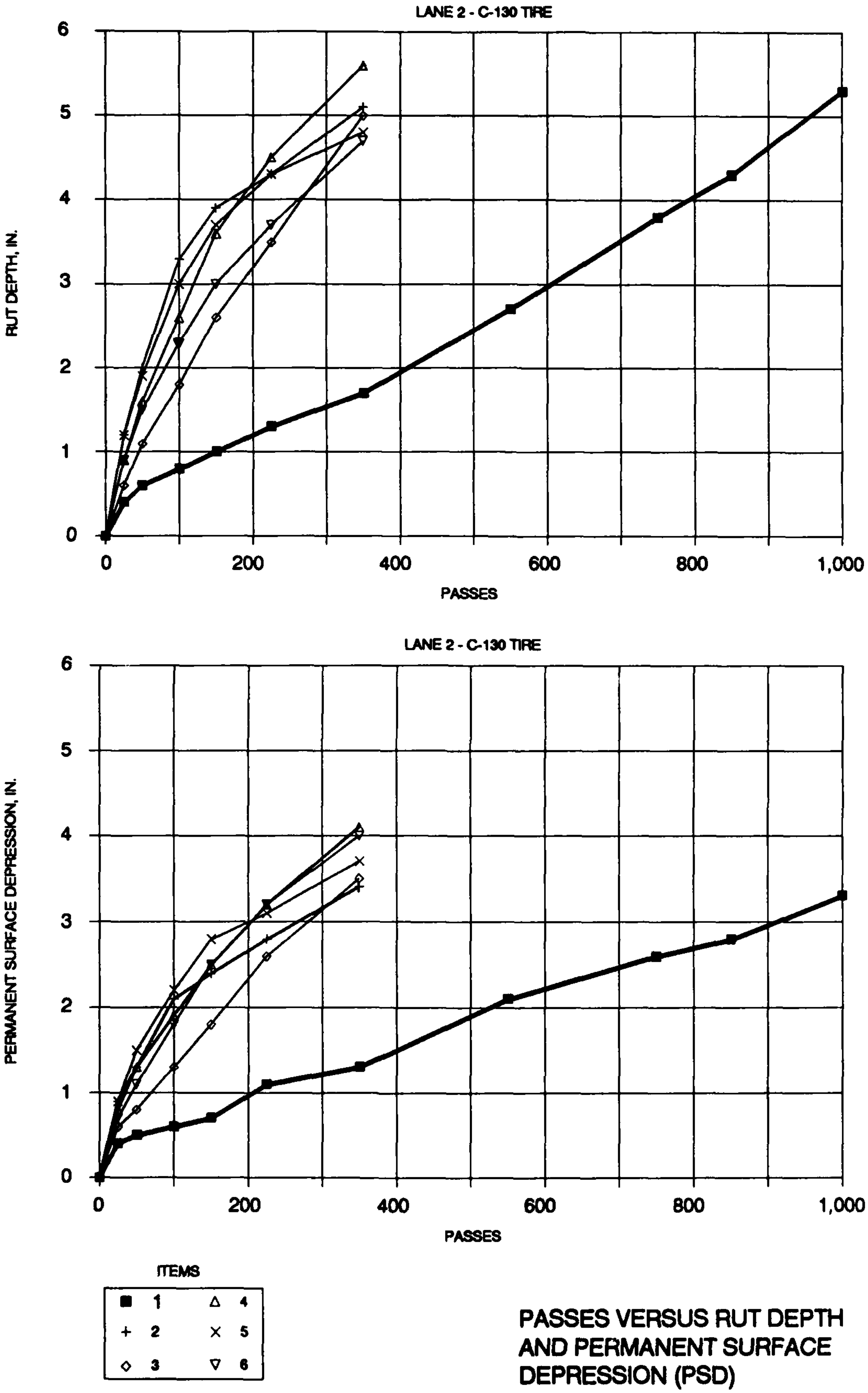
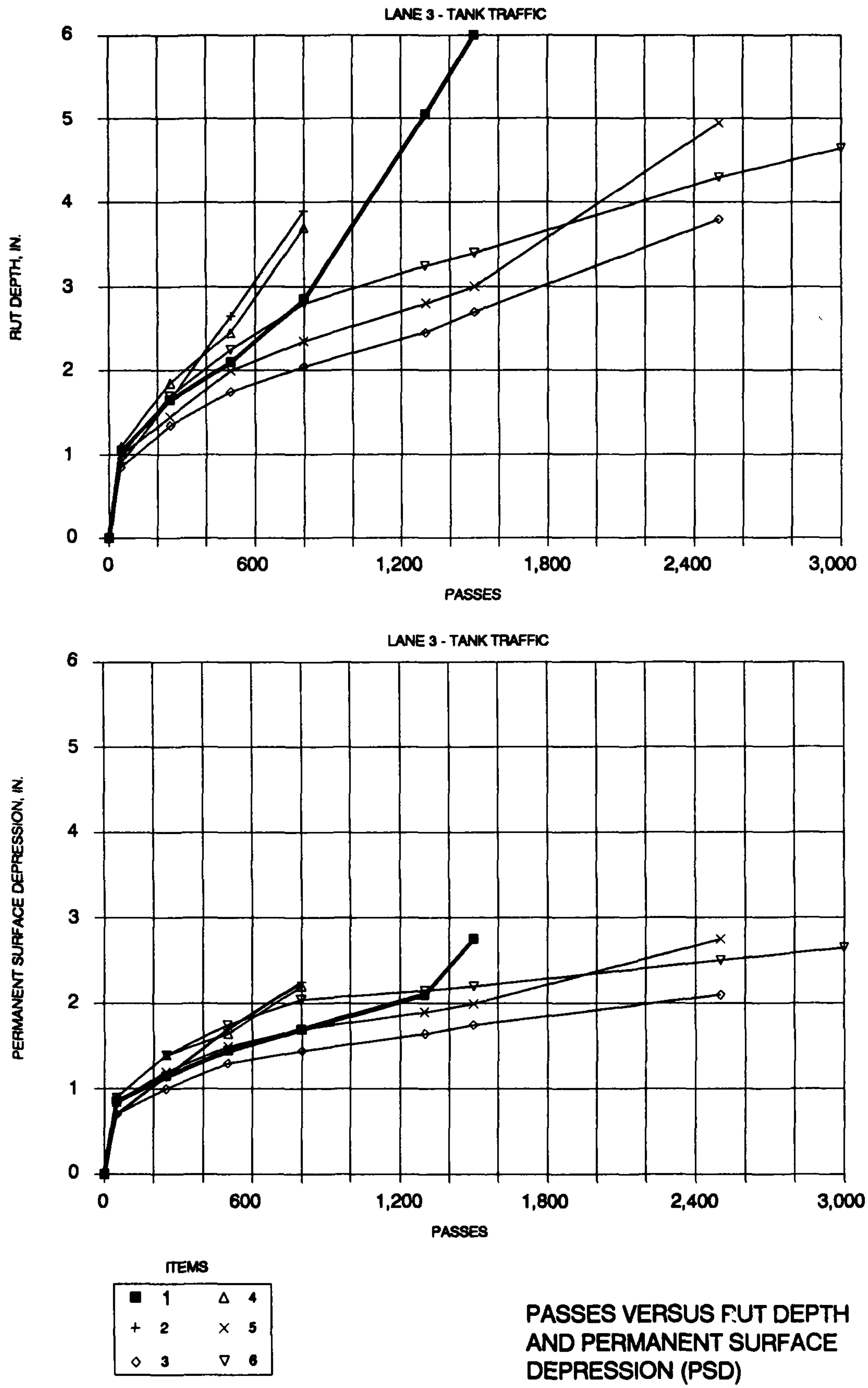


Figure 2. C-130 tire traffic



PASSES VERSUS RUT DEPTH AND PERMANENT SURFACE DEPRESSION (PSD)

Figure 3. Tank traffic

either the aggregate being forced into the subgrade by the action of the applied loads or the migration of the subgrade into the aggregate layer. The load-spreading ability of the aggregate depends on continuous contact between individual pieces of aggregate. Under applied loads such as that from vehicle wheels, the aggregate layer deforms. After a sufficient quantity of load repetitions, the surface of the layer in contact with the subgrade begins to separate, since the individual pieces of aggregate cannot resist the tension forces. At the beginning, these separations are small; however, they become larger as the load repetitions continue. The subgrade enters the separations between individual aggregate pieces and soon the pieces "float" in the subgrade. The aggregate continuity, strength, and load spreading ability are reduced. The intermixing of the aggregate and subgrade continues until the aggregate bearing capacity is reduced to that of the subgrade. As little as 10 to 20 percent (A Look at Soil Stabilization and Drainage 1988; Robnett and Lai 1982a, 1982b; Steward, Williamson, and Mohney 1977; Stabilization Design Guide 1987) intermixing of subgrade fines can completely destroy the strength of the aggregate layer. Thus, if bearing failure is prevented by the geotextile, then the subgrade should be capable of carrying the design load without distress or deterioration to the pavement system. However, localized bearing failures and subsequent subgrade/aggregate intermixing are only problems in weak soils (soils with California Bearing Ratio (CBR) values of less than 3) (Christopher and Holtz 1985, US Department of Transportation 1989a, 1989b).

Filtration

15. Filtration is the process of allowing water to easily escape from the soil while retaining the soil in place, thus preventing contamination of the aggregate layer and preserving its bearing capacity.

Drainage

16. Drainage is the function of the geotextile which allows the water to rapidly escape from the pavement structure. This prevents water pressures from building up under loading conditions which could cause subgrade failure.

Reinforcement

17. Reinforcement is strengthening of the pavement structure by including geotextile. This reinforcement (Christopher and Holtz 1985, Giroud 1987, Haliburton and Barron 1983, Hausmann 1987) can be classified as base and subgrade restraint, lateral restraint, and membrane-type support. The

geotextile tends to prevent the aggregate layer from separating and moving at the lower surface and confines the subgrade reducing soil movement and strain. The interlocking (friction) between the aggregate-geotextile and soil-geotextile surfaces minimizes lateral spreading of the aggregate and soil.

a. Base and subgrade restraint. Under load, the stress conditions in the base course are analogous to a loaded beam. Due to bending, the base experiences compression at the top and tension at the base. The cohesionless materials that make up the base have no tensile resistance and generally depend on the subgrade to provide lateral restraint. In weak subgrades, very little lateral restraint is provided. Thus, the aggregate at the bottom of the base tends to move apart, allowing intrusion of the soft subgrade. A geotextile at the bottom of the base course can provide tensile reinforcement which restrains aggregate movement. If the tensile resistance is significantly high, the fabric may also reduce bending in the system, much like the steel in a reinforced concrete beam. However, an extremely high-strength, high-modulus fabric with good friction or interlocking with the aggregate would be required. Also, a strength gain from the geotextile can be obtained only from low-strength soils that would fail in local shear without the fabric. Thus, the fabric provides restraint through the soil-fabric stress-strain characteristics and the frictional resistance of the geotextile.

b. Lateral restraint. Horizontal restraint provided by a geotextile may also resist bearing failure in the base course. If the geotextile is placed in the road structure at a depth which interferes with the normal bearing failure surfaces, failure must occur along an alternate surface. Thus, the ultimate bearing capacity is increased and an increase in the elastic modulus of the base is provided. An increase in stiffness of the base also reduced the magnitude of stresses transmitted to the subgrade.

c. Membrane-type support. In road construction applications for geotextiles to exhibit reinforcement, considerable rutting (deformation) of the subgrade must occur. As the roadway undergoes deformation, stress perpendicular to the plane of the geotextile is induced and the geotextile is stretched and develops in-plane tensile stress. The net effect is a change in the magnitude of stress imposed on the subgrade, a reduction under the load and an increase outside the load. This spreading of the stresses over a larger area improves the support properties of the pavement structure. For this type of reinforcement to be significant, the strength subgrade should be less than 3 CBR (Barksdale, Brown, and Chan 1989; Bell 1980; Koerner 1990; Robnett and Lai 1982b). Many researchers indicate that geotextiles which possess high modulus will provide more load spreading ability for the same rut depth (Christopher and Holtz 1985, DeGroat et al. 1986, Hausmann 1987, Holtz and Harr 1983, Robnett and Lai 1982a).

Geotextile Benefits

18. When considered in the design of roadways over soft subgrades, the geotextile functions mentioned above can possibly lead to several cost and/or performance benefits including those mentioned below (Barsvary and Korgemagi 1979; Brown, Jones, and Brodrick 1982; Christopher and Holtz 1985; US Department of Transportation 1989b).

a. Reduction of the stress intensity on the subgrade and prevention of the subbase aggregate from penetrating into the subgrade.

b. Prevention of subgrade fines from pumping into the subbase.

c. Prevention of contamination of the subbase materials which may allow more open-graded free draining aggregate to be considered for use.

d. Reduction of the depth of excavation required for removal of unsuitable subgrade materials.

e. Reduction of aggregate thickness required to stabilize the subgrade. Aggregate reduction in the structural design may or may not be considered.

f. Less subgrade disturbance during construction.

g. Maintaining integrity and uniformity of the pavement if settlement of the subgrade occurs. Settlement of subgrade is not prevented by the geotextile; however, its use can result in more uniform settlement.

h. Reduction of maintenance and extended service life of pavement.

i. Allows water to escape (drain) rapidly from the pavement structure which will prevent water pressures from building up under loading conditions that could cause subgrade failure.

Geotextile Properties and Criteria

19. Tables 1 and 2 (Bell and Hicks 1980, Christopher and Holtz 1985, US Department of Transportation 1989b) list important geotextile properties that should be considered for constructability, durability, mechanical and hydraulic criteria for separation, and reinforcement applications, respectively. The properties listed in those tables cover the function of a geotextile mentioned in prior paragraphs. All of the properties listed in these tables may or may not be applicable in every application.

Table 1

Important Criteria and Properties

Separation*

Criteria	Property
Constructability	Strength Temperature Stability Ultraviolet Light Stability Wet and Dry Stability Flammability Thickness Weight Absorption Puncture Resistance Cutting Resistance Modulus Flexibility Tear Resistance
Durability	Temperature Stability Chemical Resistance Wet and Dry Stability Biological Resistance Abrasion Resistance
Mechanical	Tensile Strength Fatigue Seam Strength Burst Strength Puncture Resistance Tear Strength Creep Friction/Adhesion
Hydraulic	Thickness Permeability Siphoning Capacity Pumping Resistance Intrusion Resistance

* From Bell and Hicks 1980, Christopher and Holtz 1985, and US Department of Transportation 1989b.

Table 2

Important Criteria and Properties

Reinforcement*

Criteria	Property
Constructability	Strength Temperature Stability Ultraviolet Light Stability Wetting and Drying Stability Flammability Thickness Absorption Puncture Resistance Tear Resistance Cutting Resistance Modulus
Durability	Ultraviolet Light Stability Temperature Stability Chemical Resistance Wetting and Drying Stability Biological Resistance
Mechanical	Tensile Strength Modulus - Static Modulus - Dynamic Friction/Adhesion Fatigue Creep - Static Creep - Dynamic Seam Strength
Hydraulic	Thickness Permeability

* From Bell and Hicks 1980, Christopher and Holtz 1985, and US Department of Transportation 1989b.

Geotextile Survivability

20. Geotextile survivability is defined as its resistance to destruction during placement and, after installation, the ability to perform the intended function throughout the design life. The required degree of survivability depends upon the subgrade condition, construction equipment, first construction lift thickness, cover material type, and construction equipment. Requirements for geotextile survivability as a function of subgrade condition and construction equipment and a function of cover material and construction equipment are presented in Tables 3 and 4 (Christopher and Holtz 1985, Headquarters, Department of the Army 1990, US Department of Transportation 1989a), respectively.

21. The geotextile selection for either temporary or permanent roads is basically the same. For a correctly designed road system, the stress at the geotextile level due to aggregate weight and traffic should not be greater than the bearing capacity of the soil which is low ($\leq$30 psi) where geotextiles are used. The stresses applied during construction may well be in excess of those applied to the geotextile during the design life. Therefore, the selection of the geotextile is governed usually by stresses anticipated during construction. However, in order for a geotextile to retain the desired properties after installation, it must be protected from construction damage such as tearing and puncturing (Bonaparte et al. 1988, Hausmann 1987). Minimum strength guidelines required for the geotextiles to survive the most severe construction anticipated is found in Table 5 (Christopher and Holtz 1985, Hausmann 1987, Headquarters, Department of the Army 1990, US Department of Transportation 1989a, 1989b). Final specification selection should be based on specific site condition, experience, and judgment with the geotextile survivability verified for major projects by conducting field tests under site specific conditions.

Geotextile Installation Guidelines*

22. The successful use of geotextiles in road construction requires proper installation. Although the installation techniques appear fairly

* From Christopher and Holtz 1985, US Department of Transportation 1989b.

Table 3

Geotextile Survivability as a Function of Subgrade Conditions and Construction Equipment*

Subgrade Conditions	Construction Equipment and 6 to 12 in. Cover Material Initial Lift Thickness		
	Low Ground Pressure Equipment (≤4 psi)	Medium Ground Pressure Equipment (>4 psi, ≤8 psi)	High Ground Pressure Equipment (>8 psi)
Subgrade has been cleared of all obstacles except grass, weeds, leaves, and fine wood debris. Surface is smooth and level such that any shallow depressions and humps do not exceed 6 in. in depth and height. All larger depressions are filled. Alternatively, a smooth working table may be placed.	Low**	Moderate	High
Subgrade has been cleared of obstacles larger than small- to moderate-sized tree limbs and rocks. Tree trunks should be removed or covered with a partial working table. Depressions and humps should not exceed 18 in. in depth and height. Larger depressions should be filled.	Moderate	High	Very High

(Continued)

Note:

Recommendations are for 6 to 12 in. initial lift thickness. For other initial lift thicknesses:

12 to 18 in.: Reduce survivability requirement 1 level.
18 to 24 in.: Reduce survivability requirement 2 levels.
> 24 in.: Reduce survivability requirement 3 levels.

Survivability levels are, in increasing order: low, moderate, high, and very high.

For special construction techniques such as prerutting, one should increase fabric survivability requirement 1 level.

Placement of excessive initial cover material thickness may cause bearing failure of soft subgrades.

* From Christopher and Holtz 1985, Headquarters, Department of the Army 1990, US Department of Transportation 1989a.

** See Table 5.

Table 3 (Concluded)

	Low Ground Pressure Equipment (≤4 psi)	Medium Ground Pressure Equipment (>4 psi, ≤8 psi)	High Ground Pressure Equipment (>8 psi)
Minimal site preparation is required. Trees may be cut, be delimbed, and left in place. Stumps should be cut to project not more than 6 in. ± above subgrade. Fabric may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders.	High	Very High	Not Recommended

Table 4

Geotextile Survivability as a Function of Cover Material and Construction Equipment*

	6 to 12 in. Initial Lift Thickness		12 to 18 in. Initial Lift Thickness		18 to 24 in. Initial Lift Thickness	> 24 in. Initial Lift Thickness
	Low Ground Pressure Equipment (≤4 psi)	Medium Ground Pressure Equipment (≥4 psi, ≤8 psi)	Medium Ground Pressure Equipment (≥4 psi, ≤8 psi)	High Ground Pressure Equipment (≥8 psi)	High Ground Pressure Equipment (≥8 psi)	High Ground Pressure Equipment (≥8 psi)
Fine sand to ± 2-in.-diam gravel, rounded to subangular	Low**	Moderate	Low	Moderate	Low	Low
Coarse aggregate with diameter up to one-half proposed lift thickness, may be angular	Moderate	High	Moderate	High	Moderate	Low
Some to most aggregate with diameter greater than one-half proposed lift thickness, angular and sharp-edged, few fines	High	Very High	High	Very High	High	Moderate

Note:

For special construction techniques such as prerutting, increase fabric survivability requirement level.

Placement of excessive initial cover material thickness may cause bearing failure of soft subgrades.

* From Christopher and Holtz 1985, Headquarters, Department of the Army 1990, US Department of Transportation 1989a.

** See Table 5.

Table 5

AASHTO-AGC-ARTBA* Joint Committee (Christopher and Holtz 1985, Hausmann 1987 Headquarters, Department of the Army 1990, US Department of Transportation 1989a, 1989b) Minimum** Geotextile Properties Guidelines Required For Survivability

Required Degree of Fabric Survivability	Grab Strength† (minimum values) lb	Puncture Strength†† lb	Burst Strength‡ psi	Trap Tear‡‡ lb
Very High	270	110	430	75
High	180	75	290	50
Moderate	130	40	210	40
Low	90	30	145	30

* American Association of State Highway and Transportation Officials, Associated General Contractors of America and the American Road and Transportation Builders Association Interim Specifications.

** All values represent minimum average roll values. (i.e., any roll in a lot should meet or exceed the minimum values in this table.) These values are normally 20 percent lower than manufacturer's reported typical values.

† ASTM D-4632, Grab Method.

†† ASTM D-4833, --.

‡ ASTM D-3787, Diaphragm Test Method.

‡‡ ASTM D-4535, either principal direction.

simple, a majority of the problems with geotextiles in roads have occurred as the result of improper construction techniques. If the geotextile is ripped or punctured during construction activities, it will not likely perform as desired. If the geotextile is placed with a lot of wrinkles or folds, it will not be tensioned, and therefore will not provide any reinforcing effect. Other problems occur due to insufficient cover over the fabric, rutting of the subgrade prior to placing the fabric, and placing lift thicknesses such that the bearing capacity of the soil is exceeded. The following step-by-step procedures should be followed, along with engineering monitoring of all construction activities.

a. The site should be cleared, grubbed, and excavated to design grade, taking care to strip all top soil, soft soils, or any other unsuitable materials. If moderate site conditions exist, i.e., CBR greater than 1, lightweight proofrolling operations should be considered to aid in locating unsuitable materials to be removed. Isolated pockets where overexcavation is required should be graded and backfilled so as to promote positive drainage. Optionally, special drain tiles with outlets installed to drain these isolated areas could be used.

b. During stripping operations, care should be taken not to disturb the subgrade. This may require the use of lightweight dozers or grade-alls for low strength, saturated noncohesive and low cohesive soils. For extremely soft ground, such as peat bog areas, consideration should be given not to overexcavate the surface materials such that advantage can be taken of the root mat, if it exists. In this case, all vegetation should be cut off square at the ground surface. Sawdust or sand can be placed over stumps or roots that extend above the ground surface to cushion the geotextile. The subgrade preparation must correspond to the survivability properties of the geotextile.

c. Once the subgrade along a particular segment of the road alignment has been prepared, the geotextile should be rolled in line with the placement of the new road aggregate. Field operations can be expedited if the geotextile is presewn in the factory to design widths such that it can be unrolled in one continuous sheet. The geotextile should not be dragged across the subgrade. The entire roll should be placed and rolled out as smoothly as possible. Wrinkles and folds in the geotextile should be removed by stretching and staking as required.

d. Parallel rolls of geotextiles should be overlapped, sewn, or tied as required. Specific requirements are given later.

e. For curves, the geotextile should be folded or cut and overlapped in the direction of the turn. Folds in the geotextile should be stapled or pinned 5 ft on center.

f. When the geotextile intersects an existing pavement area, the material should extend to the edge of the old system. For widening or intersecting existing roads where a geotextile has been used, consideration should be given to anchoring the geotextile at the roadway edge. Ideally, the edge of the roadway should be excavated down to the existing geotextile and the existing geotextile sewn to the new geotextile. Overlaps, staples, and pins could also be utilized.

g. Before covering, the condition of the geotextile should be observed by a qualified inspector experienced in the use of these materials to determine that no holes, rips, tears, etc., have occurred in the geotextile. If any defects are observed, the section of the geotextile containing the defect should be repaired by placing a new layer of geotextile extending beyond the defect in all directions a minimum of the overlap required for parallel rolls. Alternatively, the defective section can be replaced.

h. The subbase aggregate should be end-dumped on the geotextile from the edges of the geotextile or on the previously placed aggregate. For very soft subgrades, pile heights should be limited to prevent possible subgrade failure. The maximum placement lift thickness for such soils should not exceed the design thickness of the road.

i. The first lift of aggregate should be spread and graded down to 12 in. or to the design thickness if less than 12 in. prior to compaction. At no time should equipment be allowed on the road with less than 8 in. (6 in. for CBR $\geq$ 2) of compacted aggregate over the fabric. For extremely soft soils, lightweight construction vehicles will likely be required for access on the first lift. Construction vehicles should be limited in size and weight such that rutting in the initial lift is no greater than 3 in. If rut depths exceed 3 in., it will be necessary to decrease the size and/or weight of the construction vehicles or to increase the lift thickness. For example, it may be necessary to reduce the size of the dozer required to blade out the fill or possibly to deliver the fill in half-loaded rather than fully loaded trucks.

j. The first lift of subbase aggregate should be compacted by "tracking" with the dozer and then compacted with a smooth-drum vibratory roller to obtain a minimum compacted density. For very soft soils, design density should not be anticipated for the first lift, and in this case, compaction requirements should be reduced. One possible recommendation would be to allow compaction of 5 percent less than the required specification density.

k. Construction should be performed parallel to the road alignment. Turning should not be permitted on the first lift of subbase aggregate. Turn-outs may be constructed at the road edge to facilitate construction.

l. If the geotextile is to provide some reinforcing, pretensioning of the geotextile should be considered. For pretensioning, the area should be proof-rolled by a heavily loaded rubber-tired vehicle such as a loaded dump truck. The wheel load should be equivalent to the maximum expected for the site. The vehicle should make at least four passes over the first lift in each area of the site. Alternatively, once the design aggregate has been placed, the roadway could be used for a time prior to final surfacing such that prestressing the geotextile in key areas could be obtained.

m. Any ruts that form during construction should be filled with additional material to maintain adequate cover over the geotextile. In no case should ruts be bladed down as this would decrease the amount of aggregate cover between the ruts.

n. All remaining subbase aggregate should be placed in lifts not exceeding 9 in. in loose thickness and compacted to the appropriate specification density.

Overlaps*

23. Overlaps can be used to provide continuity between adjacent geotextile sections through frictional resistance between the overlaps. A sufficient overlap is required to prevent soil from squeezing into the aggregate at the geotextile joint. The amount of overlap depends primarily on the soil conditions and the potential for equipment to rut the soil. If the subgrade will not rut under construction activities, only a minimum overlap sufficient to provide some pullout resistance is required. As the potential for rutting and squeezing of soil increases, the required overlap increases. Since rutting potential can be related to soil strength (CBR), it can be used as a guideline for the minimum overlap required, as shown in Table 6.

Table 6

Recommended Minimum Overlap Requirements

CBR	Minimum Overlap
Greater than 2	1 - 1.5 ft
1 - 2	2 - 3 ft
0.5 - 1	3 ft or sewn
Less than 0.5	Sewn
All roll ends	3 ft or sewn

* From Christopher and Holtz 1985, US Department of Transportation 1989b.

24. The geotextile can be stapled or pinned at the overlaps to maintain them during construction activities. The 10- to 12-in.-long nails should be placed at a minimum of 50 ft on centers for parallel rolls and 5 ft on centers for roll ends.

25. Fabric widths should be selected such that overlaps of parallel rolls occur at the center line and at the shoulder. Overlaps should not be placed along anticipated main wheel path locations.

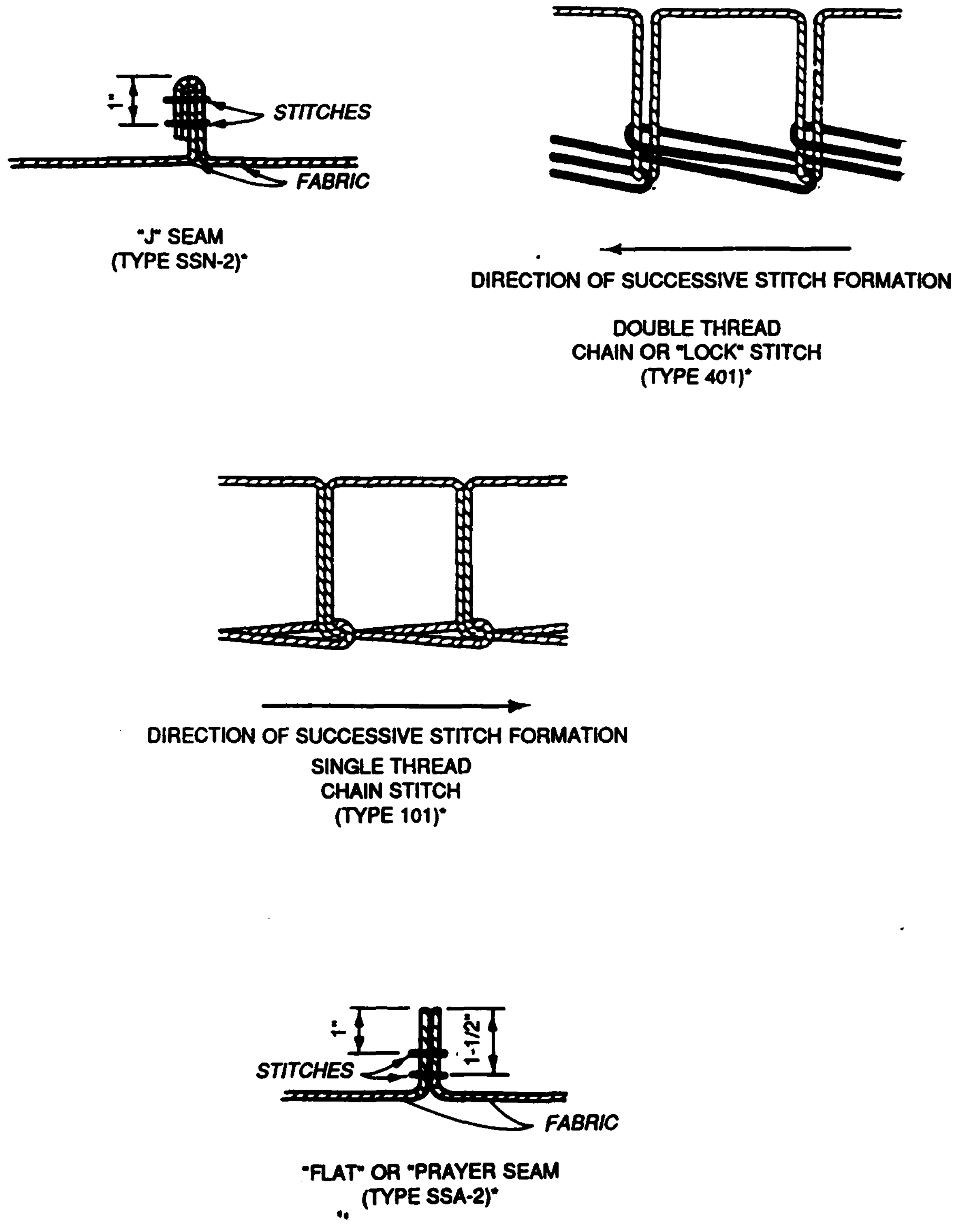
26. Overlaps at the end of rolls should be in the direction of the aggregate placement (previous roll on top).

Seams

27. When seams are required for separation applications, it is recommended that the seams meet the same tensile strength requirements for survivability as required for the geotextile (Table 5) in the direction perpendicular to the seam (as determined by the same testing methods). All factory or field seams should be sewn with thread having the same or greater durability and strength as the material in the geotextile. "J-seams" (Figure 4) with interlocking stitches are recommended. Alternatively, if single thread chain stitches, which can unravel, or flat-type seams are used, seams should be double-sewn with parallel stitching spaced no more than 1/4 to 1/2 in. apart. Double sewing is required to provide a safety factor against undetected missed stitches. The specified strength of the geotextiles may have to be based on the type of seams to be used. Additional information and details on seams may be obtained from the "Geotextile Design and Construction Guidelines" (US Department of Transportation 1989b) and Federal Standard 751A (Department of Defense 1983).

Design Guidelines and Procedures

28. The design of aggregate surfaced pavements where geotextiles are being considered in the structure has two main approaches. One is that no reinforcing effect is contributed by the geotextile. Its function is that of separation only. The other approach takes into consideration the reinforcing effect of the geotextile. The separation function is said to be more important in low embankments where small loads are applied and rutting of



*TYPES PER FED-STD-751 A (Department of Defense 1983)

Figure 4. Stitch and seam types

2 to 4 in. is anticipated. Where large loads are applied on thin embankments and rut depths of 4 in. or greater may occur and for high embankments on softer subgrades, the reinforcing function is increasingly more important to maintain stability (US Department of Transportation 1989b). A number of design procedures have been developed for using geotextiles in aggregate surfaced pavement construction. Some of these procedures are listed below; however, detailed information on each can be found in the respective references. Department of the Army Technical Manual TM 5-818-8 (Headquarters, Department of the Army 1990) lists the design procedure by Steward, Williamson, and Mohney (1977) for Army use.

a. Bender and Barenberg ((1978), Christopher and Holtz 1985, Hausmann 1987, US Department of Transportation 1989a).

b. Steward, Williamson, and Mohney (Christopher and Holtz 1985; Hausmann 1987; Steward, Williamson, and Mohney 1977; US Department of Transportation 1989a; 1989b).

c. Giroud and Noiray (Christopher and Holtz 1985, Giroud and Noiray 1981, Hausmann 1987, Koerner and Welsh 1980b, US Department of Transportation 1989b).

d. Haliburton and Barron (Christopher and Holtz 1985, Haliburton and Barron 1983).

e. Monsanto (Christopher and Holtz 1985, Hamilton and Pearce 1981).

f. Dupont (Christopher and Holtz 1985, Koerner and Welsh 1980b).

g. Imperial Chemical Industries Ltd (Christopher and Holtz 1985).

h. Exxon Chemical Americas (Exxon Geotextile Design Manual for Paved and Unpaved Roads 1985).

i. Mirafi, Inc. (Mirafi Design Guidelines and Installation Procedures Using Mirafi 1989).

j. Phillips Fibers Corp. (Stabilization Design Guide 1987).

k. Polyfelt, Inc. (Road Construction 1989).

29. A comparison of three design procedures are given in Table 7 (US Department of Transportation 1989a). This table gives a comparison of aggregate thickness required with and without the use of a geotextile in the design. Aggregate savings of from 20 to 45 percent when using a geotextile is also shown in Table 7. Work conducted by others (Barenberg, Dowland, and Hales 1975; Cook and Kennedy 1988; Robnett and Lai 1982a; Stabilization Design Guide 1987; Warwick 1983; Webster and Alford 1978) also reveal that aggregate savings of 25 to 40 percent can be realized by using geotextiles in aggregate surfaced pavement construction.

Table 7

Aggregate Thickness (in inches) Obtained for the Considered Design Example with Three Different Methods*

	Bender and Barenberg	Steward, Williamson, and Mohney		Giroud and Noiray	
Rut depth	4 in.	≥ 4 in.	≤ 2 in.	≤ 2 in.	
Number of passes	≈100	100	1,000	100	1,000
Without geotextile	28-31	23	25	22	33
Low-modulus geotextile	18	18	20	15	26
Medium-modulus geotextile	16	--	--	15	26
High-modulus geotextile	--	--	--	15	26
Geotextile average	17	18	20	15	26
Aggregate savings	39-45%	22%	20%	32%	21%

Note:

The values of the geotextile moduli used to establish this table are low modulus, ≈ 1,000 lb/in.; medium modulus, ≈ 2,000 lb/in. and high modulus, > 3,000 lb/in.

Although the method by Steward, Williamson, and Mohney does not consider geotextile modulus as a variable, this method has been established on the basis of results of field tests conducted with low-modulus geotextiles. Therefore, in this table, results of calculations made using Steward, Williamson, and Mohney's method have been assigned to the line related to low-modulus geotextiles.

* From US Department of Transportation 1989a.

30. Design examples for aggregate surfaced pavement construction are given in the "Geotextile Engineering Manual" (Christopher and Holtz 1985) and "Geotextile Engineering Workshop Design Examples (US Department of Transportation 1989a)."

PART V: FLEXIBLE PAVEMENTS FOR ROADS

31. Review of the information obtained from the various sources in this literature search revealed that some research has been conducted on the use of geotextiles in flexible pavement for road construction. Much of the work has been limited to small laboratory studies with little published information on full-scale field and/or long-term investigations. There are various standard design procedures for flexible and rigid pavements available; however, they do not include the use of geotextiles. This study revealed that there are design guidelines and procedures available where geotextiles are considered for flexible pavement road construction. Some of these procedures will be mentioned; however, details are not given in this report but can be obtained from the respective references. A brief summary on the most comprehensive work to date on geosynthetic (geogrid or geotextile) use in base courses for flexible pavements is given below along with other items related to geotextile usage that are considered to be important.

Geosynthetic Use In Flexible Pavements

32. The most comprehensive work to date on geosynthetic (geogrid or geotextile) reinforcement for base courses for flexible pavements was conducted by Barksdale, Brown, and Chan (1989). The laboratory research was conducted at the University of Nottingham, and the analytical studies were conducted at the Georgia Institute of Technology.

33. Variables investigated in the laboratory study included the following:

- a. Type and Stiffness of Reinforcement (geogrids and high modulus woven geotextiles).
- b. Reinforcement Position.
- c. Pavement Strength.
- d. Geosynthetic Prestressing.
- e. Prerutting of the Aggregate Base both with and without Reinforcement.

The laboratory tests consisted of a 1.0- to 1.5-in.-thick asphalt surfacing placed over a 6- or 8-in.-thick aggregate base. The silty clay subgrade had a CBR of 2.5. A 1,500-lb moving wheel load was employed in the experiments.

Results

34. The laboratory and analytical results indicated that geosynthetic reinforcement of an aggregate base can, under the proper conditions, improve pavement performance with respect to both permanent deformation and fatigue. Specific conclusions from the study are as follows:

a. Type and stiffness of geosynthetic. A geogrid having an open mesh has the reinforcing capability of a woven geotextile having a stiffness approximately two and one-half times as great as the geogrid. A geogrid performs differently than a geotextile. Test results indicate that the minimum stiffness to be used for aggregate reinforcement applications should be 1,500 lb/in. for geogrids and 4,000 lb/in. for woven geotextiles.

b. Geosynthetic position. For light (2.5 to 3.5 in. thick asphalt) pavement sections constructed with low quality aggregate bases, the preferred position for the reinforcement should be in the middle of the base, particularly if the subgrade has a CBR of 3 or greater. For pavements constructed on soft subgrades, the reinforcement should be at or near the bottom of the base. The reinforcement should be at the bottom of the base to be most effective in minimizing permanent deformations in the subgrade.

c. Improvement levels. Light sections on weak subgrades (CBR ≤3) reinforced with geosynthetics can give reductions in base thickness of 10 to 20 percent. For weak subgrades and/or low quality bases, total rutting in the base and subgrade may be reduced by 20 to 40 percent.

d. Fatigue. The analytical results indicated that improvements in permanent base and subgrade deformations may be greater than the improvement in fatigue life.

e. Prerutting and prestressing. Both prerutting the aggregate base and prestressing the geosynthetic can significantly reduce permanent deformations within the base and subgrade. However, stress relaxation with time could significantly reduce the effectiveness of prestressing the geosynthetic in the aggregate.

Recommendations

35. Barksdale, Brown, and Chan (1989) recommend additional research be conducted consisting of carefully instrumented, full-scale field test sections. Geogrid reinforcement is recommended as the primary reinforcement since it was found to perform better than a much stiffer woven geotextile.

Function of Geotextiles

36. The functions of separation, filtration, drainage, and reinforcement for geotextile usage in aggregate surfaced pavements were mentioned and defined in the section "Aggregate Surfaced Pavements" of this report. These functions, except for the function of reinforcement, should be considered in the design and usage of geotextiles in flexible pavements for roads (Barksdale, Brown, Chan 1989; Brown, Jones, and Brodrick 1982; Christopher and Holtz 1985; US Department of Transportation 1989b). There is no method available for quantitatively assessing the benefit of a geotextile in the structural support capacity of a roadway system. Paving surfaces (either concrete or asphalt) cannot be placed on pavement structures that yield or rut under load since the surfaces would crack after a few load applications, thus destroying the integrity of the pavement structure (Koerner 1990). Therefore, for permanent roadway design, all structural support must be carried by the pavement aggregate subgrade system exclusive of a geotextile fabric. The function of separation (of subgrade and aggregate) in flexible road construction is considered the same as mentioned for aggregate surfaced pavement construction, i.e. intermixing of subgrade and aggregate presents problem only when the subgrade soil strength is less than 3 CBR (Christopher and Holtz 1985, US Department of Transportation 1989a, 1989b). Department of the Army Technical Manual TM 5-818-8 (Headquarters, Department of the Army 1990) mentions that geotextiles are used for purposes other than reinforcement when placed in permanent pavements. The other purposes listed are separation or filtration, an aid in construction, and/or maintenance reduction.

Geotextile Benefits

37. The benefits listed in the "Aggregate Surfaced Pavements" section are applicable to flexible pavement for roads when geotextiles are used.

Geotextile Properties and Criteria

38. The properties and criteria listed in Table 1 are applicable to flexible pavements for roads and should be considered when geotextiles are used.

Geotextile Survivability

39. The properties and characteristics listed under "Geotextile Survivability" in the "Aggregate Surfaced Pavements" section of this report are applicable to flexible pavement for roads and should be considered when geotextiles are used.

Geotextile Installation Guidelines

40. The installation guidelines presented in the "Aggregate Surfaced Pavements" section of this report are applicable when geotextiles are used in flexible pavements for roads.

Design Guidelines and Procedures

41. Design guidelines and procedures for using geotextiles in flexible pavement road construction can be found in the "Geotextile Engineering Manual" (Christopher and Haltz 1985) and "Geotextile Design and Construction Guidelines." (US Department of Transportation 1989b). Design examples for geotextiles used in flexible pavement for roads are also given in the "Geotextile Engineering Manual" (Christopher and Holtz 1985) and in "Geotextile Engineering Workshop Design Examples (US Department of Transportation 1989a)."

42. In using geotextiles in the design of flexible pavement for roads no structural support is assumed to be provided by the geotextile, and therefore, no reduction is allowed in the aggregate thickness required for structural support (Christopher and Holtz 1985, US Department of Transportation 1989b). Standard design methods are used for the overall pavement system. Aggregate savings can be achieved when using a geotextile through a reduction in the aggregate required in the first lift referred to as the "stabilization lift." Sufficient stabilization of the subgrade (CBR < 3) (Christopher and Holtz 1985, US Department of Transportation 1989b) is provided to allow access of normal construction equipment for the remaining structural lifts. The stabilization lift thickness using a geotextile is determined as that for an aggregate surfaced pavement which will only be subjected to limited number of construction equipment passes.

43. Other design guidelines and procedures have been developed for using geotextiles in flexible pavement road construction. Some of these are listed below; however, detailed information on each can be found in the respective references.

a. Phillips Fibers Corp (Stabilization Design Guide 1987).

b. Exxon Chemical Americas (Exxon Geotextiles Design Manual for Paved and Unpaved Roads 1985).

c. Polyfelt, Inc. (Road Construction 1989).

d. Law Engineering Testing Company (Hamilton and Pearce 1981).

e. Mirafi, Inc. (Guidelines for Design of Flexible Pavements Using Mirafi Woven Geotextiles 1982).

PART VI: AGGREGATE SURFACED AIRFIELDS

44. In 1987 Webster (unpublished a) worked with US Army troops of the 52nd Engineer Battalion and designed an aggregate-geotextile C-130 airfield for the Army's Pinon Canyon Maneuver Site near Trinidad, Colorado. The subgrade was a silty clay soil with a design soaked CBR of 2.9. The design was completed using the Exxon 1 computer program (Exxon Geotextiles Design Manual for Paved and Unpaved Roads 1985). This program is based on the US Army Corps of Engineer's unsurfaced thickness criteria (Hammitt 1970) and Giroud and Noiray's (1981) design for geotextile reinforcement. The final design for the 125-kip C-130 aircraft was 10 in. of crushed stone base course over a geotextile with a grab strength of 270 lb (see Table 5). The 60-ft-wide by 5,000-ft-long runway was constructed in March of 1987. Based on its good performance, a parallel taxiway and parking aprons were added in 1989, using the same type aggregate-geotextile design procedure.

45. In August 1988 Webster (unpublished a) designed a second aggregate-geotextile C-130 runway, and the 52nd Engineer Battalion constructed the runway at Fort Carson, Colorado. This runway replaced the existing Red Devil clay airstrip. The existing airstrip could not be used during wet weather and required substantial maintenance due to rutting and erosion of the clay subgrade soil. The existing airstrip was reconstructed into a 60-ft-wide by 5,000-ft-long runway consisting of 8 in. of crushed aggregate over a geotextile meeting the same requirements as above. In all three construction projects, a slit-film woven geotextile was delivered as the lowest cost geotextile meeting the grab strength requirements.

46. No problems were encountered during construction of these airfields. Both airfield facilities have performed as designed.

PART VII: FLEXIBLE PAVEMENTS FOR AIRPORTS

47. The literature search for information, design guidelines, etc., related to geotextile applications in pavement construction for airports produced only three printed documents. These were "Potential Use of Geotechnical Fabric in Airfield Runway Design" by Haliburton, Lawmaster, and King (1980), "Fabric Stabilizes River Area for Runway Extension" (Fabric Stabilizes River Area for Runway Extension 1983), and "Design and Construction of a Geotextile Reinforced Taxiway Embankment Over Peat" by Gale and Henderson (1984). These reports are briefly summarized in the following paragraphs. Items pertinent to geotextile usage in aggregate surfaced pavements and flexible pavements for roads believed to be important when considering geotextiles for use in airport pavement construction are also mentioned.

48. The report "Potential Use of Geotechnical Fabric in Airfield Runway Design" (Haliburton, Lawmaster, and King 1980) was a study conducted for the US Air Force, Bolling AFB, Washington, DC. This study included a state-of-the-art literature review plus laboratory experimental research on the potential use of geotextile fabric in airfield runway design. Haliburton, Lawmaster, and King (1980) general conclusion was that geotechnical fabric, when used in pavement construction, has potential for improving airfield runway performance for all types of runways. However, the current state-of-the-art was such that site-specific design criteria were not available for either estimating performance improvement or quantitatively specifying desired fabric properties for airfield applications. Long-term laboratory and/or field evaluation is needed for determining geotextile applicability. Long-term effects on geotextile properties including fabric type, clogging resistance, quantitative penetration, abrasion, and fatigue resistance to withstand repeated dynamic loadings without failure need to be determined. Haliburton, Lawmaster, and King (1980) general recommendation was additional research should be undertaken to more quantitatively define expected behavior and develop rational criteria for design of runway systems using geotechnical fabrics. An interim recommendation was no large capital expenditures be made for geotechnical fabric to be used in airfield runway structures, especially where long-term performance is desired and permanent wearing surface contemplated without a satisfactory field performance test. This field performance

test would be conducted under expected design loading conditions with a reasonable number of load applications.

49. The article "Fabric Stabilizes River Area for Runway Extension" (Fabrics Stabilizes River Area for Runway Extension 1983) given as "Case Histories" in the fall 1983 issue of Geotechnical Fabrics Report mentions the use of a geotextile fabric in the 700-ft runway extension at Washington National Airport. All 12-ft wide strips were field sewn into a section 700 ft long and 600 ft wide. This section was then towed into place offshore from the existing runway and submerged in the Potomac River. The fabric was woven from high-tenacity polyester yarn to form a high strength permeable geotextile to stabilize and improve the bearing capacity of the loose mud and silt at the river bottom. The geotextile allowed a landfill to be placed directly on top of the geotextile covered mud and silt. The runway extension occupied approximately 7 acres of river area. Therefore, approximately 7 acres of soil were removed from the eastern portion of the airport complex. The soil from the eastern portion which was used as the fill material for the runway extension was taken to the area by trucks and barges. Hydraulic pumping was used to place the fill material. Conversations with Messrs. B. Clark and D. Jones* revealed that the runway extension was completed as planned. However, the extension was added only as an emergency overrun and was not paved for aircraft traffic. The extension which is covered with natural grass has been used only twice by aircraft since installation. No major aircraft, property damage, or loss of life occurred during the overruns. There has been minor settlement around pilings that were installed on the extension for attachment of airfield lighting. The pilings were installed through the geotextile fabric.

50. The article by Gale and Henderson (1984) is another "Case History" given in the Summer 1984 issue of Geotechnical Fabrics Report. This project involved extending the taxiway system 2,000 ft to one end of the main runway at the Duluth International Airport, Duluth, MN. The 2,000 ft of taxiway extension was over swamp deposited peat soil which ranged in depth from 8 to 10 ft. The grade of the swamp had to be raised from 7 to 10 ft in order to tie in with the existing taxiway pavement. Several construction schemes were

* Personal Communications, 19 March 1990, B. Clark, Allied Fibers, New York, and 8 May 90, D. Jones, Metropolitan Washington Airport Authority, Washington, DC.

considered, however, the decision was made to place a woven geotextile, then stage loading of fill with a final surcharge. It was critical that settlement of the peat be kept to a minimum after placement of the pavement. To achieve this, an additional 6 ft fill (surcharge) was placed above the proposed pavement surface. The fill placement was completed in November 1983. Settlement measurements made in June 1984 ranged from 3 to 4 ft which was in the predicted range. Gale and Henderson's article covered only the planned action for the spring of 1985. However, conversation with Messrs. Stephen Gale and Ken Wennberg* revealed the surcharge was removed in the spring of 1985. Final grade preparation and paving of the taxiway were completed during the summer of 1985. This paved taxiway has performed satisfactory without any problems to date.

Pertinent Items

51. The functions of geotextiles presented in the "Flexible Pavements for Roads" section of this report should be evaluated when considering the use of geotextiles in airport pavement construction. However, the need for the geotextile to perform as a separator may not be applicable in airport construction. As previously mentioned in the "Aggregate Surfaced Pavements" and "Flexible Pavements for Roads" sections of this report, the need for a geotextile to provide the separation function exists only when the strength of the subgrade is less than 3 CBR. Flexible pavement design curves in Federal Aviation Administration (FAA) Advisory Circular 150/5320-6C (US Department of Transportation 1988) for aircraft up to 30,000 lb gross weight (Figure 5) list the lower strength value of the subgrade to be approximately 3.5 CBR. Similar curves for aircraft over 30,000 lb gross weight (Figure 6) list the lower strength value of the subgrade to be 3 CBR. The potential benefits of using geotextiles for aggregate surfaced pavements and flexible pavements for roads should be investigated when considering geotextiles. The geotextile properties and criteria (Table 1), survivability properties, and characteristics and installation guidelines presented in the "Aggregate Surfaced Pavements"

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* Personal Communications, 7 May 1990, Stephan M. Gale, Project Consultant, STS Consultants, Minneapolis, MN and Ken Wennberg, Assistant Director for Operations, Duluth International Airport, Duluth, MN.

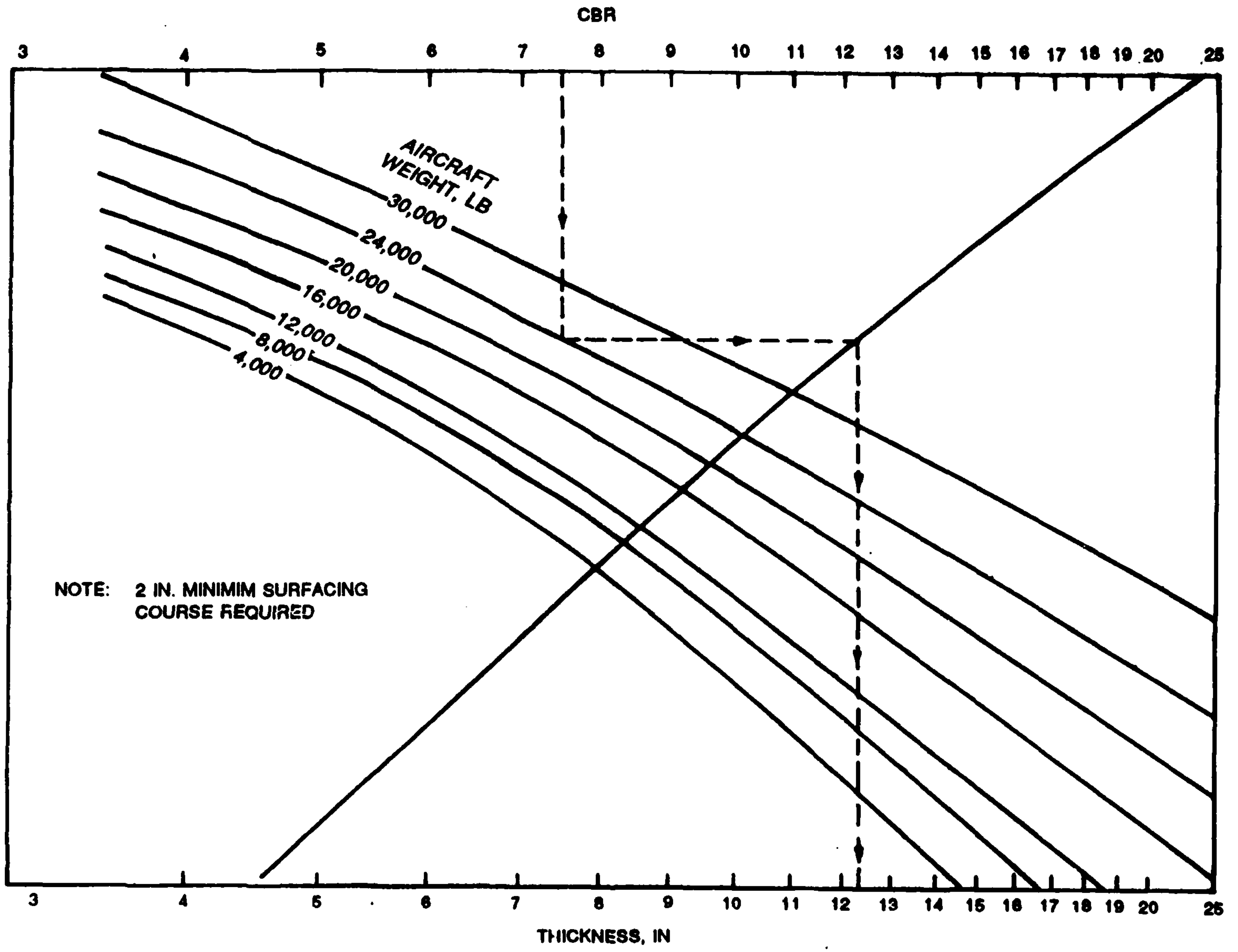

Figure 5. Design curves for flexible pavements, light aircraft (US Department of Transportation 1988)

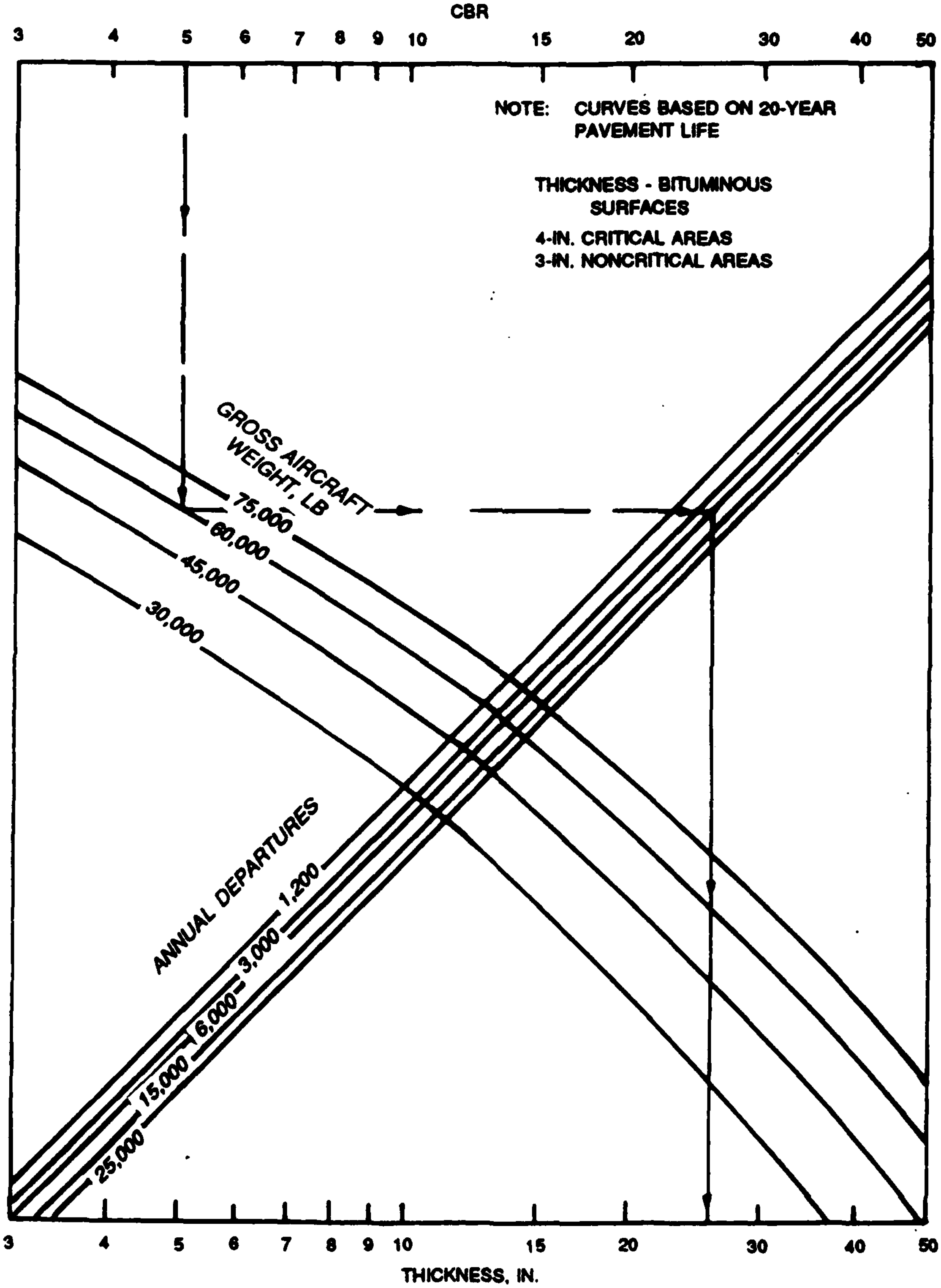

Figure 6. Flexible pavement design curves for critical areas, single wheel gear (US Department of Transportation 1988)

section should be considered if contemplating the use of geotextiles in airport pavement construction.

Design Guidelines and Procedures

52. The information obtained and reviewed in this literature search written by various researchers, engineers, and manufacturers/suppliers revealed that there are no design procedures available which specifically incorporate geotextiles in the structure of airport pavements. Various manufacturers/suppliers' literature mentioned that geotextile fabrics are applicable for airport construction. However, no specific information or design procedures/guidelines were given. The information on aggregate surfaced pavements and flexible pavements for roads contained in this report may be helpful when considering the use of geotextiles for inclusion in the pavement structure of airports. However, standard airport design methods and procedures such as those contained in Advisory Circular 150/5320-6C (US Department of Transportation 1988), TM 5-825/2/NAVFAC DM 21.3/AFM 88-6 (Headquarters, Departments of the Army, the Navy, and the Air Force 1978), and TM 5-825-3/AFM 88-6 (Headquarters, Departments of the Army and the Air Force 1988) should be used without any support attributed to the geotextile. Geotextiles may be used as an aid in the construction of the first lift of the structure or for drainage and/or filtration characteristics.

PART VIII: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

53. This literature review revealed that there are many published and available technical articles, reports, manufacturers/suppliers data covering geotextile usage in aggregate surfaced pavements and flexible pavement road construction with little information available on usage in flexible pavements for airports.

54. The state-of-the-art in geotextile usage has advanced tremendously over the last few years; however, it has not advanced to the point where there is a generally acceptable design procedure for either aggregate surfaced pavements or flexible pavements for roads. This study revealed that there are many procedures for both aggregate surfaced pavements and flexible pavements for road construction. There were no procedures revealed in this study for geotextile use in paved airports.

55. Construction/installation procedures available for using geotextiles in aggregate surfaced pavements and flexible pavement road construction may be considered as guideline information if geotextiles are considered for use in flexible pavements for airports.

56. Accepted definitive specifications for various geotextile applications (aggregate surfaced pavements, flexible pavements for roads and airports) and functions along with a uniform set of test standards for verifying the specified geotextile properties are not available.

57. The results of the comprehensive tests conducted by Barksdale, Brown, and Chan (1989) and Chan, Barksdale, and Brown (1989) show that geogrids have more potential than geotextiles for reinforcement of flexible pavements.

58. Standard airport design procedures should continue to be used for paved airports, and if geotextiles are used in the structure, no structural support should be attributed to the geotextile. Geotextiles should be used for the function of separation, filtration or drainage, or a combination of these functions.

Recommendations

59. The use of current standard airport design procedures should be continued without any structural support attributed to the geotextiles, if they are used, until such time design procedures incorporating geotextiles are developed. Geotextiles should be considered only for site specific situations such as:

a. When the subgrade strength is $\leq$ 3 CBR, geotextiles should be used to aid in establishing a stable foundation layer on which to construct a pavement system.

b. On known problem subgrades subject to rutting even when recommended FAA design thicknesses are used.

60. Further research should be delayed on the use of geotextiles to improve subgrade support for general aviation airports until the results of the laboratory grid study (Phase I, Task 4) and field grid tests (Phase I, Task 5) are known.

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APPENDIX B: PERSONS AND FIRMS CONTACTED FOR ADDITIONAL INFORMATION

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Mr. Ken Wennberg*
Assistant Director for Operations
Duluth Airport Authority
Duluth International Airport
Duluth, MN 55811

A.C.F. Inc.**
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American Sealing and Fabrics, Inc.†
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Amoco Fabrics and Fibers Company**
900 Circle 75 Parkway, Suite 550
Atlanta, GA 30339

Belton Industries, Inc.†
8613 Roswell Road
Atlanta, GA 30350

Bradley Materials Company, Inc.†
101 John Sims Parkway
Valparasso, FL 32580

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* Oral.
** Written.
† Written but no response.
†† Consultant firm.

Carthage Mills †
1821 Summet Road
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Choctaw, Inc.†
1184 Tupelo Street
Memphis, TN 38108

Culverts and Industrial Supply Company †
Box 1300
Mills, WY 82644

Contech Construction Products, Inc.**
1001 Grove Street
Middletown, OH 45044

Delaware Valley Corporation †
500 Broadway
Lawerence, MA 01841

Exxon Chemical Company†
2100 Riveredge Parkway, Suite 1025
Atlanta, GA 30328

GeoServices, Inc.‡
1200 South Federal Highway
Boynton Beach, FL 33435

Hoechst Celanese Corporation**
Interstate 85 and Road 57
Spartanburg, SC 29304

Mirafi, Inc.**
8702 Red Oak Boulevard
Charlotte, NC 28217

Pallen Enterprises, Inc.†
1507 General Arts Road
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Phillips Fibers Corporation**
P.O. Box 66
Greenville, SC 29602

Polyfelt, Inc.**
P.O. Box 727
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Resicon, Inc./Resicon Containment, Inc.†
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Sunapee, NH 03782

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