

UNIFIED FACILITIES CRITERIA (UFC)

AGGREGATE SURFACED ROADS AND AIRFIELDS AREAS



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U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by \1\ ... /1/)

Change No.	Date	Location

This UFC supersedes TM 5-822-12, dated 28 September 1990. The format of this UFC does not conform to UFC 1-300-01; however, the format will be adjusted to conform at the next revision. The body of this UFC is the previous TM 5-822-12, dated 28 September 1990.

FOREWORD

v\

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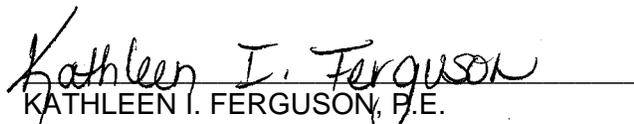
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TECHNICAL MANUAL

DESIGN OF AGGREGATE SURFACED ROADS
AND AIRFIELDS

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HEADQUARTERS, DEPARTMENT OF THE ARMY

September 1990

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DESIGN OF AGGREGATE SURFACED ROADS AND AIRFIELDS

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DESIGN OF AGGREGATE SURFACED ROADS AND AIRFIELDS

1. Purpose

This manual presents the procedures for design of aggregate surfaced roads and airfields.

2. Scope

This manual presents criteria for determining the thickness, material, and compaction requirements for all classes of aggregate surfaced roads and for Class I, II, and III airfields at US Army installations. Road classes are defined in TM 5-822-2, and airfield classes are defined in TM 5-803-4. Class IV Army airfields would normally be paved. Use of the term roads includes roads, streets, open storage areas, and parking areas. Use of the term airfields includes heliports, runways, taxiways, and parking aprons. Design requirements are presented for frost and nonfrost areas.

3. References

Publications cited in this manual are listed in appendix A.

4. Design of aggregate surfaced roads

a. Procedures. The thickness design of aggregate surfaced roads is similar to the design of flexible pavement roads as contained in TM 5-822-5. This procedure involves assigning a class to the road being designed based upon the number of vehicles per day. A design category is then assigned to the traffic from which a design index is determined. This design index is used with figure 1 to select the thickness (minimum of 4 inches) of aggregate required above a soil with a given strength expressed in terms of California Bearing Ratio (CBR) for nonfrost areas or in terms of a frost area soil support index (FASSI) in frost areas.

b. Classes of roads. The classes of aggregate surfaced roads vary from A to G. Selection of the proper class depends upon the traffic intensity and is determined from table 1.

c. Design index. The design of gravel roads will be based on a design index, which is an index representing all traffic expected to use the road during its life. The design index is based on typical magnitudes and compositions of traffic reduced to equivalents in terms of repetitions of an 18,000-pound single-axle, dual-wheel load. For designs involving rubber-tired vehicles, traffic is classified in three groups as follows:

Group 1. Passenger cars and panel and pickup trucks.

Group 2. Two-axle trucks.

Group 3. Three-, four-, and five-axle trucks.

Traffic composition will then be grouped in the following categories:

Category I. Traffic composed primarily of passenger cars, panel and pickup trucks (Group 1 vehicles), and containing not more than 1 percent two axle trucks (Group 2 vehicles).

Category II. Traffic composed primarily of passenger cars, panel and pickup trucks (Group 1 vehicles), and containing as much as 10 percent two-axle trucks (Group 2 vehicles). No trucks having three or more axles (Group 3 vehicles) are permitted in this category.

Category III. Traffic containing as much as 15 percent trucks, but with not more than 1 percent of the total traffic composed of trucks having three or more axles (Group 3 vehicles).

Category IV. Traffic containing as much as 25 percent trucks, but with not more than 10 percent of the total traffic composed of trucks having three or more axles (Group 3 vehicles).

Category IVA. Traffic containing more than 25 percent trucks or more than 10 percent trucks having three or more axles (Group 3 vehicles).

d. Tracked vehicles and forklift trucks. Tracked vehicles having gross weights not exceeding 15,000 pounds and forklift trucks having gross weights not exceeding 6,000 pounds may be treated as two-axle trucks (Group 2 vehicles) in determining the design index. Tracked vehicles having gross weights exceeding 15,000 pounds but not 40,000 pounds and forklift trucks having gross weights exceeding 6,000 pounds but not 10,000 pounds may be treated as Group 3 vehicles in determining the design index. Traffic composed of tracked vehicles exceeding 40,000-pound gross weight and forklift trucks exceeding 10,000-pound gross weight has been divided into the following three categories:

<i>Maximum Vehicle Gross Weight, pounds</i>		
<u>Category</u>	<u>Tracked Vehicles</u>	<u>Forklift Trucks</u>
V	60,000	15,000
VI	90,000	20,000
VII	120,000	35,000

e. Design index. The design index to be used in designing a gravel road for the usual pneumatic-tired vehicles will be selected from table 2.

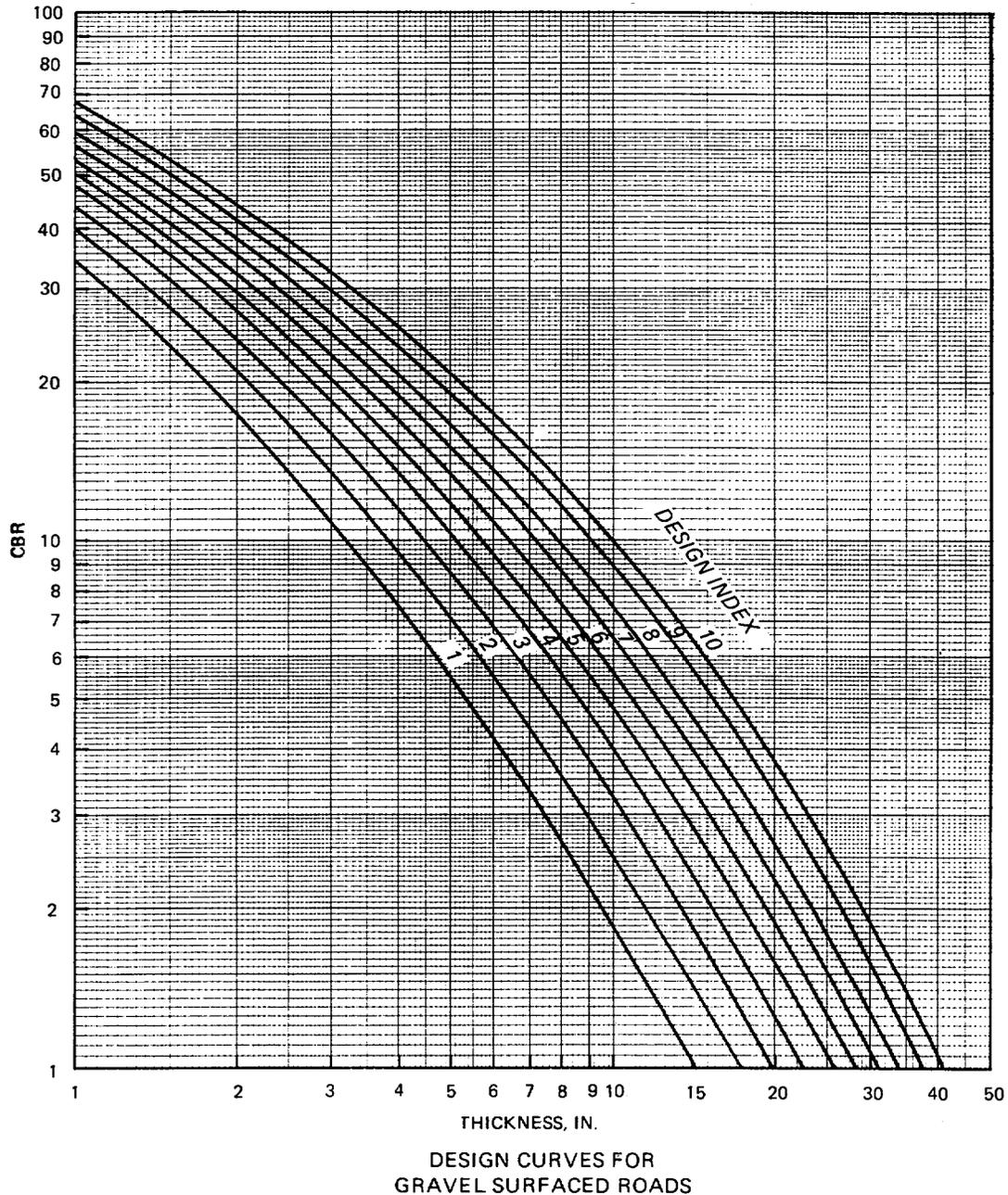


Figure 1. Thickness design curves for aggregate surfaced roads.

f. *Roads for tracked vehicles.* Roads sustaining traffic of tracked vehicles weighing less than 40,000 pounds, and forklift trucks weighing less than 10,000 pounds, will be designed in accordance with the pertinent class and category from table 2. Roads sustaining traffic of tracked vehicles, heavier than 40,000 pounds, and forklift trucks heavier than 10,000 pounds, will be designed in accordance with the traffic intensity and category from table 3.

g. *Design life.* The life assumed for design is 25 years. For a design life less than 5 years, the design indexes in' tables 2 and 3 may be reduced by one. Design indexes below three should not be reduced.

h. *Entrances, exits, and segments.* Regardless of the design class selected for hardstands, special consideration should be given to the design of approach roads, exit roads, and other heavily trafficked areas. Failure or poor performance in these channelized traffic areas

Table 1. Criteria for selecting aggregate surface road class.

Road Class	Number of Vehicles per day
A	10,000
B	8,400-10,000
C	6,300-8,400
D	2,100-6,300
E	210-2,100
F	70-210
G	under70

Table 2. Design index for pneumatic-tired vehicles.

Class	Design Index			
	Category I	Category II	Category III	Category IV
A	3	4	5	6
B	3	4	5	6
C	3	4	4	6
D	2	3	4	5
E	1	2	3	4
F	1	1	2	3
G	1	1	1	2

Table 3. Design index for tracked vehicles and forklift trucks.

Traffic Category	Number of Vehicles per Day (or Week as indicated)							
	500	200	100	40	10	4	1	1 Per Week
V	8	7	6	6	5	5	5	-
VI	-	9	8	8	7	6	6	5
VII	-	-	10	10	9	8	7	6

often has greater impact than localized failure on the hardstand itself. Since these areas will almost certainly be subjected to more frequent and heavier loads than the hardstand, the design index used for the primary road should be used for entrances and exits to the hardstand. In the case of large hardstands having multiple use and multiple entrances and exits, consideration should be given to partitioning and using different classes of design. The immediate benefits that would accrue include economy through elimination of overdesign in some areas and better organization of vehicles and equipment.

i. *Thickness criteria (nonfrost areas).* Thickness requirements for aggregate surfaced roads are determined from figure 1 for a given soil strength and design index. The minimum thickness requirement will be 4 inches. Figure 1 will be entered with the CBR of the subgrade to determine the thickness of aggregate required for the appropriate design index. The thickness determined from the figure may be constructed of compacted granular fill for the total depth over the natural subgrade or in a layered system of granular fill (including subbases) and compacted subgrade for the same total depth. The layered section should be checked to ensure that an adequate thickness of material is used to protect the underlying layer based on the CBR of the underlying layer. The granular fill may

consist of base and subbase material provided the top 6 inches meet the gradation requirements in paragraph 8.

5. Design of aggregate surfaced airfields

The thickness design of aggregate surfaced airfields is similar to the design of flexible pavement airfields as contained in TM 5-825-2. This procedure involves assigning a class to the airfield based upon the aircraft controlling the design. Having selected the class of airfield, the design is accomplished using figures 2 through 4.

a. *Classes of airfields.* There are four classes of Army airfields. These are Classes I-IV, although only Classes I-III are considered candidates for aggregate surfacing. Each class of airfield is designed for a standard loading condition and pass level as defined in TM 5-803-4. Where necessary, airfields may be designed for loads and pass levels other than the standard, and the criteria herein provide thicknesses for varying pass and load levels.

b. *Traffic areas.* Army airfields are divided into traffic areas for design purposes. Type B traffic areas consist of taxiways, the first 1,000 feet of runway ends, and aprons. Type C traffic areas are the interior portions of the runway (between the 1,000 foot runway ends).

c. *Thickness criteria (nonfrost areas).* Thickness requirements for aggregate surfaced airfields are determined from figures 2 through 4 for types B and C traffic areas. Thicknesses for type B areas are determined directly from the curves, and type C traffic areas are designed using 75 percent of the load used to design type B traffic areas. The minimum thickness requirement for all cases will be 4 inches. The figure for the appropriate airfield class will be entered with the subgrade CBR to determine the thickness required for a given load and pass level. The thickness determined from the figure may be constructed of compacted granular fill for the total depth over the natural subgrade or in a layered system of granular fill and compacted subgrade for the same total depth. The layered section should be checked to ensure that an adequate thickness of material is used to protect the underlying layer based upon the CBR of the underlying layer. The granular fill may consist of base and subbase material provided the top 6 inches meet the gradation requirements of paragraph 8.

6. Design CBR for select materials and subbases

Design CBR values and materials requirements for select materials and subbases are to be selected in accordance with TM 5-825-2 except as modified in table 4.

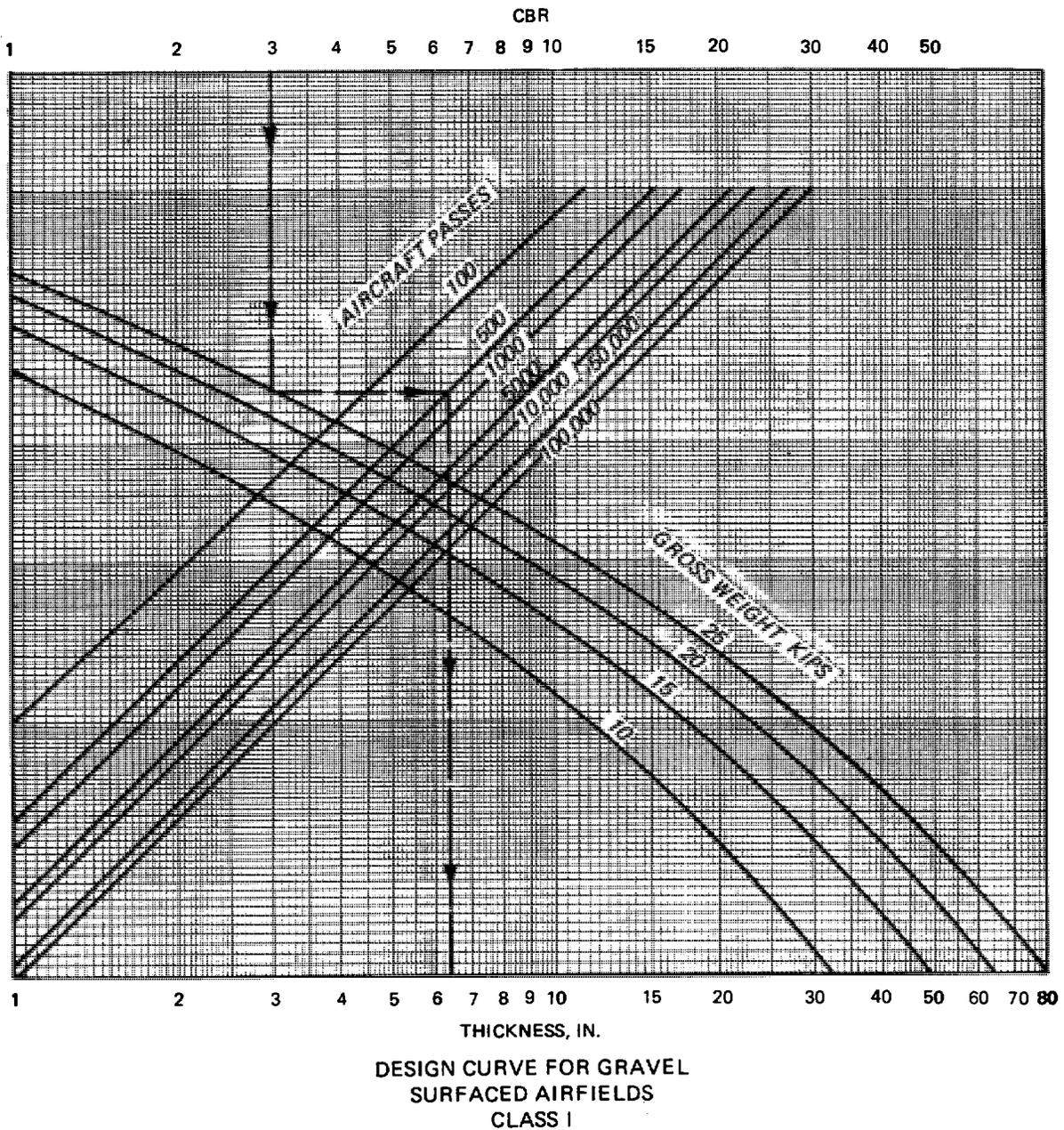


Figure 2. Aggregate surfacing design curve for Class I airfields.

7. Frost area considerations

In areas where frost effects have an impact on the design of pavements, additional considerations concerning thicknesses and required layers in the pavement structure must be addressed. The specific areas where frost has an impact on the design are discussed in the following paragraphs; however, a more detailed discussion of frost effects is presented in TM 5-818-2. For frost design purposes, soils have been divided into eight groups as shown in table 5. Only the nonfrostsusceptible (NFS) group is suitable for base course. NFS, S1, or S2 soils may be used for subbase course, and any of the eight groups may be encountered as subgrade soils. Soils are listed in approximate order of decreasing bearing capability during periods of thaw.

a. *Required thickness.* Where frost susceptible subgrades are encountered, the section thickness required will be determined according to the reduced subgrade strength method. The reduced subgrade strength method requires the use of frost area soil support indexes listed in table 6. Frost-area soil support indexes are used as if they were CBR values; the term CBR is not applied to them, however, because, being weighted average values for an annual cycle, their values cannot be determined by CBR tests. Figures 1 through 4 are entered with the soil support indexes in place of CBR values to determine the required section thickness.

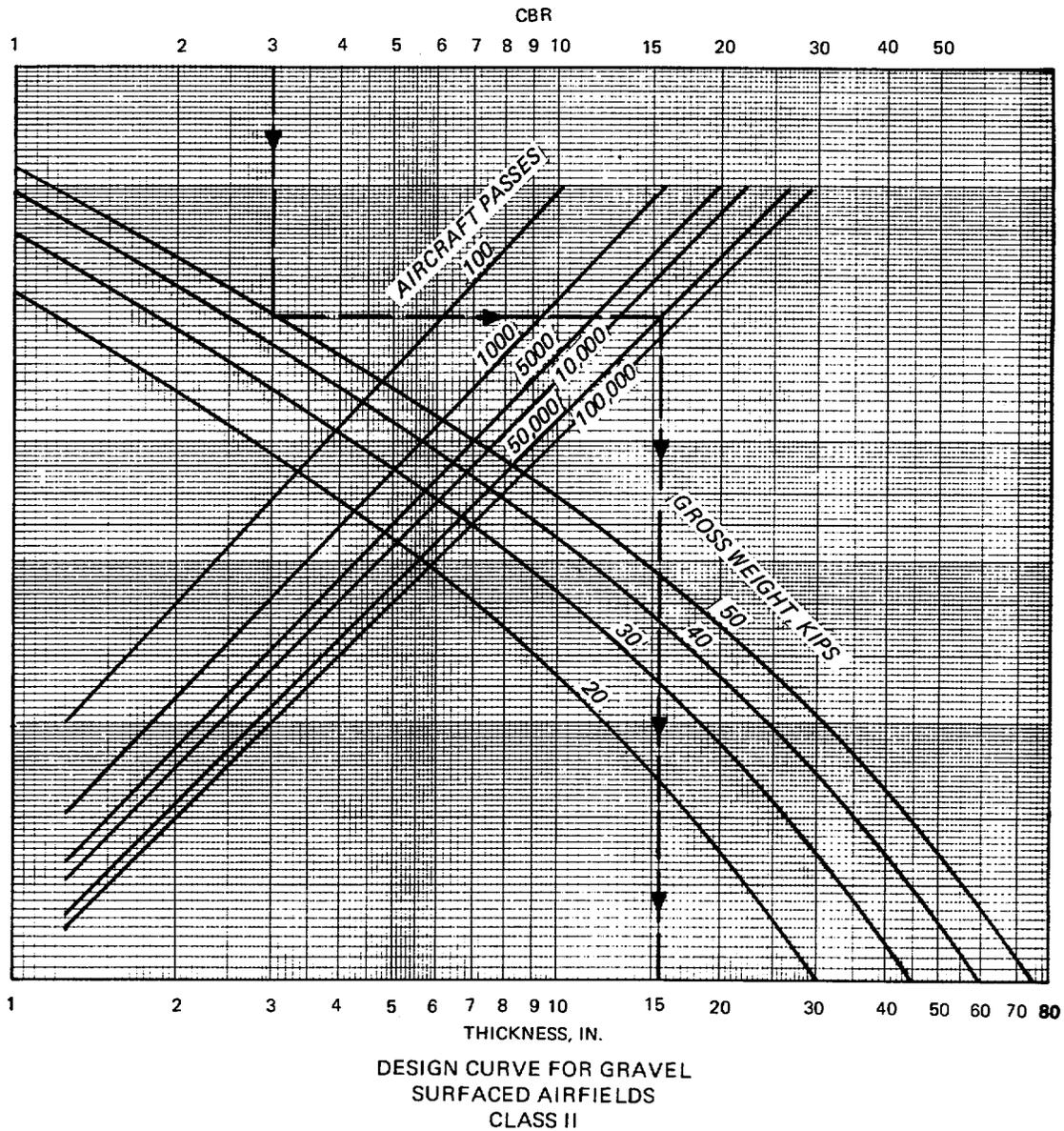


Figure 3. Aggregate surfacing design curve for Class II airfields.

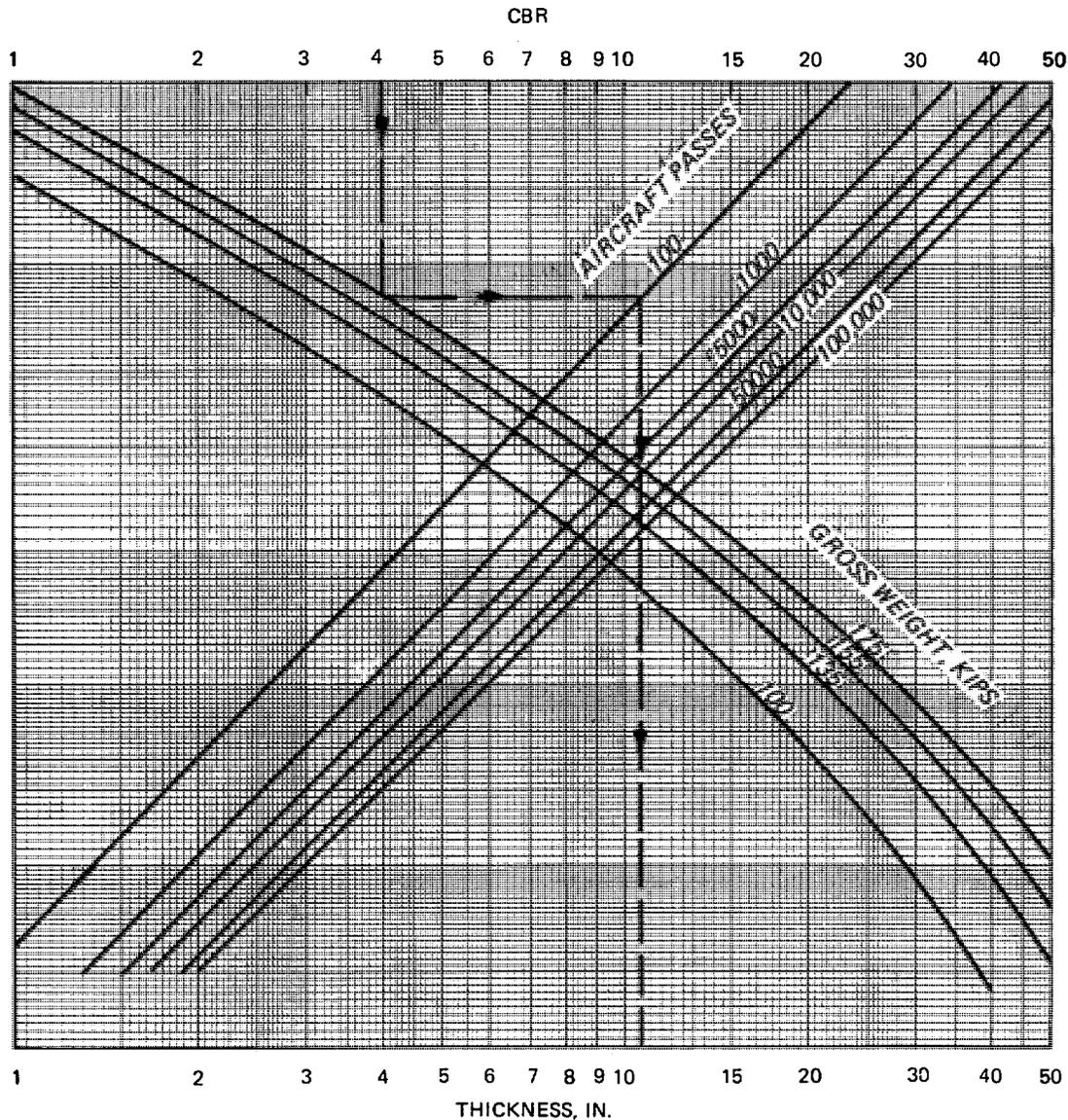
b. *Required layers in pavement section.* When frost is a consideration, it is recommended that the pavement section consist of a series of layers that will ensure the stability of the system, particularly during thaw periods. The layered system in the aggregate fill may consist of a wearing surface of fine crushed stone, a coarse-graded base course, and/or a well-graded subbase of sand or gravelly sand. To ensure the stability of the wearing surface, the width of the base course and subbase should exceed the final desired surface width by a minimum of 1 foot on each side.

c. *Wearing surface.* The wearing surface contains fines to provide stability in the aggregate surface. The presence of fines helps the layer's compaction

characteristics and helps to provide a relatively smooth riding surface.

d. *Base course.* The coarse-graded base course is important in providing drainage of the granular fill. It is also important that this material be nonfrost-susceptible so that it retains its strength during spring thaw periods.

e. *Subbase.* The well-graded sand subbase is used for additional bearing capacity over the frost-susceptible subgrade and as a filter layer between the coarse-graded base course and the subgrade to prevent the migration of the subgrade into the voids in the coarser material during periods of reduced subgrade strength. The material must therefore meet standard filter criteria.



DESIGN CURVES FOR GRAVEL
SURFACED AIRFIELDS
CLASS III

Figure 4. Aggregate surfacing design curve for Class III airfields.

The sand subbase must be either nonfrost-susceptible or of low frost susceptibility (S1 or S2). The filter layer may or may not be necessary depending upon the type of subgrade material. If the subgrade consists principally of gravel or sand, the filter layer may not be necessary and may be replaced by additional base course if the gradation of the base course is such that it meets filter criteria. However, for finer grained soils, the filter layer will be necessary. If a geotextile is used, the sand subbase/filter layer may be omitted as the fabric will be placed directly on the subgrade and will act as a filter.

f. Compaction. The subgrade should be compacted to provide uniformity of conditions and a firm

working platform for placement and compaction of subbase. Compaction of subgrade will not change its frost-area soil support index, however, because frost action will cause the subgrade to revert to a weaker state. Hence, in frost areas, the compacted subgrade will not be considered part of the layered system of the road or airfield which should be comprised of only the wearing, base, and subbase courses.

g. Thickness of base course and filter layer
Relative thicknesses of the base course and filter layer are

Table 4. Maximum permissible values for subbases and select materials.

Material	Maximum Permissible Value					
	Maximum Design CBR	Size inch	Gradation Requirements Percent Passing			Plasticity Index*
			No. 10 Sieve	No. 200 Sieve	Liquid Limit*	
Subbase	50	2	50	15	25	5
Subbase	40	2	80	15	25	5
Subbase	30	2	100	15	25	5
Select material	20	3	-	-	35	12

*Determinations of these values will be made in accordance with ASTM D 4318. variable, and should be based on the required cover and economic considerations.

h. Alternate design. The reduced subgrade strength design procedure provides the thickness of soil required above a frost-susceptible subgrade to minimize frost heave. To provide a more economical design, a frost susceptible select material or subbase may be used as a part of the total thickness above the frost-susceptible subgrade. However, the thickness above the select material or subbase must be determined by using the FASSI of the select or subbase material. Where frost-susceptible soils are used as select materials or subbases, they must meet the requirements of current specifications except that the restriction on the allowable percent finer than 0.02 mm is waived.

8. Surface course requirements

The requirements for the various materials to be used in the construction of aggregate surfaced roads and airfields are dependent upon whether or not frost is a consideration in the design.

a. Nonfrost areas. The material used for gravel surfaced roads and airfields should be sufficiently cohesive to resist abrasive action. It should have a liquid limit no greater than 35 and a plasticity index of 4 to 9. It should also be graded for maximum density and minimum volume of voids in order to enhance optimum moisture retention while resisting excessive water intrusion. The gradation, therefore, should consist of the optimum combination of coarse and fine aggregates that will ensure minimum void ratios and maximum density. Such a material will then exhibit cohesive strength as well as intergranular shear strength. Recommended gradations are as shown in table 7. If the fine fraction of the material does not meet plasticity characteristics, modification by addition of chemicals might be required. Chloride products can, in some cases, enhance moisture retention, and lime can be used to reduce excessive plasticity.

b. Frost areas. As previously stated, where frost is a consideration in the design of roads and airfields, a layered system should be used. The percentage of fines should be restricted in all the layers to facilitate drainage and reduce the loss of stability and strength during thaw periods. Gradation numbers 3 and 4 shown in table 7 should be used with caution since they may be unstable in a freeze-thaw environment.

9. Compaction requirements

Compaction requirements for the subgrade and granular layers are expressed as a percent of maximum CE 55 density as determined by using MIL-STD-621 Test Method 100. For the granular layers, the material will be compacted to 100 percent of the maximum CE 55 density. Select materials and subgrades in fills shall have densities equal to or greater than the values shown in tables 8 and 9 for roads and table 10 for airfields except that fills will be placed at no less than 95 percent compaction for cohesionless soils (PI ≤ 5; LL ≤ 25) or 90 percent compaction for cohesive soils (PI > 5; LL > 25). Subgrades in cuts shall have densities equal to or greater than the values shown in tables 8 through 10. Subgrades occurring in cut sections will be either compacted from the surface to meet the densities shown in tables 8 through 10, removed and replaced before applying the requirements for fills, or covered with sufficient material so that the uncompacted subgrade will be at a depth where the in-place densities are satisfactory. The depths shown in tables 8 through 10 are measured from the surface of the aggregate road or airfield and not the surface of the subgrade.

10. Drainage requirements

Adequate surface drainage should be provided in order to minimize moisture damage. Expedient removal of surface water reduces the potential for absorption and ensures more consistent strength and reduced maintenance. Drainage, however, must be provided in a manner to preclude damage to the aggregate surfaced road or airfield through erosion of fines or erosion of the entire surface layer. Also, care must be taken to ensure that the change in the overall drainage regime as a result of construction can be accommodated by the surrounding topography without damage to the environment or to the newly constructed road or airfield.

a. The surface geometry of a road or airfield should be designed so that drainage is provided at all points. Depending upon the surrounding terrain, surface drainage of the roadway can be achieved by a continual cross slope or by a series of two or more interconnecting cross slopes. The entire area should consist of one or more cross slopes having a gradient that meet the requirements of TM 5-820-1 and TM 5-820.4. Judgement will be required to arrange the cross slopes in a manner to remove water from the road or airfield at the nearest

Table 5. Frost design soil classification.

Frost Group	Kind of Soil	Percentage Finer Than 0.02 mm by Weight	Typical Soil Types Under Unified Soil Classification System
NFS*	(a) Gravels Crushed stone Crushed rock	0-1.5	GW, GP
PFS**	(b) Sands (a) Gravels Crushed stone Crushed rock	0-3 1.5-3	SW, SP GW, GP
S1	(b) Sands Gravelly soils	3-10 3-6	SW, SP GW, GP, GW-GM, GP-GM
S2	(b) Sands Sandy soils	3-6	SW, SP, SW-SM, SP-SM
F1	(a) Gravelly soils	6 to 10	GM, GW-GM, GP-GM
F2	(a) Gravelly soils (b) Sands	10 to 20 6 to 15	GM, GW-GM, GP-GM SM, SW-SM, SP-SM
F3	(a) Gravelly soils (b) Sands, except very fine silty sands	Over 20 Over 15	GM, GC SM, SC
F4	(c) Clays, PI > 12 (a) All silts (b) Very fine silty sands (c) Clays, PI < 12 (d) Varved clays and other fine-grained banded sediments	-- -- Over 15 -- --	CL, CH ML, MH SM CL, CL-ML CL and ML CL, ML, and SM CL, CH, and ML CL, CH, ML and SM

*Nonfrost-susceptible.

**Possibly frost-susceptible, but requires laboratory test to determine frost design soil classification.

Table 6. Frost-area soil support indexes of subgrade soils.

Frost Group of Subgrade Soils	Frost Area Soil Support Index
F1 and S1	9.0
F2 and S2	6.5
F3 and F4	3.5

possible points while taking advantage of the natural surface geometry to the greatest extent possible.

b. Adequate drainage must be provided outside the road or airfield area to accommodate maximum possible drainage flow from the road or airfield. Ditches and culverts will be provided for this purpose. Culverts should be used sparingly and only in areas where adequate cover of granular fill is provided over the culvert. Additionally, adjacent areas and their drainage

Table 7. Gradation for aggregate surface courses.

Sieve Designation		No. 1	No. 2	No. 3	No. 4
25.0mm	1 in.	100	100	100	100
9.5 mm	3/8 in.	5-85	60-100	-	-
4.7 mm	No. 4	35-65	50-85	55-100	70-100
2.00 mm	No. 10	25-50	40-70	40-100	55-100
0.425 mm	No. 40	15-30	24-45	20-50	30-70
0.075 mm	No. 200	8-15	8-15	8-15	8-15

Note: The percent by weight finer than 0.02 mm shall not exceed 3 percent.

provisions should be evaluated to determine if rerouting is needed to prevent water from other areas flowing across the road or airfield.

c. Drainage is a critical factor in aggregate surface road or airfield design, construction, and maintenance. Therefore, drainage should be considered prior to construction, and when necessary, serve as a basis for site selection.

11. Maintenance requirements

The two primary causes of deterioration of aggregate surfaced roads requiring frequent maintenance are the environment and traffic. Rain or water flow will wash fines from the aggregate surface and reduce cohesion, while traffic action causes displacement of surface materials. Maintenance should be performed at least every 6 months and more frequently if required. The frequency of maintenance will be high for the first few years of use but will decrease over time to a constant

value. The majority of the maintenance will consist of periodic grading to remove the ruts and potholes that will inevitably be created by the environment and traffic and to replace fines. Occasionally during the lifetime of the road or airfield, the surface layer may have to be scarified, additional aggregate added to increase the thickness back to that originally required, and the wearing surface recompact to the specified density.

12. Dust control

a. Objective. The primary objective of a dust palliative is to prevent soil particles from becoming airborne as a result of wind or traffic. Where dust palliatives are considered for traffic areas, they must withstand the abrasion of the wheels or tracks. An important factor limiting the applicability of the dust palliative in traffic areas is the extent of surface rutting or abrasion that will occur under traffic. Some palliatives will tolerate deformations better than others, but normally ruts in excess of 1/2 inch will result in the virtual destruction of any thin layer or shallow-depth penetration dust palliative treatment. The abrasive action of tank tracks may be too severe for use of some dust palliatives in a traffic area.

b. A wide selection of materials for dust control is available to the engineer. No one choice, however, can be singled out as being the most universally acceptable for all problem situations that may be encountered. However, several materials have been recommended for use and are discussed in TM 5-830-3.

Table 8. Compaction requirements for roads, cohesive soils.

Percent Compaction	Depth of Compaction (in inches) for Indicated Design Index									
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
100	2	3	3	3	4	4	4	5	5	6
95	4	5	5	6	7	7	8	9	10	11
90	6	7	8	9	10	11	12	13	15	17
85	7	9	10	12	13	15	16	18	20	22
80	9	11	13	14	16	18	20	22	25	27

Table 9. Compaction requirements for roads, cohesionless soils.

Percent Compaction	Depth of Compaction (in inches) for Indicated Design Index									
	1	2	3	4	5	6	7	8	9	10
100	4	5	5	6	7	7	8	9	10	11
95	7	8	10	11	12	14	15	17	19	21
90	10	12	14	16	18	20	22	24	28	30
85	13	16	18	21	23	26	29	31	35	38

Table 10. Compaction requirements for airfields.

Airfield Type	Traffic Area	Depth Below Pavement Surface, in.									
		Cohesive Soils, percent					Cohesionless Soils, percent				
		100	95	90	85	80	105	100	95	90	85
Class I	B	4	6	8	10	12	2	6	10	13	16
	C	3	5	7	9	10	1	5	8	11	14
Class II	B	5	8	12	15	19	2	8	14	21	26
	C	4	7	10	13	16	2	7	12	17	23
Class III	B	9	15	21	27	34	4	15	25	37	48
	C	7	12	17	22	29	3	12	21	31	41

13. Design examples No.1. Assume the following conditions:

CBR values.

- Natural subgrade = 5 (CL material with PI = 15, Frost group F3).
- Compacted subgrade = 8.
- Fines graded crushed rock wearing surface = 80.

- Coarse graded crushed rock base course = 80.
- Clean sand subbase = 15.
- Anticipated traffic.
- 40 passes per day of 60-ton tracked vehicles.
- Calculations:

a. From paragraph 4.d, select the traffic category for a 120,000-pounds tracked vehicle as Category VII.

b. The design index is then determined from table 3 to be 10 for 40 passes per day and Category VII traffic.

c. The required thickness of the tank trail is determined from figure 1. The following sections would be adequate if the natural subgrade has the required in-place density.

17 inches crushed rock	7 inches crushed rock 10 inches sand subbase CBR = 15
Natural subgrade CBR = 5	Natural subgrade CBR = 5

d. Where the subgrade is compacted to a CBR of 8, the following sections would be satisfactory:

12 inches crushed rock	7 inches crushed rock 5 inches sand subbase CBR = 15
5 inches compacted subgrade CBR = 8	5 inches compacted subgrade CBR = 8
Natural subgrade CBR = 5	Natural subgrade CBR = 5

e. In areas where frost is not a factor in the design of roads, the sections shown above are adequate, and the most economical should be used. The granular material should conform to the material requirements for nonfrost areas previously discussed. If available, subbase materials other than the clean sand may be used for adjusting the sections.

f. Determine the surface geometry of the tank trail in a severely cold area where subgrade freezing is predicted.

g. In areas where frost is a consideration, the tank trail should consist of the following layers:

- A wearing surface of fine-graded crushed rock.
- A base course of coarse-graded crushed rock.
- A subbase of well-graded sand, frost group soils F1 and F2, or geotextile.

As previously stated, the function of the last layer as a filter layer is not always required, depending upon the subgrade material. In this case the subgrade is a CL; therefore, it is required. According to table 6, the frost area soil support index for an F3 subgrade soil is 3.5.

With the exception of the wearing surface layer which will vary between 4 and 6 inches, the other layers are varied based on economic factors. However, the required thickness of cover over the various layers must be satisfied. Also, the minimum thickness of each layer should be 4 inches.

h. Possible alternatives for the tank trail section based on frost considerations might be:

(1) Using sand subbase. From figure 1 using a frost-area soil support index of 3.5 and a design index of 10, the total thickness required above the subgrade equals 21.0 inches. Also from figure 1, the minimum required cover over the NFS, S1, or S2 sand subbase (CBR = 15) is 7.0 inches. Using a minimum layer thickness of 4 inches in the wearing surface and the coarse graded base course, the actual cover required will be 8 inches. Therefore, the section might be:

4 inches fine-graded stone
4 inches coarse-graded crushed stone
13 inches well-graded sand subbase (CBR = 15)
Subgrade

(2) An alternative section might be to construct the wearing course and subbase to a minimum thickness of 4 inches.

4 inches fine/graded stone
13 inches coarse-graded crushed stone
4 inches well-graded sand subbase
Subgrade

(3) Using F1 and F2 soils. As previously stated, frost group soils F 1 and F2 may be used in the lower part of the granular material over F3 and F4 subgrade soils. The thickness of F2 base material should not exceed the difference between the thickness required over F3 and the thickness required over an F2 subgrade. The minimum required cover over F1 soils is 11 inches, over F2 soils is 14 inches, and over F3 soils is 21 inches. Using a minimum layer thickness of 4 inches, the following section may be used:

4 inches fine-graded stone
7 inches coarse-graded crushed stone
4 inches frost group soil F1
6 inches frost group soil F2
Subgrade - F3

For economy, based on material availability, these sections may be altered as long as a higher-quality material is used above a lesser-quality material. For example, crushed stone could be substituted for the F1 soil.

(4) Using geotextiles. Either of the designs shown above could be used by deducting 6 inches of well-graded sand subbase and replacing it with a geotextile. The total thickness above the geotextile must be a minimum of 15 inches. Alternative designs using a geotextile might be:

4 inches fine-graded stone	
11 inches coarse-graded crushed stone	geotextile
Subgrade	
or	
7 inches fine-graded stone	
8 inches well-graded sand	geotextile
Subgrade	

Notes:

- All layer depths should be rounded up to the next full inch for construction purposes.
- The granular layers should be compacted to 100 percent CE 55 maximum density.
- The subgrade should be compacted to the density required by table 8.
- The material should meet the gradation requirements shown herein.
- The frost group soils F1I and F2 used as base and subbase materials should meet the requirements in the appropriate guide specifications.
- As previously stated, after all possible design sections are determined, the final section used for the tank trail should be determined on the basis of an economic analysis.

14. Design Example No. 2. Assume the following conditions:

CBR values.

- Natural subgrade = 4 (SM - silty sand material, frost group F2).
- Compacted subgrade = 8.
- Fine-graded crushed rock wearing surface = 80.
- Course-graded crushed rock base course = 80.
- Clean sand subbase = 15.

Projected traffic.

-2,500 operations per day of Category IV traffic.

Calculations:

a. Determine the required thickness. From table 1 determine the road to be a Class D road. From table 3, select a design index = 5. From the design curves (figure 1) the required thickness above the natural subgrade with a CBR of 4 is 11.5 inches (round to next full inch of 12); the required cover over the compacted subgrade (CBR = 8) is 7 inches. Therefore, the hardstand might have the following cross sections:

12.0 inches crushed rock	4 inches crushed rock	7 inches crushed rock
Subgrade CBR = 4	8.0 inches sand subbase	Compacted subgrade CBR = 8
	Subgrade CBR = 4	

b. Determine the cross section in a severely cold area where subgrade freezing is predicted.

(1) Only the wearing surface and base course layers will apply in this section. The sand subbase is not required because the subgrade is not cohesive. The filter fabric will not be used because the subgrade soil is an F2 material and the use of this fabric is restricted to F3 and F4 subgrade soils.

(2) In this case the natural subgrade CBR of 4 is less than the frost-area soil support index and will govern the design. The total thickness required above a subgrade CBR = 4 is 12.0 inches.

(3) Therefore, the cross section for this condition will be:.

4 inches fine-graded stone
8.0 inches coarse-graded crushed stone
Subgrade CBR = 4

c. Based on economic considerations, alternative sections may be developed using frost group soils S1, S2, and F1 with lower portion of the base material. An example using F1 soils is as follows:

7.0 inches fine-graded stone
5 inches frost group soil F1
Subgrade CBR = 4

15. Design Example No. 3. Assume the following conditions:

Design is for Army Class III airfield.

Traffic protection = 10,000 passes of C-130 aircraft.

Design gross weight = 135 kips.

CBR values.

- Subgrade = 6
- Crushed stone = 80

Enter figure 4 with the subgrade CBR of 6, the 135 kip gross weight and 10,000 passes, and read the thickness required above the 6 CBR of 13.5 inches which when rounded to the next full inch will be 14.0 inches. The section therefore would be:

14.0 inches of crushed stone
Subgrade CBR = 6

**APPENDIX A
REFERENCES**

Government Publications

Department of Defense
MIL-STD-621A,
Notices 1, 2

Test Method for Pavement
Subgrade, Subbase,
and Base-Course
Materials

TM 5-822-5/AFM 88-
7, Chap. 3

Flexible Pavements for
Roads, Streets, Walks
and Open Storage
Areas

Departments of the Army, Navy, and Air Force

TM 5-803-4

Planning of Army
Aviation Facilities

TM 5-825-2/AFM 86-
6, Chap. 2

Flexible Pavement Design
/for Airfields

NAVFAC DM 21.3

TM 5-818-2

Pavement Design of
Seasonal Frost Areas

TM 5-830-3

Dust Control for Roads,
Airfields, and Adjacent
Areas

TM 5-820-1/AFM 88-
5, Chap. 1

Surface Drainage
Facilities for Airfields
and Heliports

Nongovernment Publications

American Society for Testing and Materials
(ASTM): 1916 Race Street, Philadelphia, PA 19103
D 4318-83

Test Method for Liquid
Limit, Plastic Limit,
and Plasticity Index of
Soils

TM 5-820-4/AFM 88-
5, Chap. 4

Drainage for Areas Other
Than Airfields

TM 5-822-2/AFM 88-
7, Chap. 5

General Provisions and
Geometric Design for
Roads, Streets, Walks,
and Open Storage
Areas

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