AIRFIELD PAVEMENT DESIGN

CHAPTER 12

This chapter provides information to help select design, and construct airfield structures and landing facilites. Close battle support, and rear area TO air-fields are designed according to specific aircraft characteristics and requirements governing thickness, strength, and quality of materials. Airfield location and soil strength determine the different minimum pavement thicknesses and design procedures. The proper placement of the base, subbase, and subgrade determine the effectiveness of the airfield under all climatic and seasonal conditions.

AIRFIELD STRUCTURE TYPE

Airfield structures fall into three categories: expedient-surfaced, aggregate-surfaced, and flexible-pavement. Expedient-surfaced and aggregate-surfaced airfields are used primarily in the close battle and support areas. Flexible-pavement airfields are primarily constructed in the rear area.

PRELIMINARY INFORMATION

Field condition, soil strength, and soil behavior are the three most important pieces of information used to determine the feasibility of constructing an airfield at a particular location.

Field Condition

Knowledge of the current field condition is important when designing and constructing an airfield. A proper description of the field condition at a proposed construction site includes the following elements:

- Ground cover (vegetation).
- Natural slopes.
- Soil density.
- Moisture content.
- Soil consistency (soft or hard).
- Existing drainage.
- Natural soil strength (in terms of California Bearing Ratio (CBR)).

Information about the kind and distribution of ground cover, slopes, moisture content, and natural strength is used to estimate the construction effort required for a specific type of airfield. The surface condition and the soil type must be known to predict potential dust problems at the site. Moisture content data is required to determine the effect of traffic on soil strength and to estimate water needs during construction. Soil strength data is needed to determine the surfacing requirements as well as the thickness design.

Soil Strength

From an engineering viewpoint, shearing resistance (or shear strength) is one of the most important properties that a soil possesses. A soil's shearing resistance under given conditions is related to its ability to withstand a load. The shearing resistance is especially important in its relation to the supporting strength or bearing capacity of a soil used as a base or subgrade beneath a road, runway, or other structure. For most military pavement applications, the CBR value of a soil is used as an empirical measure of shear strength. The CBR is determined by a standardized penetration shear test and is used with empirical curves for designing and evaluating unsurfaced aggregate-surfaced, and flexible pave ments for military airfields. The CBR test is usually performed on laboratory compacted test specimens when used in pavement design. When used in pavement evaluations, destructive test pits are usually dug to determine pavement layer thicknesses, and in-place field CBR tests are conducted on the base course, subbase, and subgrade materials. In-place CBR tests are time-consuming to run and are usually impractical for use in the TO.

For expedient-surfaced airfields in the close battle and support areas, the laboratory CBR test (which usually takes about four days to complete) is inappropriate due to time and equipment constraints. Therefore, several field-expedient methods of determining CBR are available in the TO.

The Unified Soil Classification System (USCS) correlation is the quickest means available for estimating CBR. For each soil classification, empirical studies have determined a range of CBR values. These ranges can be found in FM 5-410 (Table 5-3, page 5-11). Since the CBR ranges are only estimates, use the lowest CBR value in the range. The soil type usually varies across the entire airfield.

A better method for determining the CBR for in-place soils is with a penertrometer. There are currently three types of penetrometers available for airfields: the airfield cone penetrometer, the trafficability penetrometer, and the dual-mass dynamic cone penetrometer (DCP).

The airfield cone penetrometer described in Appendix I is used to determine an index of soil strengths (Fenwick 1965) for various military load applications. The airfield penetrometer consists of a 30-degree cone with a 0.2-square-inch base area. The force required to penetrate to various depths in the soil is measured by a spring, and the airfield index (AI) is read directly from the penetrometer. The airfield cone penetrometer has a range of 0 to 15 (CBR value of 0 to approximately 18). (The AI-CBR correlation is shown in Figure 12-1.) The airfield cone penetrometer is compact and sturdy. Its operation is simple enough that inexperienced military personnel can use it to determine soil strength. A major drawback to the airfield cone penetrometer is that it will not penetrate many crusts, thin base course, or gravel layers that may lie over soft layers. Relying only on the surface AI test results could cause the loss of vehicles or aircraft.

The airfield cone penetrometer must not be confused with the trafficability penetrometer, a standard military item in the soil test set. The trafficability penetrometer has a dial-type load indicator (0 to 300 range) and is equipped with two cones: one is 1/2 inch in diameter with a cross-sectional area of 0.2 square inch, and the other is 0.8

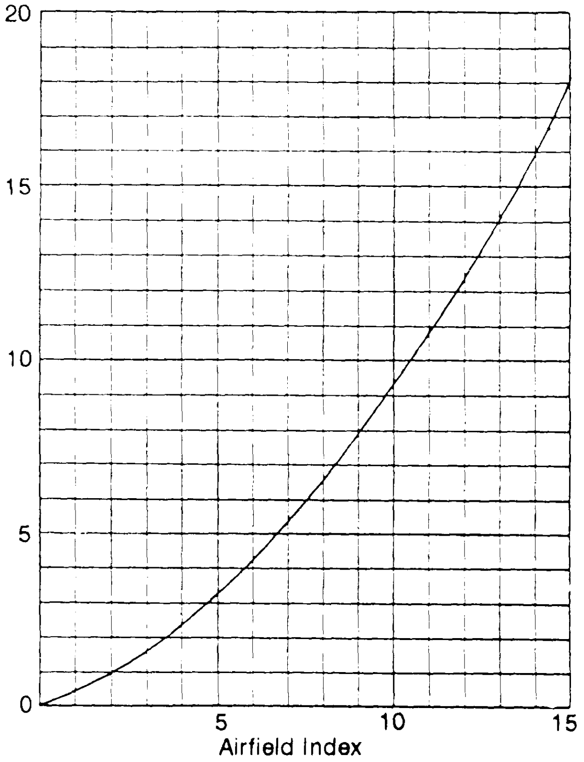


Figure 12-1. Correlation of CBR and AI

inch in diameter with a cross-sectional area of 0.5 square inch. It also will not penetrate gravelly soils or aggregate layers, but it may be useful for subgrades. If the trafficability penetrometer is used to measure AI, the readings obtained with the 0.2-square-inch cone must be divided by 20; the reading with the 0,5-square-inch cone must be divided by 50. Use the same testing procedures as discussed in Appendix I for the airfield cone penetrometer.

The dual-mass DCP described in Appendix J will overcome some of the shortfalls associated with traffic ability and airfield cone penetrometers. The DCP was originally designed and used for determining the strength profile of flexible-pavement structures. It will penetrate soil layers having CBR strengths in excess of 100 and will also measure soil strengths less than 1 CBR. The DCP is a powerful, relatively compact, sturdy device that can be used by inexperienced military personnel to determine soil strength. The DCP relation to CBR is shown in Figure 12-2. Presently, the DCP is not in the Army inventory. It was recently modified and studied by the United States Army Engineer (USAE) Waterways Experiment Station (WES). Information on procurement and use of the DCP should be directed to USAE WES, Pavement Systems Division, Geotechnical Laboratory, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

Soil Behavior

Soil is compacted to improve its load-carrying capacity and to prevent differential settlement (rutting) under aircraft traffic loads. High soil strength is usually associated with a high degree of compaction. However, attaining and maintaining a desired strength in soils is contingent upon the water content at the time of construction and throughout the period of use. Some

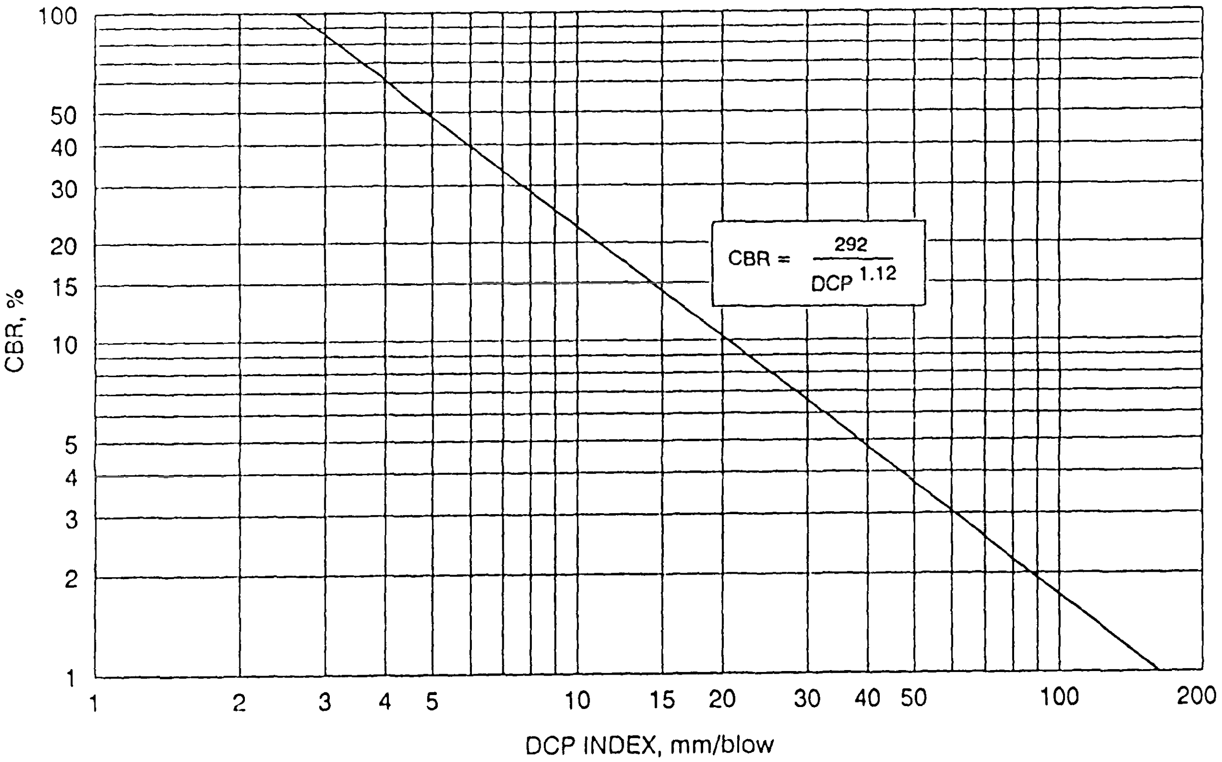


Figure 12-2. Correlation plot of CBR versus DCP index

basic moisture content-density relations for cohesive and cohesionless soils are discussed in FM 5-410. Generally, it is desirable for the soil to be compacted to American Society of Test Materials (ASTM) 1557 or to compactive effort, 55 blows per layer (CE 55), while it is within the desired moisture content range. The 4 percent moisture range and the 5 percent density range are derived from initial soil tests, and they make up the specification block. Soils are treated to improve their strength or to reduce the effects of plasticity and high liquid limits. Stabilizing a soil can also provide dust control and waterproofing. During construction, the type of soil treatment is determined by the soil characteristics and availability of stabilizing materials. (See FM 5-410 for additional information.)

DESIGN CONSIDERATIONS

The design of airfield structures is based on—

- Airfield location/mission.
- Using aircraft and associated gross weight.
- Strength of subgrade and available construction materials.
- Susceptibility of geographic area and construction materials to frost action.
- Traffic areas.
- Expected number of passes of aircraft.

Airfield Location/Mission

The location of the airfield within the TO is broken down into three major areas, as described in Chapters 10 and 11:

- Close battle area.
- Support area.
- Rear area.

These areas are designated by the mission of the airfield.

Design Aircraft and Associated Gross Weight

In TO airfield design, the design aircraft is based solely on the airfield location, as shown in Table 12-1. The gross weight is the maximum allowable weight during takeoff (worst case) and is the basis for the thickness design. Of the aircraft listed in Tables 11-1 and 11-2, pages 11-2 and 11-3, that can possibly use the airfield, the design aircraft is the one that presets the most extreme load distribution characteristics.

Expected Number of Passes

For a runway, passes are determined by the number of aircraft movements across an imaginary traverse line placed within 500 feet of the end of the runway. More simply, a pass on a runway is equivalent to a takeoff and landing of an aircraft similar in weight to the design aircraft. For taxiways and aprons, passes are determined by the number of aircraft cycles across a line on the primary taxiway that connects the

Table 12-1. Design aircraft

Airfield Location	Design Aircraft (Thickness Design)		Gross Weight (kips)	
Close battle	C-130E	C-17A	130	430
Support	C-130E	C-17A	130	430
Rear	C-141A		345	
The C-17 is the design aircraft when both aircraft are anticipated on the airfield.				

NOTE: These design aircraft should not be confused with constraining aircraft for TGR, which is mentioned in Chapter 11.

runway and parking apron. At single runway airfields, the pass level of the runway, taxiway, and apron should be the same.

For expedient-surfaced airfields, the in-place soil strength determines the number of passes. If the mission requires a longer service life, the designer must adjust the design so measures are taken to improve the in-place soil. When designing aggregate and flexible-pavement surfaces, there is a direct correlation between the number of passes and the thickness of the design.

Traffic Areas

On expedient-surfaced airfields in the close battle and support areas, traffic areas are Type A. The airfield is capable of supporting missions as soon as the runway is constructed. The layout of the runway and hammerhead turnaround areas are shown in Figure 12-3. Specific dimensions for the entire runway are shown in Chapter 11. The 63-foot turnaround area is required for the design aircraft (C-130). When C-17s are anticipated, the turnaround area does not increase the airfield width, which is 90 feet. Ensure that an extra 90-foot section is added to both ends of the runway because turnaround procedures can be detrimental to an airfield surface. Taxiways and aprons should then be continually developed to support continuous traffic.

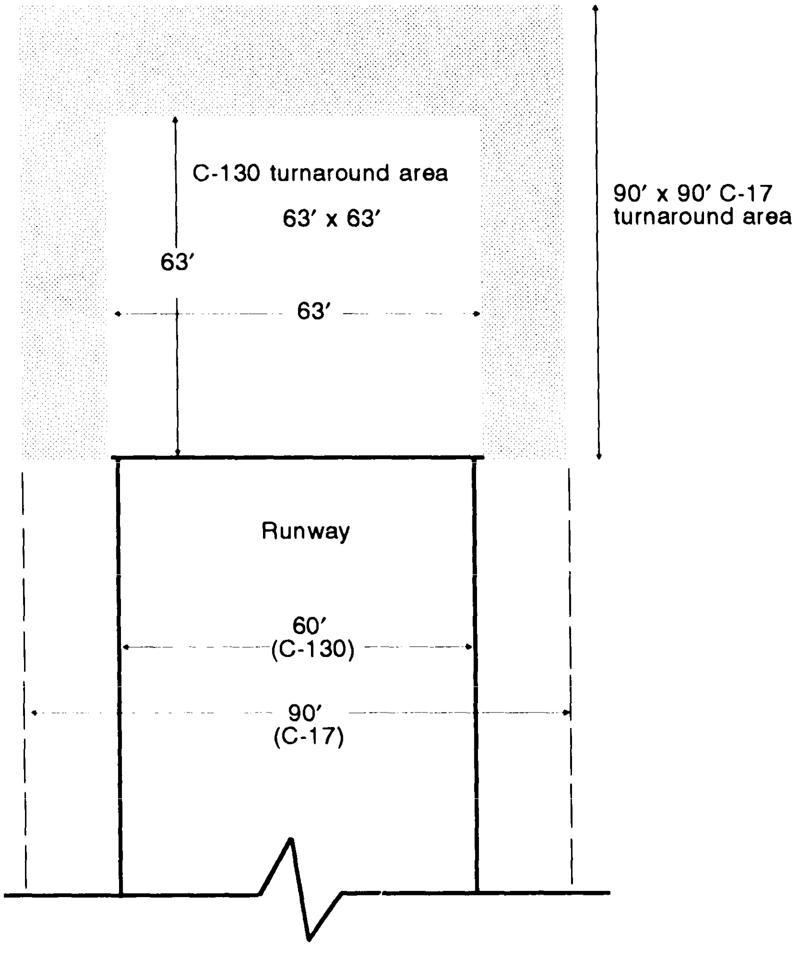


Figure 12-3. Typical layout for expedient-surfaced airfield in close battle and support areas

On aggregate-surfaced airfields in the support area, traffic areas are designated as shown in Figure 12-4. Type A areas include primary taxiways, parking aprons, washrack areas, power check pads, and 1,000 feet on both ends of the runway. The interior portion of the runway and the ladder taxiway are considered Type C areas. Since the lift on the wings accounts for some of the aircraft load, Type C areas are designed for only 75 percent of the total load.

On pavement airfields in the rear area, pavements can be grouped into four traffic areas designated as Types A, B, C, and D. They are defined below and shown in Figure 12-5.

Type A traffic areas include all primary taxiways, including straight sections, turns, and intersections. The ends (1,000 feet) are also considered Type A since the aircraft load is still fully transferred to the pavement. Although traffic tends to channelize

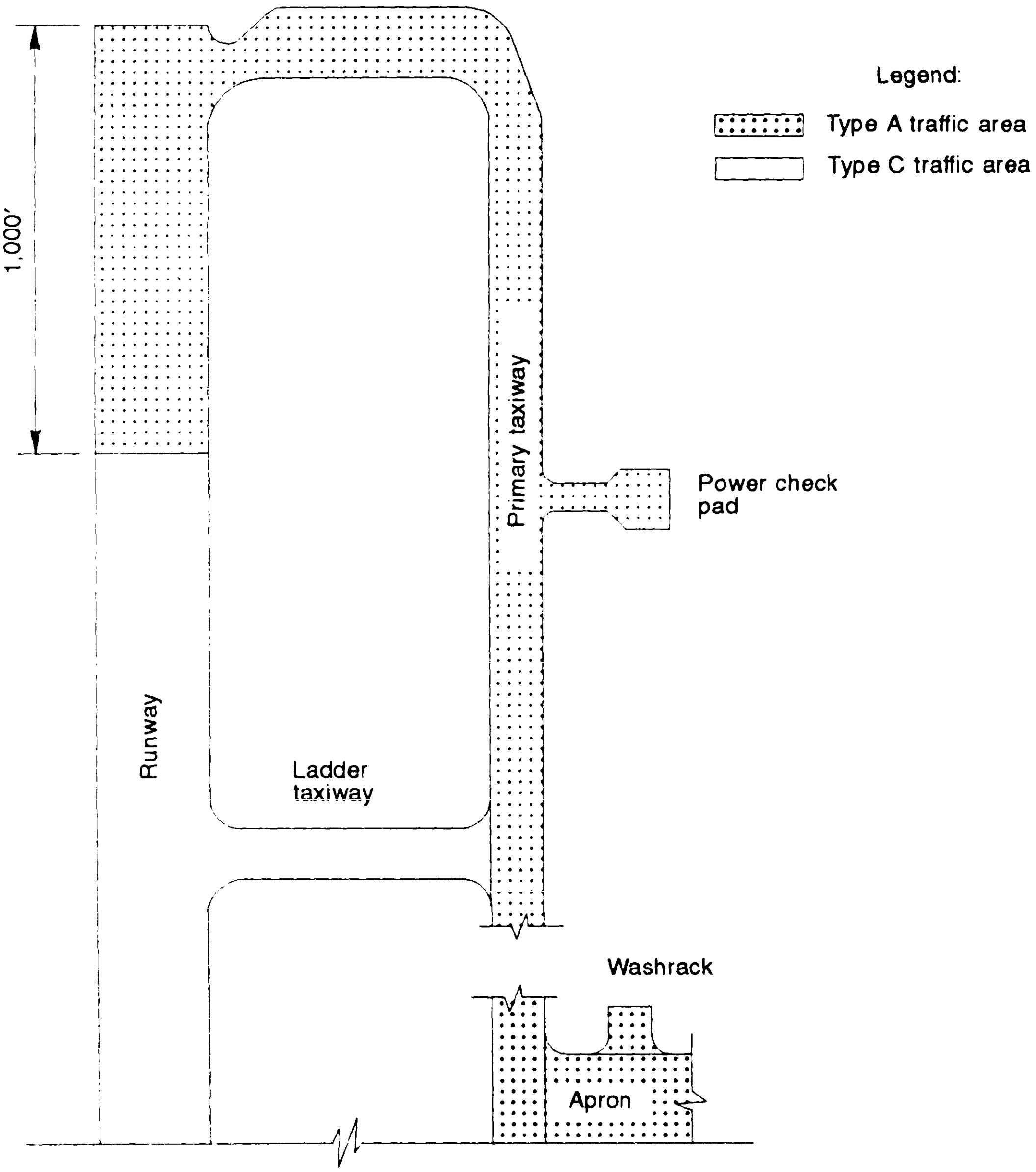


Figure 12-4. Typical layout of aggregate-surfaced airfields in the support area

in the center lane on long, straight taxiway sections, it is not practical in the TO to construct pavement sections of varying thicknesses. Type B areas include all aprons and hardstands. Type C areas include the center, 75-foot width of runway interior between the 1,000-foot runway ends and at the runway edges adjacent to intersections with ladder taxiways. Washrack pavements are also included in Type C areas. Type D areas include those areas where traffic volume is extremely low, and/or the applied weight of the operating aircraft is much lower than the design weight. Type D areas include the edges of the entire runway except for the approach and exit areas at taxiway intersections.

In designing flexible-pavement structures, the area type determines the actual load on the pavement. Type A and B areas support the entire design weight, while Types C and D should be designed for only 75 percent of the design weight.

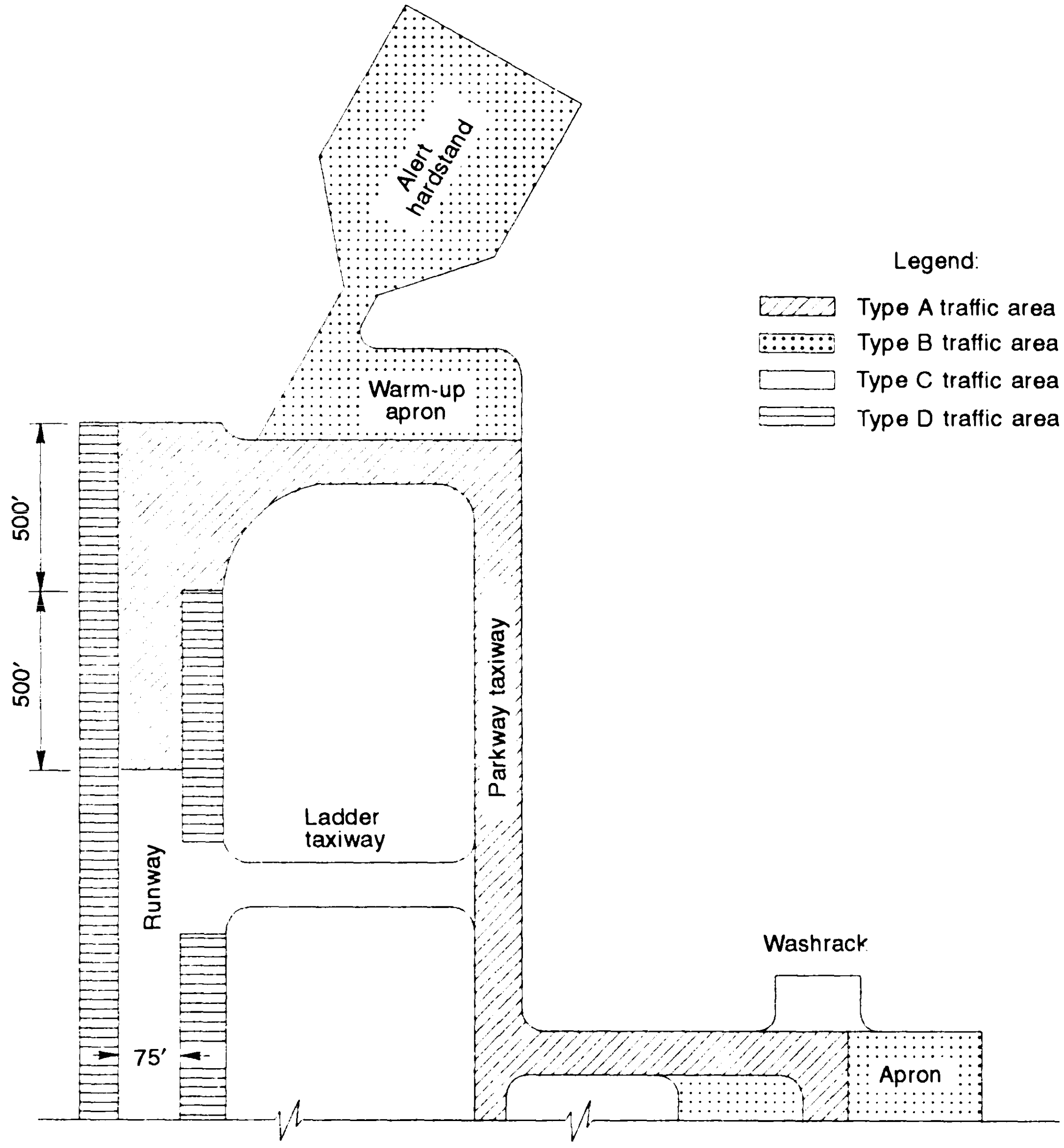


Figure 12-5. Typical layout of flexible-pavement airfields in the rear area

Soil Strength

The strength of construction materials can be determined in terms of CBR by using the laboratory CBR test, airfield cone penetrometer, trafficability penetrometer, or DCP, as discussed earlier in this chapter. The strength of both the subgrade and available construction materials can be determined in terms of CBR based on procedures outlined in Chapter 5, FM 5-430-00-1/AFPAM 32-8013, Vol 1. Strength of the in-place soil or subgrade will determine the type of surface and the number of passes for expedient-surfaced airfields. It also will determine the total thickness design in aggregate and flexible-pavement surfaces.

Frost Action

In regions subject to frost action, the design of aggregate-surfaced and flexible-pavement airfields must give consideration to measures that will prevent serious damage from frost action. Three conditions must exist simultaneously for detrimental frost action to occur: (1) soil must be frost-susceptible, (2) temperature must remain below freezing for a considerable period time, and (3) ample supply of groundwater must be available. Precise methods for estimating the depth of freeze and thaw in soils are contained in AFR 88-19, Vol 1. In addition, Chapter 4, Air Force Manual (AFM) 88-6 (TM 5-818-2), contains the criteria and procedures for design and construction of pavements subject to seasonal frost action.

Specific design procedures for frost are discussed in detail in aggregate-surfaced and flexible-pavement airfield design sections, pages 12-22 and 12-35, respectively.

EXPEDIENT-SURFACED AIRFIELDS

Unsurfaced deserts, dry lake beds, and flat valley floors serve as possible airfield sites. Normally, expedient-surfaced airfields are used for very short periods of time (zero to six months) and support C-130s, C-17s, and Army aircraft operations. Although expedient-surfaced airfields require very little initial construction, they may require extensive daily maintenance.

Expedient-surfaced airfields are primarily used for the movement of troops and supplies in the close battle and support areas. Only those Army and Air Force aircraft configured for expedient surfaces will be allowed to use the airfields. The C-130 has been the primary aircraft for missions in the close battle area because it can land on unpaved or semiprepared surfaces. The C-17, which is used primarily for strategic mobility, can also land on austere airfields. Therefore, expedient-surfaced airfields are designed for the C-130 or the C-17.

Since the close battle area is expected to change quickly, minimal resources should be committed to airfields in this area. Although the design life of expedient surfaces ranges from zero to six months (initial construction), the airfield is usually only required from zero to two weeks, unless it is upgraded to a support area. If a soil will support an unsurfaced airfield for the design aircraft, do not surface the airfield with matting unless the service life becomes significant. Use the following design procedure to determine the expedient surface type and its expected service life:

DESIGN STEPS

1. Determine the airfield location.
2. Determine the design aircraft and associated gross weight.
3. Determine the in-place soil strength.
4. Determine the required number of passes (service life).
5. Determine the allowable number of passes and surface type.
6. Outline corrective actions to increase service life as necessary.

STEP 1. DETERMINE THE AIRFIELD LOCATION

The general area (close battle, support area) will be given in the mission statement. In this case, expedient-surfaced airfields only occur in the close battle and support areas. Determining the best location should be based on a thorough reconnaissance of the area, if possible.

Site Reconnaissance

Potential LZ areas fall into three basic categories:

- *Existing.* Roads, highways, and other paved surfaces that can be used for cargo aircraft (beyond the scope of this chapter).
- *Unsurfaced.* Natural areas such as deserts, dry lake beds, and flat valley floors that may or may not include a membrane (geosynthetic covering that does not contribute strength).
- *Surfaced.* Unsurfaced airfields requiring a matting or membrane surface because of the in-place soil or to increase the service life of the airfield.

USAF combat control teams (CCTs) are trained to perform airfield surveys in support of C-130 and C-17 aircraft operations. CCTs gather all available data on the airfield and perform site visits to evaluate approach-zone obstruction clearances and weight bearing. CCTs are equipped with hand-held pocket transits, clinometers, and levels to check approach-zone clearance. Airfield and DCPs are used to check weight bearing of unsurfaced LZs. CCTs are not qualified to evaluate deteriorating existing pavements for traffic cycles and weight bearing.

CCTs gather data from an on-site survey, present an LZ survey package, and recommend approval/disapproval for use of a proposed airfield. Airlift force commanders at the Numbered Air Force/Airlift Control Center/Air Force Special Operations Base make the final decision. Airfields that require precise determination of gradients should be surveyed by Army engineering teams using theodolites, auto levels, and Philadelphia rods.

After a potential airfield site has been selected, it must be tested to ensure its suitability. The reconnaissance leader must first determine the alignment of the airfield and the location of the runway, hammerhead turnaround, taxiway, and parking apron (if any). Airfield approach zones also must be evaluated for satisfactory glide angles. (See Chapter 2, FM 5-430-00-1/AFPAM 32-8013, Vol 1.) The criteria may dictate the airfield alignment even before soil testing begins.

STEP 2. DETERMINE THE DESIGN AIRCRAFT

Design aircraft, as discussed previously, are merely a function of the area, which is determined by the mission. The design aircraft for expedient surfaces is the C-130 or C-17. When a C-17 is expected, it will become the design aircraft. The C-17 has a greater load capacity in the close battle and support areas. The gross weights for both aircraft are shown in Table 12-1, page 12-4.

STEP 3. DETERMINE THE IN-PLACE SOIL STRENGTH

This design step is significant in determining the thickness design and the service life. Therefore, it is important that accurate readings are taken from one of the expedient CBR methods. Use these procedures for determining soil strength for a uniform soil, which has equivalent CBR readings and soil characteristics (Atterberg limits, gradation) to a depth of 24 inches after organics and loose granular soil have been removed. Special cases of varying subgrades are discussed later in this chapter.

Potentially soft or dangerous areas should be tested first. Areas with poor drainage, with moist or discolored soil, or where vegetation is growing well may indicate a problem. Additionally, animal burrow holes, areas prone to flash flooding, previously forested areas, and dry lake beds may all pose potential problems. The airfield may need to be realigned, taking into consideration an area that will not lend itself to traffic.

Once the initial alignment of the airfield has been decided, determine critical CBR for the sites. To do this, test each aspect of the airfield to ensure accurate coverage in locating potential problem area. (Appendices I and J detail the recommended testing intervals for the airfield cone penetrometer and DCP, respectively.) Many soils may not be a uniform classification throughout the depth concerned (usually 24 inches.) Cases where specific layers have different CBRs pose special concerns in determining the critical CBR These cases are discussed in detail in following sections.

STEP 4. DETERMINE THE REQUIRED NUMBER OF PASSES

From the mission statement or an estimate of the situation, determine the minimum number of design aircraft passes that will accomplish the mission. Remember, a pass is considered one takeoff and one landing. Given the design aircraft, the in-place soil CBR, and the number of required aircraft passes, you can determine the airfield surface type needed. While unsurfaced airfields are favorable in minimizing resources involved in construction, some soils in their natural state cannot support traffic without a surface. For more information about specific mats and membranes, see Appendix N.

STEP 5. DETERMINE THE ALLOWABLE NUMBER OF PASSES AND SURFACE TYPE

The service life is a function of taking the design aircraft and the in-place soil CBR entering into Figure 12-6 and determining the number of allowable passes. The surface type (unsurfaced, light-duty mat, or medium-duty mat) is also a variable in determining the allowable number of passes. It does not directly increase the strength of the soil, but a surface does increase a soil's service life. Determine the surface type by checking the least resource-intensive method first. For example, if the intersection of the soil CBR and the unsurfaced curve does not meet the required number of passes, use the light-duty mat curve. Use a medium-duty mat if the number of required passes is still not met. If the soil CBR cannot support the required number of passes for any surface type, go to Step 6.

STEP 6. OUTLINE CORRECTIVE ACTIONS TO INCREASE SERVICE LIFE

After determining the allowable number of passes, compare it to the number of passes required by the mission or construction directive. There are certain courses of action available to increase the allowable number of passes. Each course of action involves increasing the strength of the in-place soil: (1) compact the in-place soil, (2) stabilize the in-place soil using mechanical, chemical, or geosynthetic stabilization, or (3) add a base course. Each of these methods is discussed in more detail later in this chapter.

DESIGN EXAMPLES

Example 1

Design an airfield for 200 passes in the close battle area given an in-place soil with AI=13. No C-17s are expected to use the airfield.

NOTE: Multiply the number of required passes by two to account for the aircraft taxiing down the runway to take off or unload.

Solution 1

Step 1. The airfield location is the close battle area.

Step 2. From Table 12-1, page 12-4, the design aircraft is a C-130, which has a gross weight of 130 kips.

Step 3. The soil strength is given as an AI. It can be converted to a CBR value through Figure 12-1, page 12-2. AI = 13 is equivalent to CBR = 14.1.

Step 4. The required number of passes is 200.

Step 5. Determine the allowable passes from Figure 12-6. Enter the chart with CBR = 14.1. Read the number of passes on the horizontal axis where the CBR intersects the C-130 curve for the appropriate

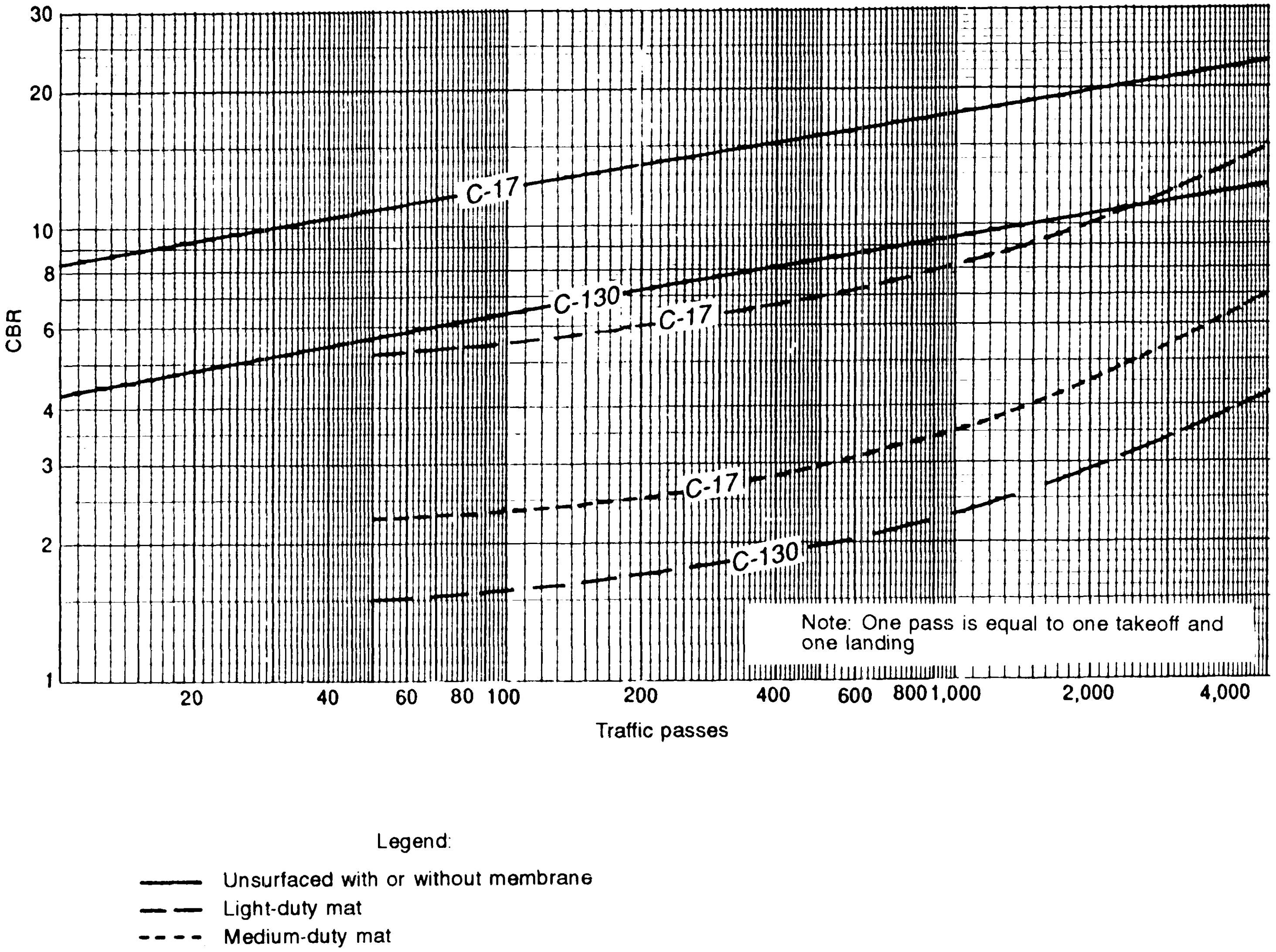


Figure 12-6. Subgrade strength requirements for C-130 and C-17

surface. In this case, the unsurfaced curve exceeds the required number of passes for a CBR = 14.1 soil; therefore, the soil will carry the 200 required passes.

Example 2

Design an airfield for logistics missions of a C-17 in the support area. The in-place soil has a DCP index of 60. The division Air Force liaison estimates the need for 600 passes.

Solution 2

Step 1. The airfield is located in the support area (given).

Step 2. Design aircraft is a C-17, which has a gross weight of 430 kips in the support area (Table 12-1, page 12-4).

Step 3. DCP index is 60. From Figure 12-2, page 2-3, CBR = 3.

Step 4. The required number of passes is 600.

Step 5. From Figure 12-6, page 12-11, the intersection of the unsurfaced curve and the soil CBR yeilds zero passes. The only surface available for this low CBR is a medium-duty mat. The allowable number of passes for a C-17 weighing 430 kips on a medium-duty treat is 540. Since the allowable number of passes exceeds the required number, proceed to Step 6.

Step 6. Outline corrective actions to increase service life. Since the DCP index reflects the soil strength in an undisturbed state, first determine the DCP index after several passes with a roller suitable to the soil type. If you improve the index only slightly, then you can meet the service life with compaction only. Consider stabilization or adding a base course as other methods if compaction alone is not enough.

EXPEDIENT AIRFIELD DESIGN—SPECIAL CASES

The previous discussion of soil-strength determination was adequate for a soil that has a uniform CBR and soil characteristics (Atterberg criteria, gradation) to a depth of 24 inches after organics and any loose, granular soil is moved aside. It is possible to determine a critical CBR for soils with varying strengths by evaluating each case separately. This changes the method of determining the in-place CBR but not the actual design procedure.

Soil-Strength Profile-Increasing with Depth

If a soil-strength profile increases with depth, the critical CBR is the average CBR for the upper 12 inches. Soil strength usually increases with depth so the weakest 12 inches are considered critical, and they control the evaluation. If the average CBR of the top 12-inch layer yields a CBR that does not meet any surfacing requirement in Figure 12-6, consider stabilizing the subgrade. (See Chapter 9, FM 5-410, for details on the type and depth of stabilization.)

Example 3

Determine the number of allowable traffic passes for a C-130 aircraft in the close battle area. Gross weight is 130 kips. The soil-strength profile is shown below.

Depth (in)	CBR
0	--
1.0	3
2.2	4
4.9	4
6.9	5
8.1	7
9.1	7
11.0	7
12.2	7
13.4	8
15.2	8
16.4	8
18.6	7
20.1	8
21.8	9
23.0	9
24.5	9

Solution 3

Step 1. Airfield location is the close battle area.

Step 2. Design aircraft is the C-130, gross weight = 130 kips.

Step 3. From the soil profile, the CBR increases with depth. The critical CBR is an average of the top 12 inches; therefore, CBR = 5.5.

Step 4. The required number of passes is not given in the mission statement, so go to Step 5.

Step 5. While the required number of passes is not given, use Figure 12-6, page 12-11, to determine the surface type and allowable number of passes. For a CBR = 5.5, an unsurfaced airfield allows only 42 passes. If a light-duty mat is used, however, the service life increases to 5,000 passes (use the largest number if it runs off the scale). Either surface would be correct, depending on the tactical situation; but if time and resources exist, use the light-duty mat.

Soil-Strength Profile-Very Soft Layer on a Hard Layer

Determining the critical CBR on a soil with a very soft layer over a hard layer can be subjective, depending on the AI or CBR value and design aircraft weight. A soft layer can be a thin layer in which there is an extreme contrast between the upper few inches and the lower level.

If a very soft layer is 4 inches thick or less, discard the CBR values from the soft layer, and determine the critical CBR from the 12-inch layer below the soft layer. For unsurfaced airfields, the allowable number of traffic passes may be reduced due to rutting in the top 6 inches, which causes excessive drag on aircraft during takeoff. This must be carefully monitored by airfield personnel. The maximum rutting depths (Table 12-2) are based on the orientation of the ruts as well as the soil strength.

Table 12-2. Maximum rutting depth

CBR	Orientation	Depth
Less than 15	Parallel or not more than a 5-degree angle off runway centerline	3 in
Less than 15	More than a 5-degree angle off runway centerline	3 in
15 or more	Any	3 in

NOTE: The aircraft cannot traffic on the surface if maximum ruts are exceeded.

If the very soft layer is more than 4 inches thick, the soft layer should be reduced by grading to at least 4 inches. If you cannot reduce the depth of the soft layer because of time or equipment constraints, determine the critical CBR as an average of the top 12 inches. The resulting low CBR will prescribe matting, which reduces the effects of rutting. Generally, the area will not be suitable as an airfield without placing matting on the traffic area or blading the soft material off and waste it, if the equipment is available.

Example 4

Determine the surface type needed to support 2,000 passes of a C-130 aircraft in the support area. Gross weight is 130 kips; soil-strength profile is indicated below.

Depth (in)	AI
0	--
2.2	0.5
4.0	0.4
6.2	6
8.0	6
9.6	7
11.2	7
13.3	7
14.9	8
16.7	8
18.0	8
20.1	7
22.4	8
23.8	8

Solution 4

Step 1. Airfield location = support area.

Step 2. Design aircraft = C-130; gross weight = 130 kips.

Step 3. The soil profile shows a soft layer that is roughly 4 inches deep. It is followed by a hard layer. Discard the data from the soft layer since the critical AI is an average of the 12-inch layer below the soft layer. The average AI from the 6.2-inch depth to the 16.7-inch depth is 7. The equivalent CBR from Figure 12-1, page 12-2, is 5.4.

Step 4. The required number of passes is 2,000.

Step 5. The surface type is a light-duty mat, capable of supporting 5,000 passes (Figure 12-6, page 12-11).

NOTE: If the CBR was high enough to justify an unsurfaced airfield, check Table 12-2, page 12-13, for maximum rutting depth. Airfield personnel should carefully monitor the runway to ensure ruts do not exceed the maximum.

Hard Layer Over a Softer Layer

Some soils may yield a profile that shows a hard layer over a soft layer. This type profile is generally exhibited by a soil that has a gravel surface over a natural or fill soil, or by a natural soil that has a hard crust in the upper layer. If the top layer of soil is adequate to support the desired aircraft passes, then the strength of the weaker soil layers beneath the top layer is used to check for the critical CBR.

The airfield cone penetrometer cannot be used to determine soil strength in a gravelly soil, but the DCP can be used. If the DCP is not available, dig a test hole or test pit to determine the thickness of the hard layer.

If the hard layer is less than 4 inches thick, the hard layer is discarded, and the critical CBR is determined by the average CBR of the 12-inch layer profile below the hard layer. The number of traffic passes is determined as before (Figure 12-6).

If the hard layer is greater than 4 inches thick, the critical layer is the 12 inches directly beneath the hard layer. If the hard layer is greater than 12 inches, simply average the CBR values of the 12- and 24-inch layers.

Example 5

Determine the surface type and the number of allowable traffic passes for a C-130 aircraft in the close battle area. Gross weight is 130 kips. The soil-strength profile yields 5 inches of gravel, and the 12-inch soil profile below the gravel layer has an average CBR = 6. The commander indicated that he needed 60 passes to accomplish the mission.

Solution 5

Steps 1-3. Close battle area; C-130 (130 kips); CBR = 6 (given).

Step 4. The required number of passes is 60 (given).

Step 5. Allowable passes = 70 (Figure 12-6) for an unsurfaced airfield.

Example 6

Design an airfield in the support area for use by both C-130s (130 kips) and C-17s (430 kips) for 1,000 passes. The soil analysts used a DCP to determine the soil strength profile below.

Depth (in)	AI
0	--
1.6	19
3.2	19
5.6	19
7.9	18
9.0	18
10.8	18
12.4	19
14.6	18
16.6	17
18.9	10
20.5	9
22.9	8
24.3	6

Solution 6

Step 1. Airfield location = close battle area (given).

Step 2. Although both aircraft will use the airfield, the C-17 is the design aircraft when both are present.

Step 3. The soil profile above shows that a soft layer exists under a hard layer. The AIs are consistently above 17 until the 18-inch depth, when they drop significantly to 10. Since the hard layer is greater than 12 inches and the soil is only evaluated to 24 inches, calculate the average of the bottom 12 inches or the 12.4-inch to the 24.3-inch layer:

$$\frac{6+8+9+10+17+18+19}{7} = 12.4$$

The critical AI is 12.4, which yields a CBR = 13 (Figure 12-1, page 12-2).

Step 4. The required number of passes is 1,000 (given).

Step 5. From Figure 12-6, page 12-11, an unsurfaced airfield allows 130 passes for a soil CBR = 13. Since this does not meet the commander's guidance, check other surfaces. A light- or a medium-duty mat can be used in this situation.

A hard soil layer over a soft layer can usually be found in dry lake beds having a high evaporation rate and a high water table. The upper crust is often 2 to 6 inches thick, and the soil beneath it generally cannot support an aircraft.

Soil-Strength Profile Decreasing with Depth

This type profile is similar to a hard layer over a soft layer. Generally, the soil exhibits a weakening with depth without a very strong surface layer. This type profile can readily be seen in areas of dry lake beds or where the groundwater can be found close to the surface. Areas such as these also may be subjected to seasonal fluctuation if the water table causes the soil profile to change.

Determine the critical CBR for this type profile by evaluating various layers to a depth of 24 inches. Determine the profile's critical CBR by choosing the lowest average CBR from the following layers: 6-18 inches, 8-20 inches, 10-22 inches, and 12-24 inches.

Example 7

Determine the number of allowable C-130 traffic passes on an airfield in the close battle area, gross weight 130 kip-pounds, and a soil strength profile shown below:

Depth (in)	AI
0	--
2.2	2
4.0	3.5
6.0	10.5
8.4	10.5
9.1	9
11.5	8.5
13.3	8
15.3	8
16.9	8
18.6	7
20.1	6
22.4	6.5
24.0	7

Solution 7

Step 1. Airfield location = close battle area (given).

Step 2. Design aircraft = C-130; gross weight = 130 kips.

Step 3. Determine the in-place soil strength by calculating averages for the following layers:

$$\text{6-18 inch: } \frac{10.5+10.5+9+8.5+8+8+8}{7} = 8.9$$

$$\text{8-20 inch: } \frac{10.5+9+8.5+8+8+8+7}{7} = 8.4$$

$$\text{10-22 inch: } \frac{8.5+8+8+8+7+6}{6} = 7.6$$

$$\text{12-24 inch: } \frac{8+8+8+7+6+6.5+7}{7} = 7.2$$

Since the lowest average CBR for the different layers is 7.2, it is the critical CBR.

Step 4. The required number of passes is not specified.

Step 5. From Figure 12-6, page 12-11, the allowable number of passes = 180 (unsurfaced) and 5,000 (light-duty mat).

SMOOTHNESS REQUIREMENTS FOR UNSURFACED AIRFIELDS

While unsurfaced airfields require little preparation, both the C-130 and the C-17 require relatively smooth surfaces for takeoff and landing. The overall grades, grade changes, and slopes must be within the limits indicated in Table 11-3, page 11-4. The random surface deviations and obstacles allowed depend on the strength, hardness, and size of items that cause roughness. They should not exceed the following limits:

- Rocks in traffic areas must be removed, embedded, or interlocked in a manner that will preclude displacement when traversed by aircraft. Tree stumps must be cut to within 2 inches of the ground.
- Dried, cohesive dirt clods (clay excluded) and soil balls (as much as 6 inches in diameter) that will burst upon tire impact are allowed. Because hardened clay clods may have characteristics similar to those of rocks, they must be pulverized or removed from traffic areas.
- Contours of dirt patterns are allowed when they result from plowing to reduce erosion, aid water drain off, and prepare the soil for planting. These contours contain a soft core that does not require removal.
- Limitations on rutting are a function of the orientation, depth of ruts, and soil bearing strength. Maximum ruts that can be traversed safely are shown in Table 12-2, page 12-13.
- Potholes must be filled if they exceed 15 inches across their widest point and 6 inches deep. Potholes are circular or oval and are distinguished from depressions by their smaller size and sharp-angled corners. Distance between repairs should be at least 20 feet apart.
- Ditches more than 6 inches deep must be eliminated from traffic areas. When ditches are filled, the bearing strength must approximate that of the surrounding soil.

If it is decided (after final analysis of the subgrade strength) to change the alignment of the airfields, test the new area as required.

Remember, these evaluations do not guarantee risk-free operation; and evaluations are affected by airfield condition, weather, and aircraft use. The commander must keep these risks in mind when making decisions on airfield use.

DESIGN REQUIREMENTS FOR MEMBRANE- AND MAT-SURFACED AIRFIELDS

Many high-performance Air Force aircraft cannot operate on the degree of surface roughness permitted by unsurfaced criteria. Heavy cargo aircraft will rarely operate on unsurfaced airfields because of their sensitivity to foreign object damage and soil strength requirements. Matting and membranes can alleviate some of these problems. A thorough discussion on membranes and matting placement is contained in Appendices L, M, and N.

Smoothness Requirement for Mats and Membrane Airfields

Membrane-surfaced airfields. Membrane coverings are impermeable nylon fabrics that protect an airfield from harmful drainage effects and act as a rustproofing agent. Membranes are used on both types of expedient surfaces (unsurfaced and surfaced) with a light- or medium-duty mat. Although the membranes do not increase the strength of in-place soil, they may increase the service life in many geographic areas. The surface smoothness requirements for this airfield category apply to the subgrade surface before placement of membrane or to an existing unsurfaced airfield where sustained operations of the C-130 are expected. Smooth grade the runway and taxiway to a crown or transverse slope that meets design standards. The overall grades and slopes will not exceed that required for the unsurfaced airfield either longitudinally or transversely at any location on the surface of the runway, taxiway. or apron.

Mat-surfaced airfields. Mat surfacing provides a very smooth, well-drained, fine-graded surface free of local depressions or potholes. Surface smoothness requirements for this air-field category apply to the surface of subgrade before placement of membrane and landing mat. For satisfactory performance, the landing mat must be supported by the subgrade and must not be required to bridge over depressions or potholes. Prepare a satisfactory surface for the landing mat by compacting and fine grading to a predetermined grade. Tables 12-3 and 12-4, page 12-18, list some mat characteristics.

Grade runways and the taxiway to provide a crown section or transverse slope that meets the design standards. Overall grades and slopes must be within the limits given in Table 11-3, page 11-4. Random surface deviations in grade will not exceed 1 inch either longitudinally or transversely from a 12-foot straightedge or string line placed at any location on the surface of the taxiway, runways, or aprons.

Table 12-3. Characteristics of M19 and ancillary items

Item	NSN	Quantity of Items Per Bundle	Bundle Weight (lb)	Outside Bundle Dimensions			Bundle Volume (cu ft)
				Length (in)	Width (in)	Depth (in)	
M19 full mat	5680-930-1524	32	2,484	51 3/4	51	55	84.0
M19 half mat	5680-930-1525	32	1,480	51 3/4	51	30	45.8
M19 repair mat	5680-089-5919	16	1,555	51 3/4	51	30	45.8
Special surf mat	None	16	1,480	51 3/4	51	31	47.3
Starter connector	5680-933-3122	15	305	51	15	9	4.0
Access adapter	5680-089-5924	25	382	51	12	11	3.9
Overlap/D1 adapter	None	30	331	50	11	12	3.9
Underlap/D1 adapter	None	30	331	50	11	12	3.9
Turn adapters							
Male/underlap	5680-933-3120	15	167	50	11	8	2.5
Male/overlap	5680-089-5925	15	167	50	11	8	2.5
Female/underlap	5680-933-3121	15	167	50	11	8	2.5
Female/overlap	5680-089-5928	15	156	50	11	8	2.5
Turndown adapter	5680-933-3119	15	181	50	11	10	3.2
Anchor	5680-089-5934	250	1,225	42	36	36	31.5
Anchor attachment							
Female	5680-089-5929	125	262	27	30	12	5.7
Male	5680-089-5930	125	262	27	30	12	5.7
Locking bar	5680-930-1526	NA	NA	48 1/2	5/8	1/16	ea

Table 12-4. Mat dimensions

	M8A1	AM2	Standard Medium Duty M19
Bundle dimensions (W x L x D), ft	1.896 x 12.021 x 1.083	2.28 x 12.58 x 2.16	4.29 x 4.25 x 4.67
Volume of bundle, cu ft	24.7	62	85.1
Placing area in bundle, sq ft	268.8	288	534.4
Area covered, sq ft, per cubic foot of cargo space	10.88	4.64	6.28
Gross weight of bundle, lb	2,036	1,980	2.484
Number of panels in bundle	13	11	32
Number of half-panels in bundle	2	2	32*
Panel placing dimensions (W x L), ft	1.625 x 11.8125	2.0 x 12.0	4.008 x 4.16
Panel depth (D), in	1.125	1.500	1.500
Panel weight, lb	144	140	71
Placing area per panel, sq ft	19.2	24.0	16.7
Weight per sq ft in place, lb	7.5	5.8	4.25
Placing rate, sq ft per man-hour:			
On 1 1/2% crown	240	163	352
On 3% crown	200	112	350
*Separate bundle of half-panels			

DESIGN IMPROVEMENTS FOR EXPEDIENT-SURFACED AIRFIELDS

When suitable in-place soils cannot be found to support expedient-surfaced airfields, improve the in-place soil of the desired location as a last resort. The extra time and resources involved in improving in-place soil is minimal when compared to reconfiguring missions based on finding a suitable subgrade.

The easiest way to increase the allowable number of passes is by compacting the in-place soil or subgrade. Through compaction, soil particles orient themselves in a denser formation, which increases the soil CBR. Compaction will only be effective if done for the entire critical layer. For uniformly distributed soil profiles, that means the top 12 inches. Since most rollers only compact to a depth of 6 to 8 inches, scarify and windrow the top 6 inches to the side in order to compact the bottom 6-inch layer. Specific guidelines for the type of roller to use can be found in FM 5-410. After you increase the soil CBR, go back through the design steps to determine the new allowable number of passes. Depending on the uncompacted CBR and the amount that it changed by compaction, the surface type or the need for a surface altogether also may have changed.

Normally, compaction will improve the strength of soils. However, there are some special cases where working a soil may actually decrease its strength. Specifically, the fine-grained soils, types CH and OH, can have high strengths in an undisturbed condition; but scarifying, grading, and compacting may reduce their shearing resistance. For more information on these soils, see Chapter 8, FM 5-410.

Another way to increase the strength of the subgrade is through soil stabilization. There are many methods of stabilization available to increase soil CBR. The three major types of stabilization are stabilization expedients (or geosynthetics), mechanical stabilization, and chemical stabilization. Choosing the best one depends on the soil characteristics as well as available resources. Specific information on each type of stabilizer can be found in Chapter 9, FM 5-410. Stabilizing an in-place soil is most commonly done to increase the soil's CBR, but it can also be used to negate the harmful effects of dust and water. Table 12-5 summarizes the possible functions of stabilizers in traffic and nontraffic areas on expedient surfaces.

Dust Control and Waterproofing

Much information needs to be developed to form comprehensive criteria for selecting and using dust-control agents and soil waterproofers on expedient airfields. There are many possible choices. Until one or two vastly superior dust-control agents or soil waterproofers are developed, the engineer should be aware of the potentially acceptable systems and some of their characteristics.

Dust Control. The presence of dust-sized particles in a soil surface may not indicate a dust problem. An external force imposed on a ground surface will generate dust. Dust may be generated as a result of erosion by an aircraft's propeller wash, engine exhaust blast, jet-blast impingement, or the draft of moving aircraft. The kneading and abrading action of tires can loosen particles from the ground surface. These particles may become airborne as dust.

On unsurfaced airfields, the source of dust may be the runway, taxiways, shoulders, overruns, or parking areas. In areas of open terrain and prevailing winds, soil particles may be blown in from distant locations and deposited on an airfield. This can contribute to dust potential despite adequate initial control measures of the soil within the construction area. Where blowing dust is a problem, it may be necessary to apply additional dust-control agents to an airfield.

The primary objective of a dust-control agent is to prevent soil particles from becoming airborne. These agents may be needed on traffic and nontraffic areas. If prefabricated landing mat, membrane, or conventional pavement surfacing is used in the traffic areas of an airfield, dust-control agents are needed only on nontraffic areas. The substance used in these areas must resist the maximum intensity of air blast impingement of aircraft.

Dust-control agents used for traffic areas must withstand the abrasion of wheels and blast impingement. Although dust-control agents may provide resistance against air impingement, they may be unsuitable as a wearing surface. An important factor

Table 12-5. Stabilization functions

Airfield Type	Possible Functions of Stabilization for Indicated Areas					
	Traffic Areas[a]			Nontraffic Areas[b]		
	Strength Improvement	Dust Control	Soil Waterproofing	Strength Improvement	Dust Control	Soil Waterproofing
Close Battle Area						
No mat	X	X	X		X	
With LM					X	
Support Area						
No mat				X	X	X
With LM	X			(X)	(X)	(X)
With MM				(X)	(X)	(X)

NOTES:

1. References to the use or no use of mat for a particular airfield apply only to their use in traffic areas.
2. X = functions for which stabilization may be considered; blank space = no function for stabilization; (X) = function will exist only if landing mat is not used in nontraffic areas.

[a] Traffic areas include runway, taxiways, and aprons.

[b] Nontraffic areas include overruns, shoulders, and peripheral zones which receive little or no traffic.

limiting the applicability of a dust-control agent in traffic areas is the extent of surface rutting that occurs under traffic. Under these conditions, the effectiveness of a shallow dust-control treatment could be destroyed rapidly by breakup and subsequent stripping from the ground surface. Some dust-control agents will tolerate deformations better than others. Normally, ruts in excess of 1/2 inch will result in the destruction of any thin layer or shallow dust-control treatment.

Waterproofing. Water may enter a soil by the (1) leaching of precipitation or ponded surface water, (2) capillary action of underlying groundwater, (3) a rise in the water table, or (4) condensation of water vapor and the accumulation of moisture under a vapor-impermeable surface.

As a general rule, areas with an existing shallow water table will have a low soil bearing strength and should be avoided whenever possible.

The objective of a soil surface waterproofer is to protect soil against water and preserve its strength during wet-weather operations. The use of soil waterproofers is limited to traffic areas except where excessive softening of nontraffic or limited traffic areas such as shoulders or overruns must be prevented.

Soil waterproofer may prevent soil erosion resulting from surface-water runoff. Like dust-control agents, a thin or shallow soil waterproofing treatment loses its effectiveness when damaged by excessive rutting. These treatments can be used efficiently only in areas that are initially firm.

Many soil waterproofers also function well as dust-control agents. A single material may be used as a treatment in areas with both wet- and dry-soil surface conditions.

Materials. Many materials for dust control and soil waterproofing are available. No one choice, however, can be singled out as acceptable for all problem situations. To simplify the discussion, materials are grouped into five general classifications: Group I, bituminous materials: Group II, cementing materials: Group III, resinous and latex systems; Group IV, salts; and Group V, miscellaneous materials.

A summary of the various materials and a guide to their applications as a dust-control agent or soil waterproofer are given in Table 12-6. This summary is the best estimate of the applicability of the materials based on existing information. Two materials in the table (asphalt penetrative soil binder (APSB) (Peneprime) and polyvinyl acetate dust-control agent (DCA 1295) warrant special mention.

- APSB (Peneprime) is a special cutback asphalt having good penetration capability and rapid curing characteristics. This material is effective in sand, gravel, silt, and lean clay. It is not effective in heavy clay or clay with excessive shrinkage or swelling characteristics. Surface application assures good penetration in granular soils. In clay, silt, and granular soils that are highly compacted, the surface should be scarified to a shallow depth before the material is applied.

  Compaction should be initiated when penetration is complete. In traffic areas, compaction can be accomplished by normal traffic. These materials are effective in traffic and nontraffic. When the material is applied on unscarified areas of well-compacted soil, reapplication may be necessary if the traffic is moderate to heavy.

- Polyvinyl acetate (DCA 1295) is an emulsion that is applied to the surface using a fiberglass scrim (screen) fabric to reinforce it. This material can be used on all types of soil, and it cures in four hours or less. This system is applicable to shoulders and overruns and is effective as a waterproofing agent. It will not support heavy fixed-wing aircraft traffic.

The following information is provided in Table 12-6:

Table 12-6. Dust-control and waterproofing applications

				Primary function, area of application, and degree of effectiveness[a]			Quantity requirements[b]			
				Dust palliative		Waterproofer (traffic or limited traffic areas only)				
Material	**Form of material**	**Acceptable application method(s)**	**Applicable soil range**	**Traffic**	**Nontraffic or limited traffic**		***gallons per square yard***	***pounds per square yard***	**Minimum curing time requirements**	**Remarks**
Group I: Bituminous Materials										
Cutback asphalts										
RC-70 to RC-250	Liquid	Admix	Gravel to sand	M	V	M	0.18-0.25	1.5-2.0	12-24 hours	All cutback asphalts will require preheating for penetration or admix application.
		Penetration	Gravel to silty sand	M	V	X	0.25-0.50	2.1-4.0	12-24 hours	
MC-70 to MC-250	Liquid	Admix	Sand to silt	M	V	M	0.25-0.55	2.0-4.5	>24 hours	
MC-30 to MC-250	Liquid	Penetration	Gravel to silty sand	M	V	X	0.25-0.50	2.1-4.0	>24 hours	
SC-70 to SC-250	Liquid	Admix	Sand to clay of moderate plasticity	M	V	M	0.55-0.72	4.5-6.0	>24 hours	
		Penetration	Gravel to silty sand	M	V	X	0.25-0.50	2.1-4.0	>24 hours	
Road tars										
RT-3 to RT-6	Liquid	Admix	Gravel to clay of moderate plasticity	V	V	V	0.30-0.50	2.5-4.0	Several days	Same comments as above for cutbacks.
RT-1 to RT-6	Liquid	Penetration	Gravel to silty sand	X	X	X	0.25-0.50	2.1-4.0	Several days	
Emulsified asphalts										
SS-1 or SS-1h (Anionic)	Liquid	Admix	Gravel to silty sand	X	X	X	0.10-0.50	0.8-4.0	Several hours	Requires water for dilution and requires careful control control for proper emulsion break. Dilutions up to 5:1 by water are used.
		Penetration	Gravel to silty sand	X	X	X	0.10-0.50	0.8-4.0	Several hours	
Special asphalts										
APSB (Peneprime)[c]	Liquid	Penetration	Gravel to clay of moderate plasticity	M	V	M	0.25-0.5	2.1-4.0	4-8 hours	Excellent penetration ability; required heating.
Lion Prime	Liquid	Penetration	Gravel to clay of moderate plasticity	M	V	M	0.25-0.5	2.1-4.0	4-8 hours	Excellent penetration ability; required heating for spraying.
Group II: Cementing Material										
Portland cement	Powder	Admix	All	S	S	S	--	1.5-4.0	12-24 hours	*Normally used for strength,* but will also provide modest benefits for dust control and waterproofing when used in low quantities as a soil modifier.
Lime (hydrated)	Powder	Admix	Clays of moderate high plasticity	S	S	S	--	1.5-4.0	12-24 hours	Same as cement above.
Group III: Resinous or Latex Systems										
Lignin	Liquid or powder	Admix	Sand to clay of low plasticity	S	S	S	--	4.0-8.0	12-24 hours	Benefits may be only temporary since resin is water soluble.
Membrane, liquid form (Polyvinyl acetate DCA 1295)	Liquid	Surface application	All	S	V	S	--	3.0-7.0	4 hours	Use with reinforced fiberglass screen.
Concrete curing compound (with paraffin base resin)	Liquid	Penetration	Sand to silty sand	X	X	X	0.50-1.0	4.0-8.0	2-6 hours	Fairly viscuous; requires special spray nozzels, forms thin, moderately flexible film on surface when cured; curing depends on temperature and humidity.
		Penetration	Silts to clays	S	M	X	0.1-0.2	1.0-2.0	2 hours	
Group IV: Salts										
Sodium chloride	Granular	Admix	Gravel to silt (with fines present)	S	S	--	--	0.4-0.8	0	All salts are corrosive to metal; subject to leaching; rely on absorption of moisture from air to palliate dust. Brine solution forms surface crust.
Calcium chloride	Powder or flakes	Admix	Gravel to silt (with fines present)	S	S	--	--	0.4-0.8	0	
Magnesium chloride	Liquid	Penetration	Gravel and sand	M	V	--	0.5	--	0	
Brine solution	Liquid	Penetration	Sand to clay of low plasticity	S	S	--	0.5-1.5 (20% solution)	--	0	
Group V: Miscellaneous Materials										
Water	Liquid	Penetration	All	S	S	--	As n	--	0	Temporary measure only.
Various oils	Liquid	Penetration	All	S	X	--	0.5-1.0	--	0	Temporary measure only; may require frequent application.

[a] Relative degree of effectiveness as follows: S = slightly; M = moderately; V = very; X = applicable, but effectiveness unknown; blank = not applicable.

[b] For all admixture treatments, the quantities indicated are for a 1-inch depth of treatment and assume a compacted dry density of 100 pcf.

[c] Proprietary material.

- Column 1 identifies the material.
- Column 2 indicates the usual form in which the material is supplied.
- Column 3 indicates the most acceptable method of application. Where a material may be applied either as an admixture or as a surface penetration treatment, the preferred and most generally used method is indicated first.
- Column 4 shows applicable soil ranges. The range of soils indicated will normally result in reasonably satisfactory results with the particular material. Sometimes the materials may be used outside this range with decreased effectiveness. In general, granular soils (gravel to coarse sand) may or may not require treatment for dust control or waterproofing, depending on the amount of fines present. Fine sands (such as dune or windblown sands) will probably require a dust-control treatment but will not need to be waterproofed. Soils ranging from silty sand to highly plastic clay may require a dust-control agent or a soil waterproofer.
- Columns 5, 6, and 7 show the primary function of the materials as either a dust-control agent or soil waterproofer, and where known, the relative degree of effectiveness that can be expected. Rarely will nontraffic areas require waterproofing because there is usually no need to maintain soil strength in nontraffic areas. If such a requirement exists, materials suitable for traffic areas can be considered acceptable for use in nontraffic areas.
- Columns 8 and 9 reflect the quantity requirements applicable to the soil range indicated in column 4. The lower quantity of the range generally is suitable for coarse soils, and the greater quantity is needed for fine soils. These quantity requirements are given only as a general guide, and in some cases, effective results may be achieved with lesser or greater amounts than those given in the table. (Detailed information on dust control is in TM 5-830-3.)
- Column 10 indicates the minimum curing time requirements.

AGGREGATE-SURFACED AIRFIELDS

While time and resources are limited in the close battle area, it may be possible to commit resources in the support area to aggregate-surfaced airfields. Most airfields in the support area initially have expedient surfaces, which may be upgraded to aggregate surfaces for sustained operations. Sometimes a former close battle area is redesignated as a support area and upgraded to an aggregate surface for ensuing operations.

The design of aggregate-surfaced airfields is similar to the design of expedient-surfaced airfields. In aggregate-surfaced airfields, however, a layer of high-quality material is placed on the compacted subgrade to improve its strength. The thickness design is a function of the CBR of the in-place soil and the design aircraft. Instead of determining the number of allowable passes based on the CBR, use the required number of passes to determine the total thickness design. For a given CBR, the thickness design increases with increased number of passes. Normally, aggregate-surfaced airfields are used from one to six months and support C-17 and C- 130 sorties.

Design the layout of aggregate-surfaced airfields like expedient-surfaced airfields. The runway with turnarounds should be constructed first as shown in Figure 12-3, page

12-5. As time permits, complete the airfield layout according to Figure 12-4, page 12-6.

MATERIALS

Materials used in aggregate airfields must meet the requirements stated in Chapter 5, FM 5-430-00-1/AFPAM 32-8013, Vol l, and in the following paragraphs. The materials should have greater strength than the subgrade and should be placed so the higher quality material is on top of the lower quality material. All layers in an airfield design require a minimum layer thickness of 6 inches and should conform to the CBR and compaction criteria shown in Table 12-7.

Table 12-7. Compaction criteria and CBR requirements for aggregate-surfaced airfields (MIL STD 621 method 100 CE 55)

CBR Requirements	Layer	Compaction Requirements
80-100	Base course	Asphalt: 98-100% @ CE 55 Soil: 100-105% @ CE 55
20-50	Subbase course	100-105% @ CE 55
0-20	Select material	Cohesive: 90-95% @ CE 55 Cohesionless: 95-100% @ CE 55
	Compacted subgrade	Cohesive: 90-95% @ CE 55 Cohesionless: 95-100% @ CE 55
	Uncompacted subgrade	

Subgrade

The in-place soil or subgrade requires more attention in aggregate-surfaced airfield structures. Before developing the thickness design, determine the compacted CBR of the subgrade. Since laboratory CBR tests are impractical for initial construction, use the penetrometers discussed earlier.

Determine the soil's CBR profile as discussed previously for expedient surfaces. Like road design, the CBR of the subgrade determines the thickness of the whole design. If you can improve the CBR through compaction, the thickness of the aggregate airfield structure will decrease. The depth to which an in-place soil should be compacted is normally 6 inches, but the depth is determined in the design procedure.

Select and Subbase Materials

Select and subbase materials used in aggregate airfields provide granular fill to meet the thickness design based on the subgrade CBR. Select materials and subbase courses must meet the Atterberg limits and gradation requirements of Table 12-8, which are the same criteria used for roads.

Base Course

Only good quality materials should be used in base courses of aggregate airfields. Since the base course is also the surface course, it must meet specifications for both strength anti gradation. The minimum CBR

Table 12-8. Maximum permissible values for subbases and select materials

Material	Maximum Permissible Value					
	Maximum Design CBR	Size (inch)	Gradation Requirements Percent Passing		Liquid Limit*	Plasticity Index*
			No. 10 Sieve	No. 200 Sieve		
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

*Determination of these values will be made in accordance with ASTM D 4318.

for an airfield base course is 80 (Table 12-7, page 12-23). Since CBR tests require time, use one of the base-course materials shown in Table 12-9, if possible. They are materials of known strength. If a material not listed is more easily obtained, use a test strip to determine its compacted CBR with a DCP.

Gradation requirements for aggregate-surfaced layers are given in Table 12-10, where the specifications depend on the maximum size aggregate (MSA). These are the same gradation requirements as given in Chapter 5, FM 5-430-00-1/AFPAM 32-8013, Vol 1, for base courses for aggregate-surfaced roads.

FROST CONSIDERATIONS

Aggregate-surfaced airfields, unlike roads or expedient surfaces, require much more restrictive tolerances in construction and general maintenance. For this reason and the potential for catastrophic accidents in the case of structural failure, frost must be considered in the design of aggregate airfields. The specific areas where frost has an impact on the design are discussed in the following paragraphs:

Table 12-9. Assigned’CBR ratings for base-course materials

Number	Type	Design CBR
1	Graded, crushed aggregate	100
2	Water-bound macadam	100
3	Dry-bound macadam	100
4	Bituminous base course, central plant, hot mix	100
5	Limerock	80
6	Bituminous macadam	80
7	Stabilized aggregate	80
8	Soil cement	80
9	Sand shell or shell	80

Table 12-10. Desirable gradation for crushed rock or slag, and uncrushed sand and gravel aggregates for nonmacadam base courses

Sieve Designations	Percent Passing Each Sieve (Square Openings) by Weight			
	Maximum Aggregate Size			
	2-Inch	1 1/2-Inch	1-Inch	1-Inch Sand Clay
2-inch	100			
1 1/2-inch	70-100	100		
1-inch	55-85	75-100	100	100
3/4-inch	50-80	60-90	70-100	
3/8-inch	30-60	45-75	50-80	
No. 4	20-50	30-60	35-65	
No. 10	15-40	20-50	20-50	65-90
No. 40	5-25	10-30	15-30	33-70
No. 200	0-10	5-15	5-15	8-25

As discussed earlier, three conditions must exist for detrimental frost action to occur: (1) the subgrade must be frost susceptible, (2) the temperature must remain below freezing for a considerable amount of time, and (3) an ample supply of groundwater must be available. Since aggregate-surfaced airfields have a design life up to six months, the effects of frost may not be relevant because of the time of year. In any case, evaluate the frost effects during the design process in the event the airfield is needed for sustained operations.

In general, frost-susceptible soils are those with considerable amount of fines or with at least 6 percent of materials finer than 0.02-millimeter grain size by weight. You do not have to relocate or find another soil when faced with one of these situations; however, you need to adjust the thickness design to account for the frost action. When water in a subgrade freezes, additional water travels by capillary rise and increases the ice lense. The ice lenses can disturb the compacted layers enough to create large voids during the next thaw cycle.

THICKNESS DESIGN PROCEDURE

The design procedure for aggregate-surfaced airfields in the support area is very similar to expedient-surfaced airfields. The major difference is that the outcome is the thickness of the aggregate structure, which is a function of the subgrade CBR, the design CBR, and the number of passes.

DESIGN STEPS

1. Determine the airfield location.
2. Determine the design aircraft and gross weight.
3. Check soils and construction aggregates.
4. Determine the number of passes required.
5. Determine the total surface thickness and cover requirements.
6. Complete the temperate thickness design.
7. Adjust thickness design for frost susceptibility.
8. Determine compaction requirements and subgrade depth.
9. Draw the final design profile.

Step 1. Determine the Airfield Location

The airfield location is always the support area. While aggregate-surfaced airfields are too resource intensive for the close battle area (unless they are existing airfields), they do meet the surface requirements for the rear area.

Step 2. Determine the Design Aircraft and Gross Weight

The C-17 and C-130 are the only possibilities for design aircraft in the support area. Aggregate surfaces are considered a semi-prepared surface where only the C-17 and C-130 can land. Since the support area is primarily a connector of the rear and close battle areas, it is logical that the design aircraft be able to land in all three areas. The aircraft also have the same design weights for the support and close battle areas as shown in Table 12-1, page 12-4.

Step 3. Check Soils and Construction Aggregates

This design step has three parts: (1) check the local area for possible borrow sites to be used as select materials and subbases, (2) check the strength and gradation of a possible base course, and (3) check the frost susceptibility of all materials, if necessary.

- Check construction aggregates for use as select and subbase materials. This is similar to road design discussed in Chapter 9, FM 5-430-00-1/AFPAM 32-8013, Vol 1. Conduct soil tests on any borrow sites to determine the soil's CBR, gradation, and liquid and plastic limits. Compare these values to Table 12-8, page 12-23, to determine if the borrow material can be used in a layer of the design.
- Check the strength and gradation of the base course. The base course must have a CBR = 80 or higher and meet the gradation criteria of Table 12-10.
- Check frost susceptibility of materials. If detrimental frost action (as defined earlier) is a concern, evaluate each layer soil below the base course for frost susceptibility. A soil is frost susceptible if it has 6 percent fines and/or 6 percent (by weight) 0.02 millimeter grain size.

For frost design purposes, soils have been divided into seven groups (Table 12-11, page 12-26). Only the nonfrost-susceptible (NFS) group is suitable for base course. Soils are listed in approximate order of decreasing bearing capability during periods of thaw.

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.

Do not use a soil above the compacted subgrade if it is frost susceptible. For example, a borrow material that meets the criteria for a subbase should not be used in the design if it has more than 6 percent finer than 0.02 millimeter by weight.

Table 12-11. Soil classification for frost design

Frost Group	Type of Soil	% By Weight < 0.02 mm	Typical Soil Types Under the USCS
NFS	(a) Gravels (e ≥ 0.25)	0 - 3	GW, GP
	Crushed stone	0 - 3	GW, GP
	Crushed rock	0 - 3	GW, GP
	(b) Sands (e ≤ 0.30)	0 - 3	SW, SP
	(c) Sands (e > 0.30)	3 - 10	SP
S1	(a) Gravels (e < 0.25)	0 - 3	GW, GP
	Crushed stone	0 - 3	GW, GP
	Crushed rock	0 - 3	GW, GP
	(b) Gravelly soils	3 - 6	GW, GP, GW-GM, GP-GM, GW-GC, GP-GC
S2	Sandy soils (e ≤ 0.30)	3 - 6	SW, SP, SW-SM, SP-SM, SW-SC, SP-SC
F1	Gravelly soils	6 - 10	GW-GM, GP-GM, GW-GC, GP-GC
F2	(a) Gravelly soils	10 - 20	GM, GC, GM-GC
	(b) Sands	6 - 15	SM, SC, SW-SM, SP-SM, SW-SC, SP-SC, SM-SC
F3	(a) Gravelly soils	> 20	GM, GC, GM-GC
	(b) Sands, except very fine silty sands	> 15	SM, SC, SM-SC
	(c) Clays (PI > 12)	-	CL, CH, ML-CL
F4	(a) Silts	-	ML, MH, ML-CL
	(b) Very fine sands	> 15	SM, SC, SM-SC
	(c) Clays (PI < 12)	-	CL, ML-CL
	(d) Varved clays and other fine-grained, banded sediments	-	CL or CH layered with ML, MH, SM, SC, SM-SC, or ML-CL

NOTE: e = void ratio.

If a subgrade is frost susceptible, determine its frost group from Table 12-11, and find the frost area soil support index from Table 12-12. This value is needed to adjust the thickness design in Step 8.

Table 12-12. Frost area soil support index

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

Step 4. Determine the Number of Passes Required

Unlike design for expedient surfaces, you can control the thickness design by the number of passes required. As the number of passes increases, so does the thickness design and, consequently, the construction effort. You may be given the required number of passes in a mission statement or you can adjust it based on the thickness design.

Step 5. Determine the Total Surface Thickness and Cover Requirements

The total thickness of the aggregate structure is a function of the subgrade CBR, the design aircraft, and the number of passes. Since the thickness design is usually greater than 6 inches (the minimum layer thickness), multiple soil layers are used. For example, if the thickness required over a subgrade was 18 inches, it would be expensive and wasteful to fill the entire 18 inches with a high-quality base course. Instead, use borrow materials to fill all but the top 6 inches. The CBR of each soil used in the design determines the required cover.

After evaluating the available soils and determining the number of passes, enter Figure 12-7 or 12-8, page 12-28, with the subgrade CBR until it intersects the gross weight of the design aircraft. Trace a line horizontally until you intersect the desired number of passes and determine the minimum cover required over the subgrade from the horizontal axis. Determine the minimum cover required over each soil that could be used in the design.

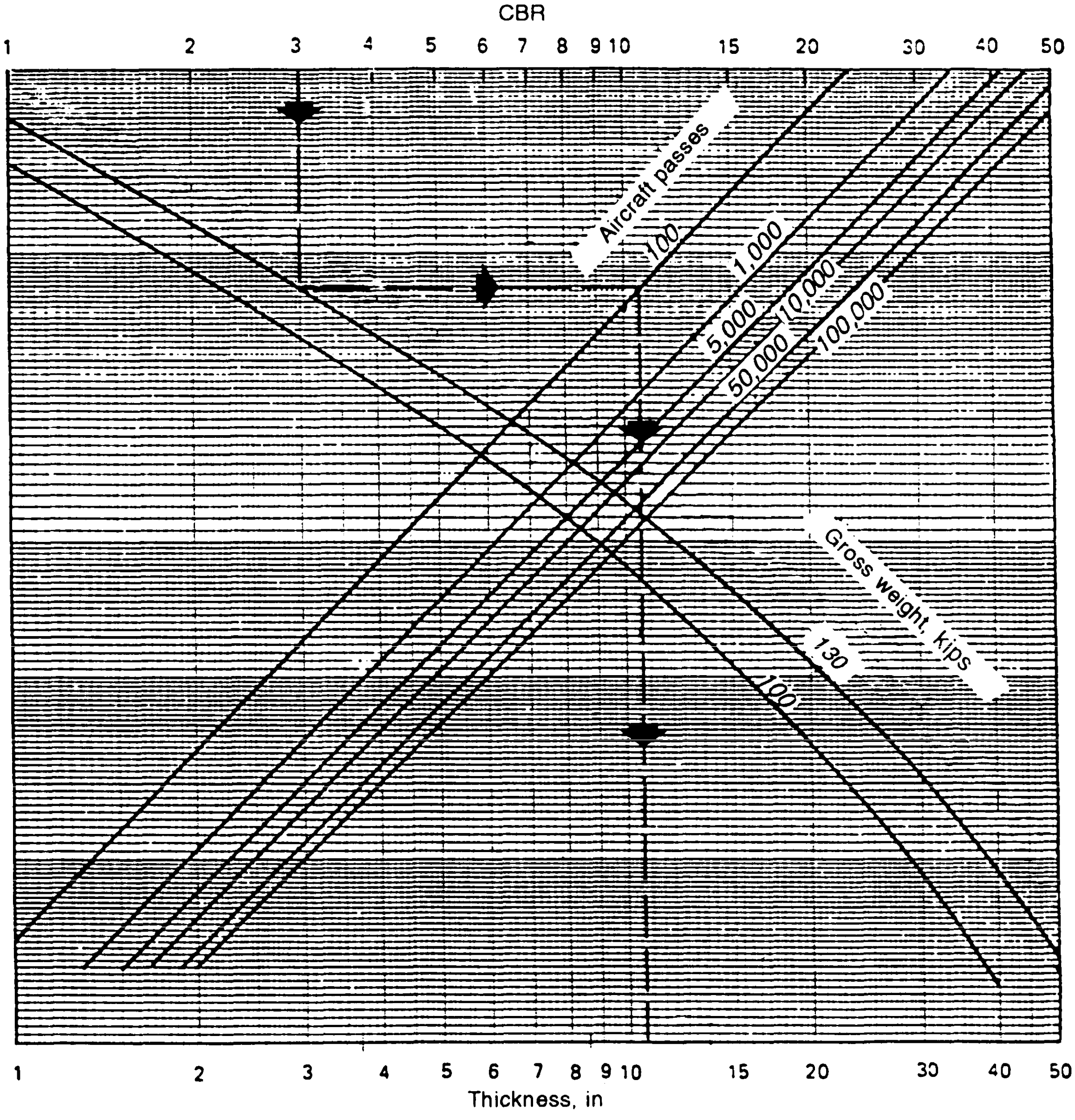


Figure 12-7. C-130 design curves for gravel-surfaced airfields

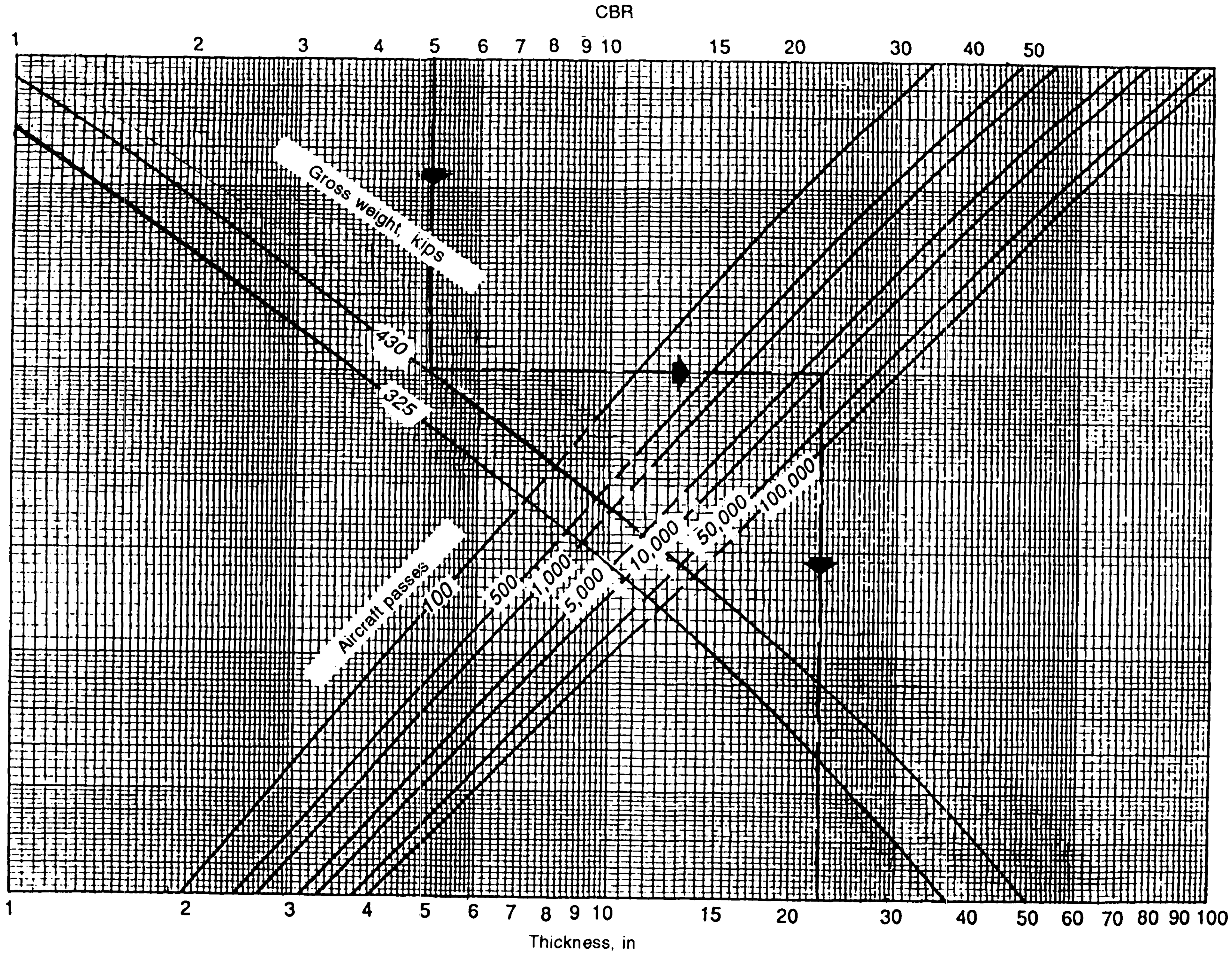


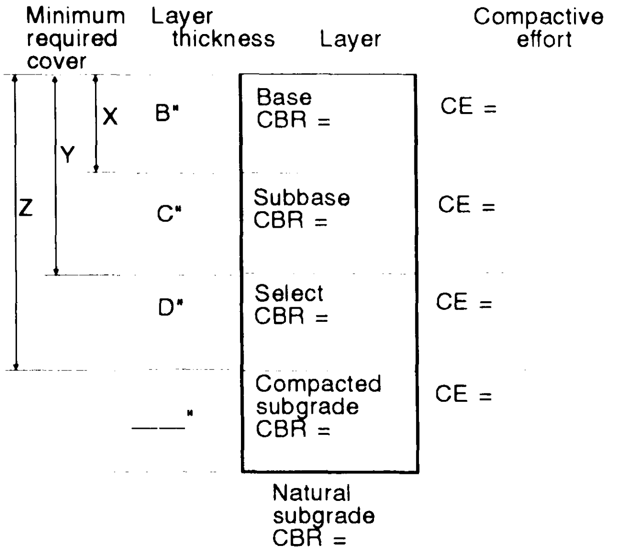
Figure 12-8. C-17 design curves for gravel-surfaced airfields

Step 6. Complete the Temperate Thickness Design

After finding the cover requirements, you can complete the thickness design without considering the effects of frost. The method is similar to road design in that you determine the layer thicknesses that satisfy the minimum cover requirements for each layer. Remember that each layer must be a minimum of 6 inches thick. Also, do not use soil layers in the design if they are not necessary to satisfy the cover requirements. For example, if a subgrade only requires 5 inches of granular fill, then the base course is the only aggregate layer required. Even though you may have determined that subbases and select materials are readily available nearby, they are not necessary for the airfield design. Figure 12-9 illustrates the relationship between minimum cover and layer thickness.

Step 7. Adjust Thickness Design for Frost Susceptibility

If you are not designing in a frost area or if the subgrade in a frost area is not frost susceptible (see Step 1), go to Step 9.



B = X
X = Minimum cover over subbase (Figure 9-54, Page 9-72, FM 5-430-00-1/AFPAM 32-8013 Vol 1)
C = Y - B
Y = Minimum cover over select (Figure 9-54)
D = Z - B - C
Z = Minimum cover over compacted subgrade (Figure 9-54)

Figure 12-9. Thickness design procedure

Since the freeze-thaw cycles associated with frost areas weaken soils, you now have to consider frost and how it will affect the thickness design. Since the subgrade is the only frost-susceptible material at this point, retrieve the subgrade information from Step 1.

Determine the frost-area soil-support index from Table 12-12, page 12-26. Use the index to enter Figure 12-7, page 12-27, or Figure 12-8 instead of the compacted CBR.

For example, for a C-130 airfield, if the compacted subgrade CBR was found to have CBR = 8 and the subgrade was found to be an F2 type soil, enter Figure 12-7 with CBR = 6.5 instead of 8. Since the lower value increases the thickness design for the same number of passes, choose the thicker of the two designs.

The frost design will not always increase the thickness design. For instance, if Step 7 indicates a total thickness design of 14 inches over a subgrade with a CBR = 3 and the soil is an F3 soil, use Table 12-12, page 12-26, to determine the soil support index of 3.5. Since 3.5 is greater than 3, it requires thinner design (determined by Figure 12-7).

After choosing the thicker of the two designs, you must add a frost filter to the design and adjust the layer thicknesses. A frost filter is sand or a uniformly graded, cohesionless material that allows the lateral movement of water. Place a 4-inch layer directly on the compacted subgrade and compact it to the specifications outlined in Step 8.

Geotextiles may be used over F3 and F4 subgrade materials in seasonal frost areas to help prevent intrusion of fines into base layers during periods of thaw. The geotextile should provide at least 110 pounds at 10 percent strain when the material is tested by the Grab Strength Test (ASTM D-5034 and D-5035). If the material exhibits different strengths in perpendicular directions, the lowest value is used. If longitudinal seams are required, they must meet the requirements in ASTM D-1683. End overlap at transverse joints should be a minimum of 2 feet. The fabric will be placed directly on the subgrade and must extend laterally to within 1 foot of the toe of slope on each side. A frost-filter layer is not required when a geotextile is placed directly on the compacted subgrade.

Step 8. Determine Subgrade Depth and Compaction Requirements

The layer thickness of an in-place soil is the depth to which you must ensure adequate compaction. Determine the depth by entering Table 12-13 with the appropriate traffic area and soil information.

The actual depth of subgrade compaction is the difference between the total thickness above the subgrade and the value from Table 12-13 or 6 inches, whichever is greater. For example, if the thickness above the cohesive subgrade (Type B traffic area) is 16 inches, then the depth of subgrade compaction is 21 inches (Table 12- 13) - 16 inches = 5 inches. However, since 5 inches is less than 6 inches, compact to a depth of 6 inches. Since the equipment effort for compaction is about the same for depths of 1 to 6 inches, the minimum depth of subgrade compaction is 6 inches.

Because most road construction missions require cut-and-fill operations, the subgrade depth requirement is only significant in cut sections since the soil in fill sections is placed and compacted in lifts (usually 6 inches). In cut sections, however, the subgrade must be scarified and compacted in place to the depth required after the cut is made.

Table 12-13. Depth of compaction required for subgrades

Traffic Area	Minimum Compacted Depth Below Surface (inches)	
	Cohesive Soils	Cohesionless Soils
B	21	25
C	17	21

Compaction requirements for subgrade and granular layers are expressed as a percent of maximum CE 55 density as determined by using Military Standard (MIL-STD) 621 Test Method 100 (ASTM 1557). The specifications for each layer in the design are listed in Table 12-7, page 12-23.

Remember, there are special cases for subgrades that lose strength when being remolded. These are generally soil types CH and OH. See Chapter 8, FM 5-410, for more information on these soils.

Step 9. Draw the Final Design Profile

This step is a culmination of the previous eight steps into a picture that the builder can understand. It shows the layer thicknesses, soil CBRs, and compaction requirements. It also shows the compactive effort of any fill sections, which is the same soil as the subgrade. Figure 12-10 shows the specific detail included in the profile.

______" Base course CBR @ 100-105% CE 55

______" Subbase[1] CBR ___ @ 100-105% CE 55

______" Select Mat'l[1] CBR ___ @ __%-__% CE 55

______" SCIP[2] CBR ___ @ __%-__% CE 55

TDF[3] @ ___%-___% CE 55

1 These are optional layers depending on the materials available and the thickness design.
2 Scarifiy and compact in place.
3 Total depth of fill.

Figure 12-10. Final design profile

Example 8

Design the taxiways and ends of the runway (Type B area) for an aggregate-surfaced airfield in the support area (Honduras) for 1,000 passes of a C-130. The in-place soil is a well-graded, sandy clay with a PI = 6, and has 7 percent finer than 0.02 millimeter by weight. Your soils analyst reports a uniform CBR = 5. After he set up a test strip, he found that the CBR increased to 7 with compaction. From the reconnaissance teams, you have one potential borrow site with the following soil characteristics:

Borrow A: GP-GC; CBR = 35, PI = 8, LL = 28; 60 percent passes Number 10 sieve; 15 percent passes Number 200 sieve.

Base course: Nearby civilian batch plant has been leased by the US; well-graded, crushed limestone available with the following gradation specifications:

Sieve	Percent Passing
2"	100
1.5"	93
1"	63
3/4"	54
No. 4	42
No. 10	18
No. 200	6

Solution 8

Step 1. Airfield location = support area (given).

Step 2. Design aircraft = C- 130/130 kips (given).

Step 3. Check construction aggregates.

a. Check materials for use as select/subbase. Since there is only one potential source, check it according to Table 12-9, page 12-24. Since PI = 6, the soil does not meet the Atterberg criteria for a subbase. Therefore, determine whether it meets select material criteria. Since its LL < 25 and the PI < 12, it can be used as a select material CBR = 20.

b. Determine the base course CBR. From Table 12-10, page 12-24, since the base course material is a well-graded, crushed aggregate (limestone), the CBR = 100.

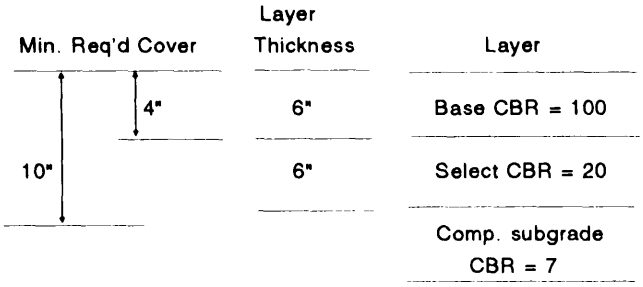
c. Check materials for frost susceptibility. Since the location of the airfield is Honduras, frost is not a concern.

Step 4. Determine the number of passes required. Passes required = 1,000 (given).

Step 5. Determine the total surface thickness and cover requirements. Using CBRs for each soil layer that requires cover, enter Figure 12-7, page 12-27, to determine the cover requirements.

Material	Minimum Required Cover
Compacted subgrade CBR 7	9.1" ♂ 10"
Select material CBR 20	3.9" ♂ 4"

Step 6. Complete the temperate thickness design. Draw a figure to determine the layer thicknesses based on the cover requirements.



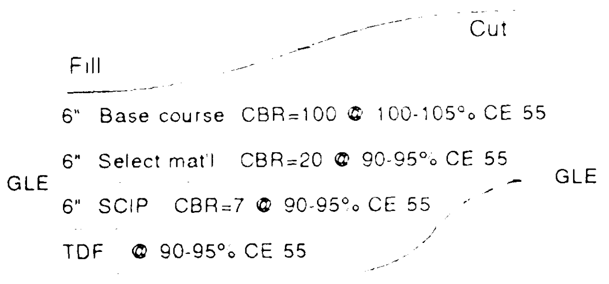
Calculate the layer thicknesses from the surface down. First, look at the cover required above the select layer. It requires a minimum of 4 inches above it. The base course has a layer thickness of 6 inches because the minimum layer thickness in an airfield is 6 inches. Next, look at the cover required above the CBR = 7 subgrade. While 10 inches are required, you already have 6 inches in the base. Therefore, the subgrade requires an additional 4 inches of cover. Again, since the minimum layer. thickness is 6 inches, round the select layer thickness up to 6 inches.

Step 7. Not applicable since the airfield is located in a nonfrost area.

Step 8. Determine the subgrade depth and compaction requirements. (See Table 12-13, page 12-30, to find the minimum depth of compaction below the surface.) Because the subgrade soil has a PI = 6, it is a cohesive soil. For a cohesive soil in a Type C area, the required depth of compaction is 17 inches below the surface. Since the total thickness design is 12 inches, the actual depth of subgrade compaction is 17 - 12 = 5 (rounded up to 6 inches.) The compaction requirements (from Table 12-7, page 12-23) for the three layers is shown below:

Layer	Compaction Requirement
Compacted subgrade	90-95% CE 55
Select material	90-95% CE 55
Base course	100-105% CE 55

Step 9. Draw the final design profile.



Example 9

Design a Type B area for an aggregate-surfaced airfield in northeastern Turkey that can withstand 10,000 passes of a C-17 (gross weight = 430 kips). The area is subjected to seasonal frost conditions (assume that seasonal frost will occur during the airfield service life). Below is a summary of soil and construction aggregate data.

- Subgrade: CL: PI = 14: natural CBR = 3: compacted CBR = 5: 7 percent finer than 0.02 millimeter by weight.

- Borrow A: GP: CBR = 35: PI = 8; LL = 28: 10 percent pass Number 80 sieve; 5 percent pass Number 200 sieve; NFS.

- Borrow B: GW-GC; CBR = 45; PI = 5; LL = 23; 65 percent pass Number 10 sieve; 12 percent pass Number 200 sieve; NFS.

- Base course: Limestone; meets gradation limits for 2-inch MAS (Table 12-10, page 12-24).

Solution 9

Steps 1 and 2. Support area is the only choice for aggregate-surfaced airfields; C-17 (430 kips) is the design aircraft.

Step 3. Check soils and construction aggregates.

a. Check possible subbases and select materials.

- Borrow A: Fails as a subbase due to Atterberg criteria, but meets select material criteria. Therefore, it can be used as a select material CBR = 20.
- Borrow B: Meets criteria for a subbase CBR = 50; therefore, use it as a subbase CBR = 45.

b. Check strength and gradation of the base course. Since the base course is limestone, the CBR = 80 (Table 12-9, page 12-24). The soils analyst already checked the gradation information and said it met the specifications.

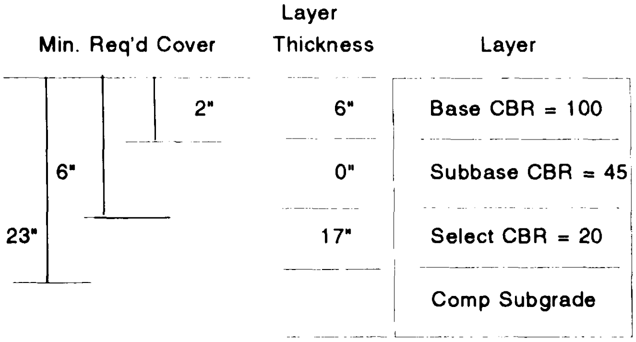
c. Check for frost susceptibility. No materials above the compacted subgrade are frost susceptible. Since the subgrade has greater than 6 percent finer than 0.02 millimeter by weight, it is frost susceptible. From Table 12-11, page 12-26, the soil falls into frost group F3. The soil support index from Table 12-12, page 12-26, is 3.5.

Step 4. The number of passes required is 10,000 (given).

Step 5. Determine the cover requirements from Figure 12-8, page 12-28.

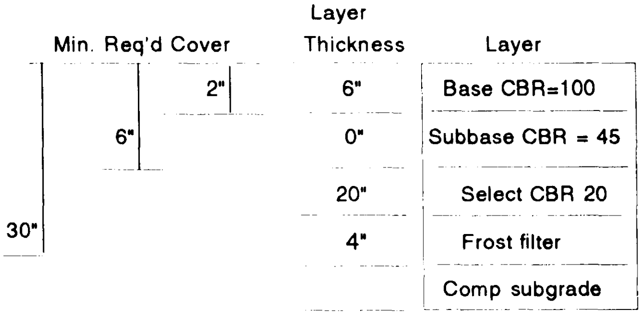
Layer	Minimum Required Cover
Compacted subgrade CBR 5	22.5" ♂ 23"
Select material CBR 20	5.9" ♂ 6"
Subbase CBR 45	1.7" ♂ 2"

Step 6. Complete the temperate thickness design.



The required cover above the select material CBR=20 is only 6 inches. Since the base course already has a layer thickness of 6 inches, the select's cover requirement is satisfied. Therefore, there is no need for the subbase layer. The cover required over the subgrade is 23 inches; consequently, the select material must be 23 - 6 = 17 inches. This is the most cost-effective design under normal conditions because there are fewer restrictions on select materials than on subbases. Keeping a subbase layer would be acceptable if the material is readily available and usable in its borrowed or quarried state.

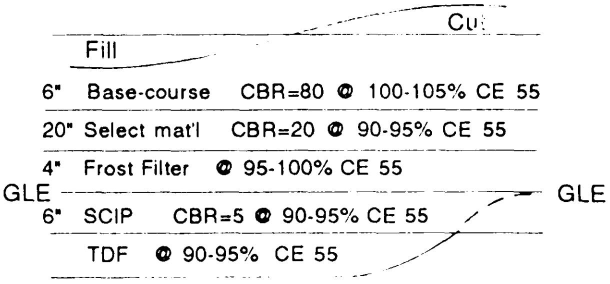
Step 7. Adjust thickness design for frost. Since the subgrade is a frost-susceptible soil (frost group F3) and the area is subjected to frost, the total thickness design must be derived from the soil-support index, which is 3.5 (Table 12-12, page 12-26). Entering Figure 12-8 with 3.5 yields a minimum required cover of 29.2 inches (rounded up to 30 inches.) Since this thickness is greater than the 23 inches required for the temperate design, use this design for the airfield. Also, you must add a 4-inch frost filter. This changes the thickness design shown below.



Step 8. Determine subgrade depth and compaction requirements. From Table 12-13, page 12-30, the required depth of compaction below the surface is 21 inches. Since the actual thickness design is greater than 21 inches, use the minimum depth of subgrade compaction = 6 inches. To find the compaction requirements for the soil layers, see Table 12-7, page 12-23.

Material	Minimum Required Cover
Compacted subgrade CBR 7	9.1" ♂ 10"
Select material CBR 20	3.9" ♂ 4"

Step 9. Draw the final design profile.



SPECIAL DESIGN CONSIDERATIONS

Stabilized Soil Design

The use of stabilized soil layers for aggregate-surfaced pavement structures (as described in Chapter 5, FM 5-430-00-l/AFPAM

32-8013, Vol 1, and FM 5-410) provides the opportunity to reduce the overall thickness required to support a given load. Designing an airfield with stabilized soil layers requires the application of equivalency factors to a layer or layers of a conventionally designed structure.

To qualify for the application of equivalency factors, the stabilized layer must meet appropriate strength and durability requirements. An equivalency factor represents the number of inches of a conventional base or subbase that can be replaced by 1 inch of stabilized material. Equivalency factors are determined as shown in Table 9-21, page 9-76, FM 5-430-00-l/AFPAM 32-8013, Vol 1, for bituminous-stabilized materials and in Figures 9-55 and 9-56, page 9-76, FM 5-430-00-1/AFPAM 32-8013, Vol 1, for materials stabilized with cement, lime, or fly ash mixed with cement or lime. Selecting an equivalency factor from the tabulation depends on the classification of the soil to be stabilized. Selecting an equivalency factor from Figures 9-55 and 9-56 requires the unconfined compressive strength (as determined by ASTM D 1633) be known. Figure 9-55 shows equivalency factors for subbase materials, and Figure 9-56 shows equivalency factors for base materials.

Minimum thickness. The minimum thickness requirement for a stabilized base or subbase is 6 inches.

Application of equivalency factors. The use of equivalency factors requires that a road or airfield be designed to support the design load conditions. If a stabilized base or subbase course is desired, the thickness of a conventional base or subbase is divided by the equivalency factor for the applicable stabilized soil. (See page 9-77, FM 5-430-00-1/AFPAM 32-8013, Vol 1, for examples of applying equivalency factors to base and subbase thicknesses.)

Drainage Requirements

Adequate surface drainage should be provided in order to minimize moisture damage. Expeditiously removing 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 airfield from erosion of fines or the entire surface layer. Also, ensure 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 airfield.

The surface geometry of an airfield should be designed to provide drainage at all points. Depending on 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. Judgment is required to arrange the cross slopes in a manner to remove water from the airfield at the nearest possible points while taking advantage of the natural surface geometry.

It is also essential to provide adequate drainage outside the airfield area to accommodate maximum flow from the area to be drained. One or more such provisions will be required if they do not already exist. Additionally, adjacent areas and their drainage provisions should be evaluated to determine if rerouting is needed to prevent water from other areas flowing across the airfield.

Drainage should be considered a critical factor in aggregate-surface airfield design, construction, and maintenance. Therefore, drainage should be considered before construction and, when necessary, serve as a basis for site selection.

Maintenance Requirements

Environment and surface migration of materials as the result of traffic are the primary reasons that an aggregate surface requires frequent maintenance. Also, rainfall and water running over the aggregate surface tend to reduce cohesiveness by washing the fines from the surface course. Maintenance should be performed at least weekly and, if required, more frequently. Experience with aggregate surfaces indicates that the frequency of maintenance is initially high, but it will decrease over time to a constant value. Although the design life of an aggregate-surfaced airfield is only 6 months, the decreasing maintenance allows the design life to be easily increased for sustained operations in the support area. Most maintenance consists of replacing fines and grading periodically to remove ruts and potholes created by passing traffic and the environment. During the lifetime of the airfield, occasionally scarifying the surface layer might be required to bring fines back to the surface. Additional aggregate must be added to restore the thickness, and the wearing surface must be recompacted to the specified density. Additional maintenance information is provided in Chapter 8, FM 5-430-00-1/AFPAM 32-8013, Vol 1.

Dust Control

The primary objective of a dust palliative is to prevent soil particles from becoming airborne as a result of wind or traffic. Where dust palliative are considered for traffic areas, they must withstand the abrasion of wheels and tracks. An important factor limiting the applicability of the dust palliative in traffic areas is the extent of surface rutting or abrasion that occurs under traffic. Some palliative 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 penetration dust-palliative treatment. The abrasive action of aircraft landing gear may be too severe for the use of some dust palliative in a traffic area.

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.

FLEXIBLE-PAVEMENT AIRFIELDS

Bituminous (flexible)-pavement designs permit the maximum use of readily available local construction materials. They are easier to construct and upgrade than rigid-pavement designs. Thus, they permit greater flexibility in responding to changes in the tactical situation.

Each type airfield in the basic airfield complex has a specific purpose. The type, volume, composition, and character of anticipated traffic is much greater in the rear area than in the close battle or support areas. Therefore, a different pavement structure and a resilient, waterproof, load-distributing medium that protects the base course from detrimental effects of water and the abrasive action of traffic may be required in the rear area. In designing a flexible-pavement structure, the design values for various layers are determined and applied to the curves and criteria in this chapter to determine the best structure. Generally, several designs are possible for a specific site. Only the most economical, practical design should be selected. Because the decision may be largely a matter of judgment, full details regarding the selection of the final design should be included in the analysis.

Circumstances may warrant the evaluation of an airfield pavement for aircraft other than the controlling aircraft. In this case, the design evaluation curves in Appendix M may be used for the pass level required. These evaluation curves can be used for design by entering them in reverse order and may be used when estimating the number of passes for unknown (captured) airfields. Evaluation of pavements is discussed later in this chapter.

Pavement Types and Uses

The descriptions, uses, advantages, and disadvantages of bituminous pavements and surfaces presented in TM 5-337 are applicable to TO construction except as modified in the following paragraphs:

Hot-mix bituminous-concrete pavements. Dense-graded, hot-mix bituminous-concrete mixtures are suited for paving airfields with volumes of 1,000 or more aircraft passes. Where conditions warrant, use these mixtures to pave airfields having traffic volumes of less than 1,000 aircraft passes. Select exact percentages of bituminous materials on the basis of design tests described in TM 5-337 and Chapter 9, TM 5-822-8/AFM 88-6.

Cold-laid bituminous-concrete plant mix. Where hot-mix bituminous-concrete mixtures are not available, use cold-plant bituminous concrete to pave areas subject to pneumatic-tired traffic only.

Bituminous road mix. Use road mix as a wearing course for TO roads or as the first step in stage construction for airfields. When the existing subgrade soil is suitable or satisfactory aggregates are nearby, road mixing saves time in handling and transporting aggregates as compared with plant mixing. When properly designed and constructed, the quality of road mix approaches that of cold-laid plant mix.

Flexible-Pavement Structure

A typical flexible-pavement structure is shown in Figure 9-32, page 9-34, FM 5-430-00-1/AFPAM 32-8013, Vol 1, and illustrates the terms used to refer to the various layers.

A bituminous pavement may consist of one or more courses depending on stage construction features, job conditions, and economical use of materials. The pavement should consist of a surface course, an intermediate (binder) course, and when needed, a leveling course. These courses should be thick enough to (1) prevent displacement of the base course because of shear deformation, (2) provide long life by resisting the effects of wear and traffic abrasion and acting as a waterproofing agent, and (3) minimize differential settlements.

Sources of Supply

If time and conditions permit, investigate subgrade conditions, borrow areas, and all sources of select materials, subbase, base, and paving aggregates before designing the pavement. When determining subgrade conditions in cut sections of roads, conduct test borings deeper than the frost penetration depth. The minimum boring should never be less than 4 feet below the final grade.

NOTE: Not all layers and coats are present in every flexible-pavement structure. Intermediate courses may be placed in one or more lifts. Tack coats may be required on the surface of each intermediate course while a prime coat may be required on the uppermost aggregate course.

MATERIALS

Select Materials and Subbases

The criteria for aggregate layers in a flexible-pavement structure are the same as previously discussed for aggregate-surfaced airfields. Local materials used to satisfy the subgrade's minimum required cover must satisfy all the requirements for a given layer that are listed in Tables 12-8 and 12-9, pages 12-23 and 12-24. (See Chapter 5, FM 5-430-00-1/AFPAM 32-8013, Vol 1, for more specific information.)

Base Courses

Although a base course can be either bituminous or aggregate, the latter is more common because of its availability and the resources involved to work with it. The specifications for an aggregate base course in a flexible-pavement structure are the same as the base course in an aggregate-surfaced airfield. Since a flexible pavement transfers most of any load to the underlying base course, aggregate strength, gradation and compaction are essential. The CBR strength of a base course can be determined by the material type in Table 12-10, page 12-24; gradation specifications are listed in Table 12-11, page 12-26. (See Chapter 5, FM 5-430-00-1, AFPAM 32-8013, Vol 1, for more information.)

Bituminous Pavements

Bituminous pavements may be made up of one or more courses, depending on the total pavement thickness, economic use of materials, stage construction features. availability of equipment, and job conditions. Usually, flexible-pavement airfields in the TO resemble aggregate structures with an asphaltic concrete (AC) wear surface. For most aircraft in the rear area, an aggregate structure is suitable only when it has a smooth, water-shedding surface like AC.

If time and resources exist, a flexible pavement with a surface course and one or more intermediate courses is preferred. Once the total thickness is known, you can design for intermediate courses based on Table 12-14. Table 12-15 shows the recommended pavement thicknesses based on the traffic area and the strength of the base course.

- Generally, if the thickness of the bituminous layer is greater than 2 inches, it should be placed in two lifts to ensure that each is properly compacted. Compacting a lift greater than 2 inches may result in the asphalt cooling before it is compacted to the required density. The compaction requirement for AC is 98-100 percent CE 55. After the pavement meets the required density, it must be proof rolled. A proof roller is a heavy, rubber-tired roller having four tires, each loaded with 30,000 pounds or more and inflated to at least 150 pounds per square inch (psi). Type A and Type C areas require a proof roller to make at least 30 coverages, where a single coverage is the application of one tire print over each point on the surface.

Designing the actual bituminous pavement mix consists of (1) selecting the bitumen and aggregate gradation, (2) blending aggregates to conform to the selected gradation, (3) determining the optimum AC content, and (4) calculating the job mix formula. Mix design is further discussed in Chapter 4, TM 5-337, and Chapter 9, TM 5-822-8/AFM 88-6.

TRAFFIC AREAS

For previous airfield designs, only Types B and C were considered. Since rear area airfields have a design life up to two years, it is practical to consider all traffic areas of a full-service airfield. (See Figure 12-5, page 12-7, for the following descriptions.)

- *Type A.* Primary taxiways, through taxi lanes, and portions of the 1,000-foot ends of the runway are all Type A areas and are designed for the full gross weight of the design aircraft. Although the effects of channelization are evident in the center lane of taxiways, it is impractical in temporary construction to construct pavements of alternating variable thicknesses.
- *Type B.* These areas are also designed for the gross weight of the design aircraft, but the repetition of such stress is less than Type A areas. Essentially, all aprons and hardstands are considered Type B.
- *Type C.* These areas are characterized by a low volume of traffic or a decrease in the applied weight of the operating aircraft due to lift on the wings. The 75-foot width of the interior portion of the runway (excluding 1,000-foot end sections), ladder taxiways, hangar access aprons and floors, and washrack pave-

Table 12-14. Intermediate asphalt courses

Pavement Thickness (in)	Intermediate (Binder) Course Thickness (in)	Surface Course Thickness (in)
2	--	2
3	1 1/2	1 1/2
4	2 1/2	1 1/2
5	2 + 1 1/2*	1 1/2
6	2 1/2 + 2*	1 1/2

*This intermediate course is placed in two lifts.

Table 12-15. Minimum thicknesses, pavement and base course

Traffic Area	Minimum Thicknesses (in)			
	100-CBR Base		80-CBR Base	
	Pavement	Base	Pavement	Base
A	4	6	5	6
B	3	6	4	6
C	3	6	4	6

ments are all Type C areas. Decrease the design gross weight by 25 percent when designing a Type C area.

- *Type D.* The outside edges of the entire length of runway except for the approach and exit areas at taxiway intersections are Type D areas. Expected traffic volume in these areas is extremely low, or the applied weight of the aircraft is considerably less. Therefore, like Type C areas, decrease the design gross weight by 25 percent when designing these structures.

- *Overruns.* Overruns are generally surfaced with a multiple surface treatment. The thickness design is usually the same as the runway design, but it may be decreased based on design loading. If the airfield is designed for jet aircraft, an overrun blast area may be desirable. This 150-foot strip of overrun is immediately adjacent to the runway and is for the full width of the runway, excluding shoulders. Surface this area with 2 inches of hot-mix AC.

- *Shoulders.* The thickness of the shoulders is determined by Figure 12-11, which is valid for all design aircraft. Enter the figure with the compacted CBR of the subgrade and insect the curve. From the intersection point, draw a line to the left-hand side of the figure. The result will be the thickness of the shoulder after compaction.

THICKNESS DESIGN PROCEDURE

The design procedure for flexible-pavement surfaces is almost identical to that of aggregate surface. Since flexible pavements exist only in the rear area, however, they are subjected to fighter and cargo aircraft. While some of the curves and specifications may be different, the design steps are exactly the same.

DESIGN STEPS

1. Determine the airfield location.
2. Determine the design aircraft and gross weight.
3. Check soils and construction aggregates.
4. Determine the number of passes required.
5. Determine the total surface thickness and cover requirements.
6. Complete the temperate thickness design.
7. Adjust thickness design for frost susceptibility
8. Determine compaction requirements and subgrade depth.
9. Draw the final design profile.

Step 1. Determine the Airfield Location

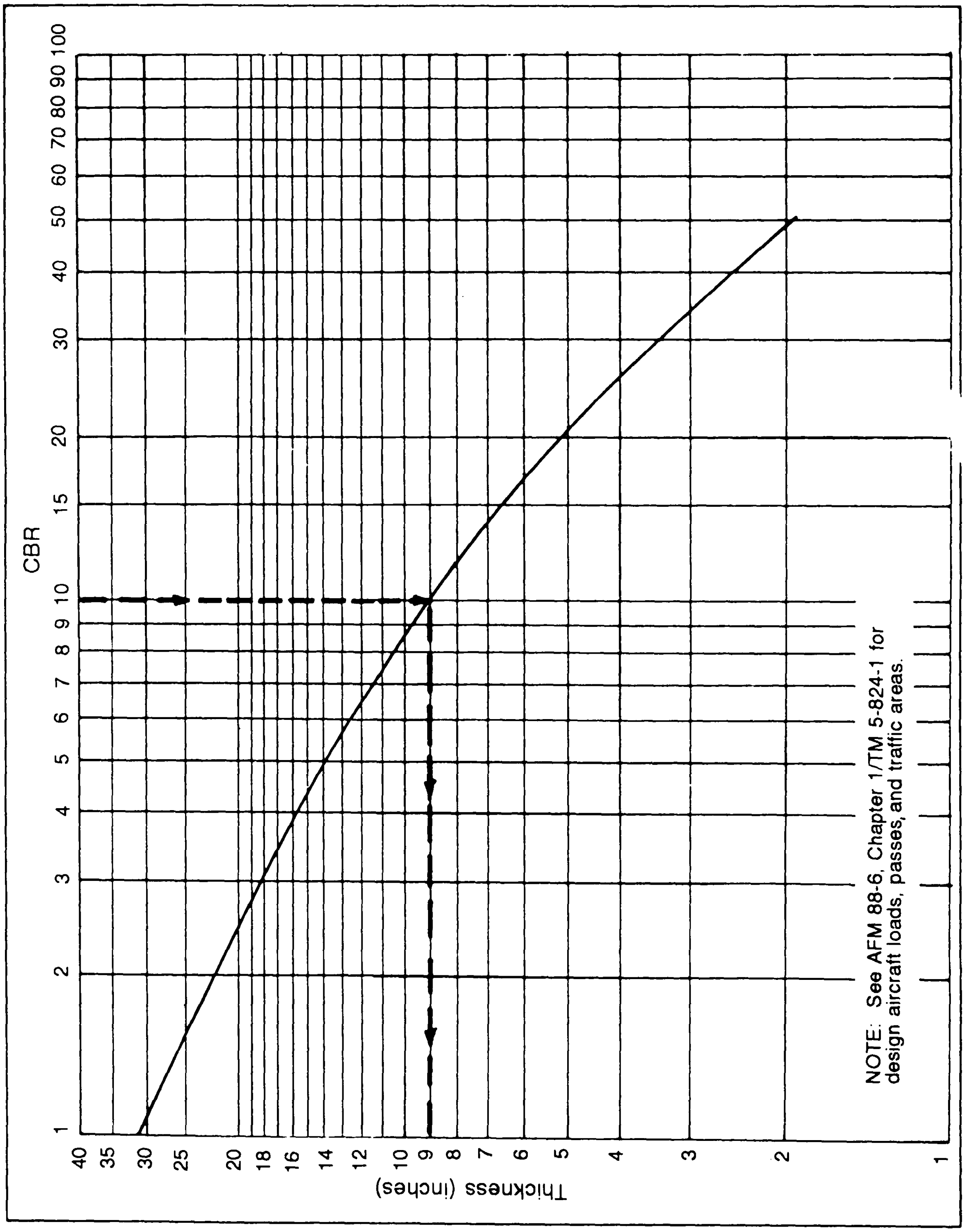
Flexible pavements are only constructed in the rear area. While existing airfields may provide flexible-pavement surfaces in the support or even close battle areas, the rear area requires a flexible-pavement surface to support fighter aircraft as well as large cargo aircraft.

Step 2. Determine the Design Aircraft and Gross Weight

While previous airfield types limited aircraft based on their landing capability, the rear area has no constraints about the type of aircraft that can land. Flexible-pavement structures have the capability to support large cargo aircraft with tremendous gross weights as well as small fighter aircraft with large tire pressures. Because of the rear area's diverse mission and the service life (six months to two years), it is logical to design the airfield for only the most constraining aircraft, the C-141 Starlifter. While it is not the heaviest aircraft in the rear area, its gross weight (345 kips) is not distributed like that of the C-5 or C-17.

Step 3. Check Soils and Construction Aggregates

The procedure for evaluating materials for flexible-pavement structures is the same as for aggregate-surfaced airfield structures. First, locate borrow sites and evaluate them for suitability as select and subbase courses. Use Table 12-8, page 12-23, to check soil characteristics and strength against the specifications for each layer. Second, check the strength and gradation of the base course. The strength of a known material is determined from Table 12-9, page 12-24, while the gradation of a soil must meet the specifications in Table 12-10, page 12-24, based on the MSA. Third, check the materials for frost susceptibility. Any frost-susceptible borrow materials cannot be used in the design. If the subgrade is frost susceptible, determine the frost group and soil support index from Tables 12-11 and 12-12, page 12-26.



NOTE: See AFM 88-6, Chapter 1/TM 5-824-1 for design aircraft loads, passes, and traffic areas.

Figure 12-11. Flexible-pavement design curves for shoulder pavement

Step 4. Determine the Number of Passes Required

Since the rear area is considered temporary construction (6 to 24 months), design flexible-pavement airfields to sustain an appropriate number of passes.

Step 5. Determine the Total Surface Thickness and Cover Requirements

The procedure for designing the total thickness for flexible pavements differs in two ways. First, since the design aircraft is different, you must use a different curve. Enter the curve for the appropriate traffic area with the soil CBR and number of required passes. The thickness design curve for the C-141 is found in Figure 12-12. The resulting thickness is the cover required above that particular soil layer to protect it from shear failure. Second, the asphalt thickness is a function of the traffic area and the strength of the base course, and it can be determined from Table 12-15, page 12-37.

Steps 6 and 7. These design steps are the same as previously discussed for aggregate-surfaced airfields. See pages 12-25 through 12-30 for a review.

Step 8. Determine the Compaction Requirements and Subgrade Depth

While compaction requirements are the same as previously discussed, the required depth of subgrade compaction changes because of the significant loads in the rear area. Table 12-16 shows the depth of required compaction below the surface of the pavement. Choose the depth for the type subgrade or 6 inches, whichever is greater.

Table 12-16. Depth (inches) of required subgrade compaction below the surface of rear area flexible-pavement airfields

Traffic Area	Minimum Compacted Depth Below Surface (inches)	
	Cohesive Soils	Cohesionless Soils
A	48	54
B	42	48
C	36	42
D	24	30

Step 9. Draw the Final Design Profile

Draw the final design profile as previously shown for aggregate airfields.

Example 10

Design a rear area airfield in Central America, Type B traffic area, capable of handling 100,000 passes of a C-141 aircraft. Soil layers have already been determined by the soils analyst, as follows:

- Subgrade: Clay, PI = 12, LL = 20, natural CBR = 4, compacted CBR = 5.
- Borrow A: Select material CBR = 15, PI = 7.
- Borrow B: Subbase material CBR = 40, PI = 4.
- Base course (limestone): CBR = 80, PI = 4. Meets gradation specifications for 2-inch MSA (Table 12-11, page 12-26).

Solution 10

Step 1. Airfield location (given) = rear area/Type B traffic area.

Step 2. Design aircraft (always) = C-141/345 kips.

Step 3. Check soils and construction aggregates:

- Select and subbase (given): Borrow A, select material CBR = 15: borrow B, subbase CBR = 40.
- Base course: Limestone, CBR = 80; meets gradation.
- Frost is not a concern in Central America.

Step 4. Number of passes (given) = 100,000.

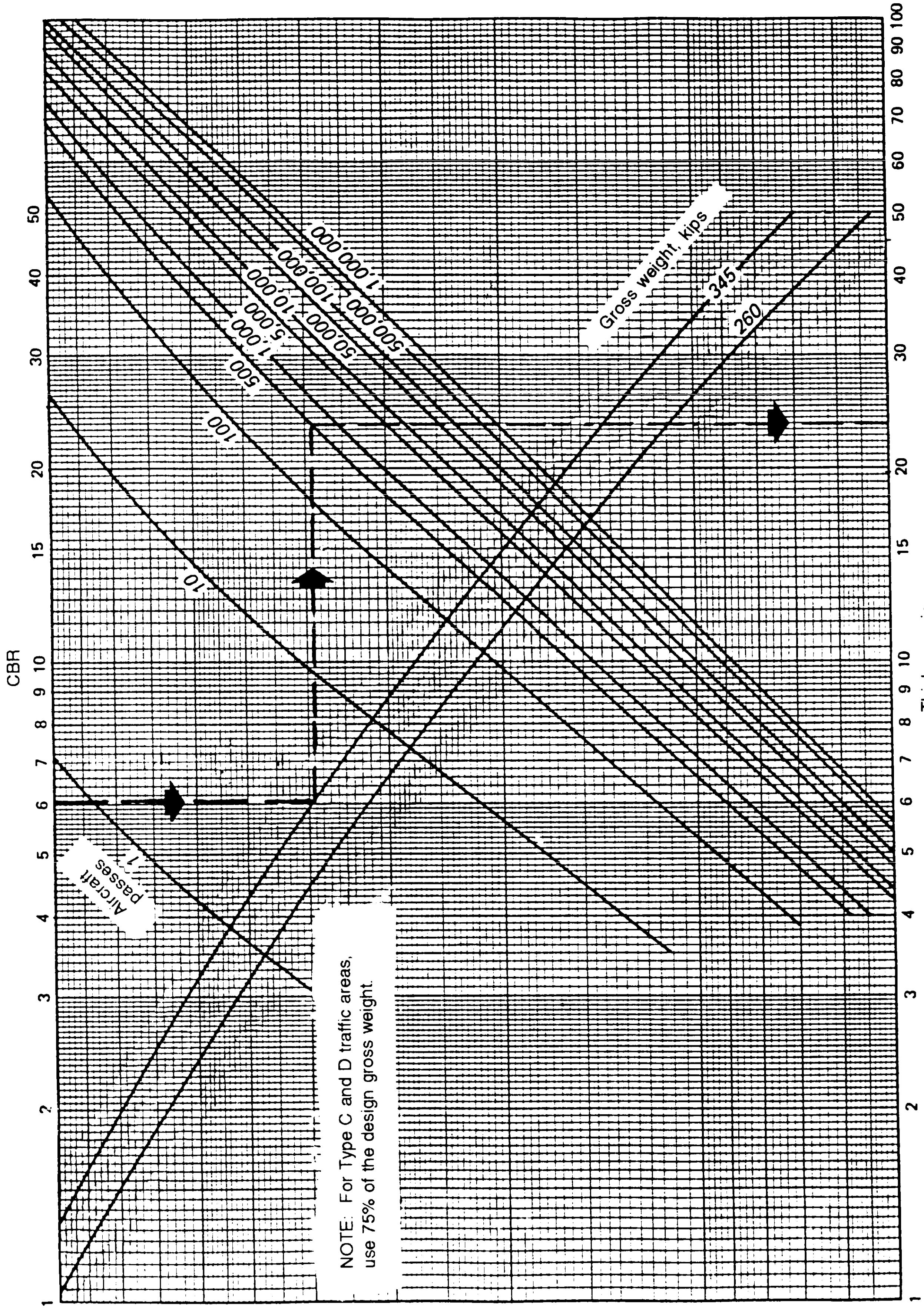
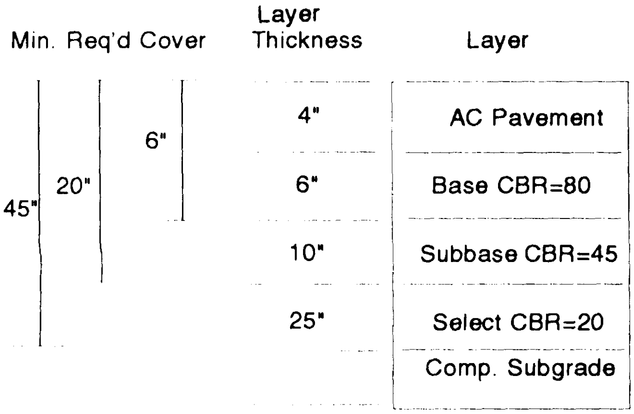


Figure 12-12. Flexible-pavement design curves for C-141 aircraft runway > 5,000 feet.

Step 5. Determine the thickness requirements from Figure 12-11, page 12-39 (Type B traffic area):

Material	Minimum Required Cover
Compacted subgrade CBR 5	45"
Select material CBR 15	19.7" or 20"
Subbase CBR 40	6"

Step 6. Complete the temperate thickness design.



See Table 12-15, page 12-37, with the traffic area (B) and the base course CBR (80) to find that the thickness of the AC pavement = 4 inches. See Table 12-14, page 12-37, for a further breakdown of the specific course in the pavement design. Next, from Step 4, calculate the layer thicknesses. For instance, the cover required over the select material is 20 inches. With the base course and the AC pavement combined, the thickness is already 10 inches. To meet the cover requirement over the select material, the thickness of the subbase must be at least 10 inches.

Step 7. Frost adjustment not applicable.

Step 8. Determine subgrade depth and compaction requirements. From Table 12-16, page 12-40, determine the required depth of subgrade compaction. Since the subgrade is cohesive (P = 15) and the traffic area is a Type B, the depth required = 42 inches. The total design thickness is 45 inches; therefore, the depth of subgrade compaction is 6 inches since 6 inches >3 inches. Next, determine the compaction requirements for each layer from Table 12-17.

Layer	Compaction Requirement
Compacted subgrade	90-95% CE 55
Select material	90-95% CE 55
Subbase	100-105% CE 55
Base course	100-105% CE 55
AC pavement	98-100% CE 55

Table 12-17. Compaction criteria and CBR requirements for a flexible-pavement structure

CBR Requirements	Layer	Compaction Requirements
	Pavement	98-100%
80-100	Base course	Asphalt 98-100% Soil: 100-105%
20-50	Subbase course	100-105%
0-20	Select material	Cohesive: 90-95% Cohesionless: 95-100%
	Design subgrade (SCIP)	Cohesive: 90-95% Cohesionless: 95-100%
	Uncompacted subgrade	

NOTES:

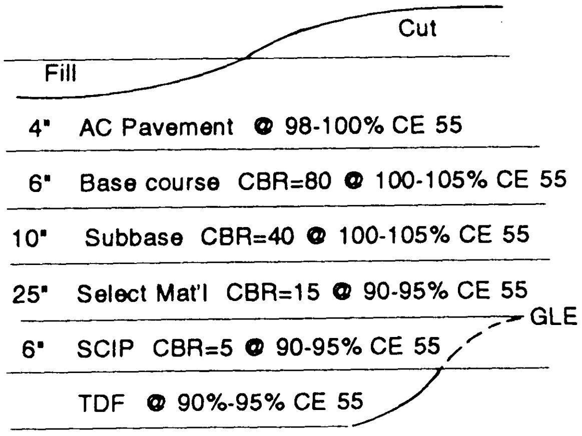
1. All lifts (excluding the pavement) in an airfield must be at least 6 inches.

2. A cohesive soil is one with a PI above 5.

3. A cohesionless soil is one with a PI of 5 or less.

4. Percent compaction is compared to CE 55 compactive effort.

Step 9. Draw the final design profile.



SPECIAL DESIGN CONSIDERATIONS

STABILIZED SOIL DESIGN

The use of stabilized soil layers within a flexible-pavement airfield structure provides the opportunity to reduce the overall thickness required to support a given level. The section on stabilized soil design (described in detail in Chapter 9, FM 5-430-00-1/AFPAM 32-8013, Vol 1) pertains to airfield flexible pavements as well. As such, only examples of procedural applications for flexible-pavement airfields are discussed below:

Design Example

Assume a conventional flexible-pavement airfield has been designed that requires a total thickness of 10 inches above the subgrade. The minimum thicknesses of AC and base are 2 and 6 inches, respectively. The thickness of the subbase is 6 inches, the minimum layer thickness. Replace the base and subbase with a cement-stabilized, gravelly soil having an unconfined compressive strength of 890 psi. From Figure 9-55, page 9-76, FM 5-430-00-l/AFPAM 32-8013, Vol 1, the equivalency factor for a subbase having an unconfined compressive strength of 890 is 2; and from Figure 9-56, page 9-76, FM 5-430-00-l/AFPAM 32-8013, Vol 1, the equivalency factor for the base is 1.

Therefore, the thickness of the stabilized subbase is 6 inches/2 = 3 inches, and the thickness of the stabilized base course is 6 inches/ 1 = 6 inches. The final section would be 2 inches of AC and 9 inches of cement-stabilized, gravelly soil. The subgrade still has an equivalent cover of 11 inches within the newly designed 2 inches of AC and 9 inches of cement-stabilized, gravelly soil. The savings of 3 inches of aggregate may prove to be more economical and efficient, depending on material, equipment, and time constraints.

The other alternative would be to increase the base course thickness to 9 inches. If material and resources are available, this may be the most efficient method. However, if the base course material is coming from a batch plant or leased contractor, you may save time by stabilizing a soil and using equivalency factors to reduce the thickness design.

FROST REGIONS

Pavements frequently break up or are severely damaged when subgrades and materials within the flexible-pavement structure freeze in the winter and thaw in the spring. Besides the physical damage suffered by pavements during periods of freezing and thawing and the high cost of time, equipment, and personnel required in maintenance, the military loss to the using agency may be very great (or intolerable) from the strategy standpoint. The design engineer for TO rear area airfields must decide whether to design for frost, given the increased thickness and material quality requirements.

Investigational Procedures for Frost Action

Field and laboratory investigations conducted in accordance with FM 5-410 usually provide sufficient information to determine whether a given combination of soil and water conditions beneath the pavement will be conducive to frost action. The procedures for determining whether the conditions necessary for ice segregation are present at a proposed site are described in the following paragraphs:

Soil. Inorganic soils containing 6 percent or more (in the TO) by weight of grains finer than 0.02 millimeter are generally considered susceptible to ice segregation. Thus, examination of the fines portion of the gradation curves obtained from hydrometer analysis or recantation process for these materials indicates whether they are frost susceptible. In borderline cases or where unusual materials are involved, slow laboratory freezing tests may be performed to measure the relative frost susceptibility.

Depth of frost penetration. The depth to which freezing temperatures penetrate below the surface of a pavement kept cleared of snow and ice depends principally on the magnitude and duration of below-freezing air temperatures, the properties of the underlying materials, and the amount of water that becomes frozen. Methods are described in Engineering Manual (EM) 1110-3-138 and TM 5-818-2.

Water. A potentially troublesome water supply for ice segregation is present if the highest groundwater at anytime of the year is within 5 feet of the proposed subgrade surface or the top of any frost-susceptible base materials. When the depth to the uppermost water table measured from the subgrade surface is in excess of 10 feet throughout the year, a source of water for substantial ice segregation is usually not present. In silts or homogeneous clay soils, the water content of the subgrade under pavement is usually sufficient to provide water for ice segregation even with a remote water table. Additional water may enter a frost-susceptible subgrade by surface infiltration through pavement and shoulder areas.

Consider all reliable information concerning past frost heaving and performance during the frost-melting period of airfield pavements previously constructed in the area. Place emphasis toward modifying or increasing frost design requirements.

Counteractive Techniques for Frost Action

The military engineer cannot prevent the basic condition of temperature affecting frost action. If a runway is constructed in a climate where freezing temperatures occur, in all probability the soil beneath the pavement will freeze unless the period of lowered temperature is very short. There are, however, several construction techniques that may be applied to counteract the presence of water and frost-susceptible soil.

Lowering water table. Try to lower the groundwater table in relation to the elevation of the runway. This may be accomplished by installing subsurface drains or opening side ditches if suitable outlets are available and the subgrade soil drains. (See Chapter 5, FM 5-430-00-l/AFPAM 32-8013, Vol 1.) It also may be accomplished by raising the grade line in relation to the water table. Whatever means are employed, the distance from the top of the proposed subgrade surface to the highest probable elevation of the water table should not be less than 5 feet. Distances greater than 5 feet are desirable if they can be obtained at reasonable cost.

Preventing upward water movement. In many cases, it may not be practical to lower the water table. In swampy areas, for example, an outlet for subsurface drains may not be present. Treatments that successfully prevent the rise of water include placing a 4- to 6-inch layer of pervious, coarse-grained soil between the maximum expected frost depth and the water table. This layer must be designed as a filter to prevent clogging the pores with fine material. If the depth of frost penetration is not too great, it may be cheaper to backfill with granular material.

Another method (successful, though expensive) is to excavate to the frost line, lay prefabricated bituminous surfacing (PBS), and backfill with granular material. In some cases, soil-cement and asphalt-stabilized mixtures, 6 inches thick, have been used effectively to cut off the upward movement of water. Waterproof membranes also may be used.

Removing frost-susceptible soil. Even though the site selected may be on ideal soil, long or wide expanses of runways probably will have localized areas containing frost-susceptible soils. These must be identified, removed, and replaced with select granular material. Unless this procedure is meticulously carried out, differential heaving or frost boils may result.

Insulating subgrade against frost. The most widely accepted method of preventing pavement failure due to frost action is to provide adequate thickness of pavement, base, and subbase over the subgrade. This prevents excessive frost heave and provides necessary load-carrying capacity during thawing periods. Extruded polystyrene thermal insulation has been successfully used to replace a substantial portion of the base and subbase.

Snow removal. During freezing weather, if the wearing surface is cleared of snow, it is important that the shoulders also be kept free of snow. When this precaution is not followed, freezing will set in first beneath the wearing surface. This permits water to be drawn into and accumulated in the subgrade from the unfrozen shoulder area, which is protected by the insulating snow.

If both areas are free of snow, freezing will begin in the shoulder area because it is not protected by pavement. Under this condition, water is drawn from the subgrade to the shoulder area. As freezing progresses to include the subgrade, there will be little frost action unless more water is available from groundwater or seepage.

Base Composition Requirements for Preventing Frost Action In Flexible Pavements

Base courses may be made of granular, unbound materials; bound materials; or a combination of both. However, an unbound base course will not be placed between two impervious, bound layers. If the combined thickness, in inches, of pavement and contiguous, bound base course is less than 0.09 multiplied by the design freezing index, and the pavement is expected to have a life exceeding one year, not less than 4 inches of free-draining material should be placed directly beneath the lower layer of bound base. If there is no bound base, material should be placed directly beneath the pavement slab or surface course.

Frost filter. The free-draining material should contain 2 percent or less, by weight, of grains that can pass the Number 200 sieve. To meet this requirement, the material probably will need to be screened and washed. The material in the 4-inch layer also must conform to the filter requirements prescribed in the following paragraphs. If the structural criteria for design of the pavement does not require granular, unbound base other than the 4 inches of free-draining material, the material in the 4-inch layer must be checked for conformance with the filter requirements. If it fails the test of conformance, an additional layer meeting those requirements must be provided.

Other granular unbound base course. If the structural criteria for design of the pavement requires more granular, unbound base than the 4 inches of free-draining material, the material should meet the applicable requirements of current guide specifications for base and subbase materials. In addition, the top 50 percent of the total thickness of granular unbound base must be NFS and must contain not more than 5 percent, by weight, of particles passing a Number 200 sieve. The lower 50 percent of the total thickness of granular, unbound base may be NFS or partially frost-susceptible (PFS) material (S1 or S2). (See Table 12-11, page 12-26.) If the subgrade soil is PFS material meeting the requirements of current guide specifications for base or subbase, the lower 50 percent of granular base will be omitted. If subgrade freezing will occur, an additional requirement is that either the bottom 4-inch layer in contact with the subgrade must meet the filter requirements, or a geotextile fabric meeting the filter requirements must be placed in contact with the subgrade. The dimensions and permeability of the base should satisfy the base course drainage criteria given in Chapter 2, TM 5-820-2/AFM 88-5, and the thickness requirements for frost design. If necessary, thicknesses indicated by frost criteria should be increased to meet subsurface drainage criteria. Base course materials of borderline quality should be tested frequently after compaction to ensure they meet these design criteria. Subbase and base materials must meet applicable compaction requirements.

Use of F1 and F2 Soils for Base Courses in Roads and Airfields with Short Life spans

A further alternative is the use of PFS base materials permitted for all roads and airfields with short life spans (less than one year).

Materials of frost groups F1 and F2 may be used in the lower part of the base over F3 and F4 subgrade soils. F1 materials may be used in the lower part of the base over F2 subgrades. The thickness of F2 base material should not exceed the difference between the reduced subgrade strength thickness requirements over F2 and F3 subgrades. The thickness of F1 base should not exceed the difference between the thickness requirements over F1 and F2 subgrades. Any F1 or F2 material used in the base must meet the applicable requirements of the guide specifications for base, subbase, or select materials. The thickness of the F1 and F2 materials and the thickness of pavement and base above the F1 and F2 materials must meet the nonfrost criteria.

Filter Over Subgrade

Granular filters. For both flexible and rigid pavements where subgrade freezing will occur, at least the bottom 4 inches of granular unbound base should consist of sand, gravelly sand, screenings, or similar material. It should be designed as a filter between the subgrade soil and overlying base course material to prevent mixing of the frost-susceptible subgrade with the base during and immediately following the frost-melting period. This filter is not intended to serve as a drainage course. The gradation of this filter material should be determined in accordance with the following criteria to prevent movement of particles of the protected soil into or through the filter(s):

$$\frac{\text{15 percent size of filter material}}{\text{85 percent size of protected soil}} \le 5$$

and

$$\frac{\text{50 percent size of filter material}}{\text{50 percent size of protected soil}} \le 25$$

The percent size in these equations is used to determine a particle size. For example, the 15 percent size refers to a grain size in millimeters at which 15 percent passes on a Grain Size Distribution Graph.

To offset the tendency of segregation of the filter material, a coefficient of uniformity of not more than 20 will be required.

The filter material must be NFS or PFS. Experience shows that a fine-grained subgrade soil will work up into a coarse, open-graded overlying gravel or crushed stone base course under the kneading action of traffic during the frost-melting period if a filter course is not provided between the subgrade and the overlying material. Experience and tests indicate that well-graded sand is especially suitable for this filter course. The 4-inch minimum filter thickness is dictated primarily by construction requirements and limitations. Greater thicknesses should be specified when required to suit field conditions. Over weak subgrades, a 6-inch or greater thickness may be necessary to support construction equipment and to provide a working platform for placement and compaction of the base course.

Geotextile fabric filters. The use of geotextile filters in lieu of a granular filter is encouraged. No structural advantage will be attained in the design when a geotextile fabric is used; it serves as a separation layer only. Filter criteria for geotextile filters found in Chapter 2, AFM 88-5, is as follows:

$$\frac{\text{85 percent size of material adjacent to fabric}}{\text{equivalent size of fabric openings}} \ge 1$$

DESIGN OF PAVEMENTS FOR FROST ACTION

In the reduced subgrade strength method of design, the design curves for the C-141 (Figure 12-12, page 12-41) should be used to determine the combined thickness of flexible pavement and base required for aircraft loads. The curves should not be entered with subgrade CBR values determined by tests or estimates but with one of the applicable frost area soil support indexes shown in Table 12-11, page 12-26.

The soil support index for PFS soils meeting current specifications for base and subbase will be determined by conventional CBR tests in the unfrozen state.

FIELD CONTROL FOR FROST CONDITIONS

Inspection of airfield and road pavement construction in areas of seasonal freezing and thawing should emphasize looking for conditions and materials that promote detrimental frost action. Remove unsuitable materials where such conditions exist. Personnel assigned to quality control must be able to recognize unsuitable materials.

Subgrade Preparation

Where laboratory and field investigations indicate that the soil and groundwater conditions will not result in ice segregation in the subgrade soils, the pavement design is based on the assumption that the inspection personnel must check the validity of the design assumptions and take corrective action if pockets of frost-susceptible material and wet subgrade conditions are revealed.

The subgrade is to be excavated and scarified to a predetermined depth, windrowed, and bladed successively to achieve adequate blending. It is then relaid and compacted. The purpose of this work is to achieve a high degree of uniformity of the soil conditions by mixing stratified soils, eliminating isolated pockets of soil of higher or lower frost susceptibility, and blending the various types of soils into a single, homogeneous mass. It is not intended to eliminate soils from the subgrade in which detrimental frost action will occur, but it is intended to produce a subgrade of uniform frost susceptibility and thus create conditions tending to make both surface heave and subgrade thaw weakening as uniform as possible over the paved area.

The depth of subgrade preparation, measured downward from the top of the subgrade, should be the lesser of the following:

- 24 inches.
- 72 inches, less the actual combined thickness of pavement, base, and subbase.

Prepared subgrade must meet the compaction requirements stated in Step 8 of the flexible-pavement airfield design procedure, page 12-40. At transitions from cut to fill, the subgrade in the cut section should be undercut and backfilled with the same material as the adjacent fill. (See TM 5-818-2.)

Exceptions to the basic requirement for subgrade preparation in the preceding paragraph are limited to the following:

- Subgrades known to be NFS to the depth prescribed for subgrade preparation and known to contain no frost-susceptible layers or lenses, as demonstrated and verified by extensive and thorough subsurface investigations and by the performance of nearby existing pavements.
- Fine-grained subgrades containing moisture well in excess of the optimum for compaction, with no feasible means of drainage nor of otherwise reducing water content. Consequently, it is not feasible to scarify and recompact the subgrade. If wet, fine-grained soils exist at the site, it is necessary to achieve equivalent frost protection with fill material. This may be done by raising the grade by an amount equal to the depth of subgrade preparation that would otherwise be prescribed, or by undercutting and replacing the wet, fine-grained subgrade to the same depth. In either case, the fill or backfill material may be NFS or frost-susceptible material meeting specified requirements. If the fill or backfill material is frost-susceptible, it should be subjected to the same subgrade preparation procedures prescribed above.

Correction for gradation changes. Perform gradation tests on all questionable materials found during grading operations. In an otherwise NFS subgrade, remove all pockets of frost-susceptible soils to the full depth of frost penetration. Replace frost-susceptible soils with NFS material when possible.

Wherever the design indicates that frost action may be a problem, the construction engineer must ensure that special frost protection measures are adequate and provisions in this chapter for base composition design are strictly followed.

Correction for special subgrade conditions. Besides abrupt variations in soil characteristics, frequent sources of trouble include sudden changes in groundwater conditions; changes from cut to fill; and location of under-pavement pipes, drains, or culverts. The top soil and humus materials at the transition between cut-and-fill sections should be completely removed for the full depth of frost penetration in otherwise NFS materials, even though the specifications may not require stripping of the subgrade in fill areas.

Carefully check wet areas in the subgrade. and install special drainage facilities as required. The most frequent special need in airfield construction is to provide intercepting drains. These drains prevent infiltration of water into the subgrade from higher ground adjacent to the road.

Preparation of rock subgrades. In areas where rock excavation is required, examine the character of the rock and seepage conditions. The excavation should always provide transverse drainage to ensure no pockets are left in the rock surface that permit pending of water within the maximum depth of freezing. The irregular presence of groundwater may result in heaving of the pavement surface under freezing conditions. It may be necessary to fill drainage pockets with lean concrete. Stones larger that 12 inches in diameter should be removed from frost-susceptible subgrades to prevent boulder heaves from damaging the pavement. This boulder removal must be accomplished to the depth of subgrade preparation outlined in the preceding paragraphs.

Where seepage is great, cover the rock subgrade with a high pervious gravel material so water can escape. Fractures and joints in the rock surface frequently contain frost-susceptible soils. Clean these soils out of the joints to the depth of frost penetration and replace them with NFS material. If this is impractical, it may be necessary to remove the rock to the full depth of frost penetration. Blasting the rock in place to provide additional cracks for the downward and lateral movement of water has also been successful. If blasting is used, rock should be broken to the full depth of frost penetration.

Base-Course Construction

Where available, base-course materials (including any select and subbase layers) are clearly NFS; base-course construction control should be in accordance with normal practices. When the selected base-course material is borderline frost susceptibility (usually having as much as 3 percent by weight of grains finer than 0.02 millimeter), make frequent gradation checks to ensure materials meet design criteria.

If pit selection of base material is required, inspect the materials at the pit. It is easier to reject unsuitable material at the source when large volumes of base course are being placed.

It is frequently desirable to check the gradation of materials taken from the base after compaction; for example, check gradations on density test materials. This procedure determines whether fines are being manufactured in the base under the passage of the base course compaction equipment.

Avoid mixing base-course materials with frost-susceptible subgrades by ensuring the subgrade is properly graded and compacted before placing the base course. Also, ensure the first layer of base course or subbase is thick enough and provides sufficient filter action to prevent penetration of subgrade fines under compaction. Excess wetting by hauling equipment may cause mixing of subgrade and base materials. This can be greatly reduced by frequently rerouting hauling equipment.

After completing each layer of the aggregate course, carefully inspect them before permitting placement of additional material. This ensures there are no areas with a high percentage of fines. These areas may frequently be recognized by visual examination of the materials and by observation of their action under compaction equipment, particularly when the materials are wet.

Remove materials that do not meet the requirements or specifications and replace them with suitable material.

FROST DESIGN FOR STABILIZED RUNWAY OVERRUNS

A runway overrun pavement must be designed to withstand occasional short landings, aborted takeoffs, long landings, and possible barrier engagements. The pavement also must give service under the traffic of various maintenance vehicles such as crash trucks and snowplow equipment.

Frost Condition Requirements

The design of an overrun must provide for the following frost conditions:

- Adequate structure for infrequent aircraft loading during the frost-melting period.
- Adequate structure for normal traffic of snow-removal equipment and other maintenance vehicles during frost-melting periods.
- Sufficient thickness of frost-free, base- or subbase-course materials to protect against objectionable heave during freezing periods.

Frost Design Criteria

To provide adequate strength during frost-melting periods, the combined thickness of flexible pavement and NFS base and subbase course must be equal to 75 percent of the thickness required for normal frost design, based on reduced subgrade strength. The thickness established by this procedure will not be less than that required for conventional flexible-pavement design.

Arid regions. In regions where the annual precipitation is less than 15 inches and the water table (including perched water table) is at least 15 feet below the finished pavement surface, the danger of high moisture content in the subgrade is reduced. Where information on existing structures in these regions indicates that the water content of the subgrade will not increase above optimum (as determined by the CE 55 compaction test), the total thickness above the subgrade (as determined by CBR tests on soaked samples) may be reduced by 20 percent. The reduction is made in the select material or in the subbase courses having the lowest CBR value. The reduction applies to the total thickness dictated by the subgrade CBR.

If only limited rainfall records are available or the annual precipitation is near the 15-inch criterion, before any reduction in thickness is made, carefully consider such factors as the number of consecutive years in which the annual precipitation exceeds 15 inches and the sensitivity of the subgrade to small increases in moisture content.

Arctic regions. Airfield construction in arctic regions will be a rare occurrence. When construction is called for, engineer units will find construction in extreme environmental conditions difficult at best. Snow pavements requiring strength characteristics above CBR = 40 are difficult to produce with practical construction methods. With specialized equipment, the strength of snow pavement can be achieved with dry-processing methods (milled or mixed snow, compacted with tractor tracks, vibrators, and rollers) if temperatures during construction are in the -12° to -1° Celsius (C) range. As the temperature decreases, particularly below -18°C, the compaction effectiveness decreases, the rate of age hardening (or sintering) decreases, and equipment operational problems increase.

Due to the low rate of the age-hardening process in arctic temperature conditions, a one-year waiting period after construction may be required before C-141 aircraft operations could be considered. That is, if runway construction can be successfully completed during one season, the hardening process may require a full season to progress to a stage where the snow strength approaches that required for C-141 aircraft. A design-and-testing manual for the construction of compressed-snow runway pavement can be found in Appendix B of the Corps of Engineers Cold Regions Research and Engineering Laboratory Special Report 89-10, April 1989. Appendix C contains a construction manual for compacted snow runways. The report is available from the US Army Cold Regions Research and Engineering Laboratory, 72 Lyme Road, Hanover, NH 03755-1290.

Airfields also can be constructed on glacial ice. Unlike cold, dry snow, blue ice (typical of most ice found on Antarctica) has sufficient bearing capacity to support heavy wheel loads without rutting, even at the highest imaginable inflation pressures for aircraft tires. Blue ice is solid glacier ice. It is usually hundreds of meters thick and rests on solid rock (on an ice shelf, it may be afloat). By contrast, typical sea ice is a thin (<3 meters), viscoelastic plate floating freely on a liquid foundation and should not be considered for airfield construction. If blue ice is smooth and level over a sufficient distance and approaches are unobstructed by high terrain, then it is highly suitable for use as an airfield. Unfortunately, there are few blue-ice ablation areas in arctic regions. Most of the existing areas are unsuitable for use as airfields because they are not smooth, level, and unobstructed.

EVALUATION OF AIRFIELD PAVEMENTS

The design of airfield pavement is based on covering a subgrade of given strength with adequate thickness of a suitable base course and pavement to prevent the subgrade from being overstressed under a given load. This same principle applies to any layer in the system—the base, subbase, select material, or subgrade.

The evaluation of an expedient, aggregate, or flexible pavement is the reverse of this process. It determines the allowable loading when the in-place thickness, strength, and quality of the materials in the various layers have been established. The thickness of the pavement and soil layers is determined by actual measurement. The strength of the subgrade and overlaying subbase and base courses is determined using CBR tests. Also, the purpose of a pavement evaluation may be much different than that of a design. You should design the airfield for the design aicraft, but to ensure the airfield's suitability to changing conditions, you may evaluate an airfield for use by only one particular aircraft for one or more missions. Since the C-130 and C-17 are the predominant aircraft in the close battle and support areas, evaluation becomes significant only in rear areas, where existing pavements may support missions short of the large cargo aircraft. For this reason, Appendix K includes flexible-pavement curves for most aircraft that normally operate on flexible pavements in the rear area.

The quality of the bituminous pavement structure is the ability of the various layers to support traffic and withstand jet-fuel spillage and blast. The quality of materials in the various layers is determined by visual observation, tests on in-place materials, laboratory tests on samples of the materials, and construction data.

The load-carrying capacity of a flexible pavement is limited by the strength of its weakest component—the bituminous pavement, base, subbase, select, or subgrade. The ability of a given subsurface layer to withstand the loads imposed on it depends on the thickness of material above it and its strength in its weakest condition.

An evaluation must consider possible future increases in moisture content, increases or decreases in density, and the effects of freezing and thawing. The expected use governs the amount of time and effort spent on the evaluation of an existing airfield. If time permits and the required life of the pavement is two years, the evaluation effort should be thorough with appropriate modification for lesser life requirement.

Pavement evaluation may be based on existing design- and construction-control data, data obtained in tests performed especially for evaluation, or a combination of the two. Condition surveys record the existing pavement condition of the facilities being evaluated.

NEW PAVEMENTS

If the airfield to be evaluated was built by US forces, construction-control test data adequate for an evaluation may be secured. Extract data from these records on conditions and materials pertinent to the evaluation. The number of test values needed for an evaluation cannot be prescribed, but obtain enough data to establish a reasonably good statistical probability curve. Where data is insufficient and time permits, perform supplemental tests in accordance with the discussion in the following section:

OLD PAVEMENTS

The following paragraphs describe procedures for evaluating an existing field for which no design or construction-control data is available and for which field and laboratory tests must be made. The condition survey mentioned above is made first. Then, test locations are selected, in-place tests are made, samples for laboratory tests are secured, and test pits are backfilled. Laboratory tests are the final phase in data procurement.

Selection of Test Locations

Selecting the most representative test locations is essential for an accurate evaluation. Also, hold the number of test locations to a minimum to reduce interruptions in normal aircraft operations on the facilities being tested.

The first step in the selection of test locations is to prepare longitudinal profiles of the runways, taxiways, and aprons. This develops a general picture of subgrade, subbase, base, and pavement conditions. From these profiles, select test pit locations where more detailed tests can be performed.

The profiles should show information regarding thickness and types of pavement, base (includes all aggregate layers), and subgrade soil classification. Obtain this data by cutting small holes in the pavement through which thickness measurements can be made. Then, sample the base course, subbase course, and subgrade. Space the small holes about 500 feet apart. A wider spacing may be adequate when uniform conditions exist. Classify the samples in accordance with the USCS (see FM 5-410). Determine the moisture content because variations in moisture content often indicate variations in soil strength.

After profiles have been developed, study them to determine representative conditions. Test pits should be located in typical base and subgrade conditions or where significant strength or traffic intensity exists. Ensure test pits are placed where maximum information can be obtained with minimum testing.

After typical areas of high and low strengths in each material have been determined by observing pavement condition or by studying soil profile, place test pits in areas where traffic intensity is high. This permits determination of the soil strength under traffic conditions.

When no weak areas are found, place test pits where traffic is heavy and loading con ditions are most severe. These cond it ions are usually found in the 1,000-foot sections at runway ends, in the entire lenght of taxi ways, and in taxi lanes on aprons. An air field having a runway, an apron, and connecting taxiways usually requires 12 to 20 test pits for adequate overall evaluation. A minimum of two pits (one at each end) should be required on aprons and on the taxiway system. More pits may be necessary when weak or failed areas are encountered.

Test pits. Test pits (approximately 4 feet wide by 6 feet long) are dug through the pavement to permit the performance of in-place tests and to obtain samples for laboratory tests. Record a description of general conditions in each test pit and visually classify the materials from pit to pit. Measure the pavement thickness to the nearest quarter of an inch. Make several measurements around the sides of the pit to obtain representative values.

Describe each soil course, giving color, in situ conditions, texture, and visual classifications. Perform in-place moisture content, CBR (except when moisture conditions are not satisfactory), and density tests on the base course and subgrade. Use judgment when selecting test locations in the pit. Place the CBR piston or penetrometer so the surface to be penetrated represents an average condition of the surface being tested. The piston should not be set on unusually large pieces of aggregate or other materials.

Space CBR tests in the pit so that areas covered by the surcharge weights of the individual tests do not overlap. Perform these tests on the surface and at each full 6-inch depth in the base and subbase courses, on the surface of the subgrade, and on underlying layers in the subgrade as needed.

Determine the density and moisture content at 1 -foot intervals to a total depth of 4 feet below the surface of the subgrade. Use the results of density and moisture tests at these depths to decide whether additional CBR tests are needed. Locate the tests in the pit so the density determinations are performed between adjacent CBR tests.

Moisture content determination. When coarse material makes up 40 percent or more of the base course, the moisture content of the fine portion may influence the behavior of the base course more, with respect to strength, than the moisture content of the total sample.

The critical portion of material considered is that part passing sieve sizes ranging from Number 200 to Number 4. The Number 40 sieve is the sieve on which separations for the Atterberg liquid and plastic limit determinations are made. The material passing the Number 40 sieve is used to determine the soil's plastic and liquid limits.

CBR tests. Perform three in-place CBR tests (as described in FM 5-5301) or equivalent tests with one of the CBR expedient methods at each elevation tested. However, if the results of these three tests do not show reasonable agreement, make three additional tests. A reasonable agreement among three tests permits a tolerance of 3 where the CBR is less than 10, 5 where it ranges from 10 to 30, and 10 where it ranges from 30 to 60. Where the CBR is above 60, variations in individual readings are not important.

For example, test results of 6, 8, anti 9 are reasonable and can be averaged as 8. Results of 18, 20, and 23 are reasonable and give an average of 20. If the first three tests do not fall within this tolerance, make three additional tests at the same location and use the numerical average of the six tests as the CBR for that location.

Generally, CBR values below 20 are rounded to the nearest point. Values above 20 are rounded to the nearest 5 points. Obtain a moisture-content sample at the point of each penetration.

Density determination. Make three density determinations at each elevation tested if samples of about 0.05 cubic foot volume are taken. If somewhat larger samples are taken, decrease the number of density determinations to two. If a reasonable agreement is not found among the test results, perform two additional tests. A reasonable agreement is considered to provide for a tolerance of about 5 pounds per cubic foot (pcf) wet density. For example, test results of 108, 111, and 113 pcf wet density are in reasonable agreement and can be averaged as 111 pcf.

Sampling. Obtain samples of typical pavement, base-course, and subgrade materials for laboratory tests. Take the base and subgrade samples to ensure representative materials.

Backfilling. Holes cut in flexible pavements can be backfilled satisfactorily if a few precautions are followed. Backfill the subgrade with a material similar to that removed. Place the material in about 3-inch lifts and compact them to the required density with a pneumatic tamper. The backfill for the base course should consist of a material similar to that removed and should be compacted to a high density. The surface of the base course should be primed and the sides of the adjacent pavement swabbed with a liquid asphalt. Use an RC-70 in cold weather and an MC-80 in hot weather.

A hot-mix AC is best for patching pavement, but many successful patches have been made with a cold mix. Avoid a cold mix when it will be subjected to jet blast or fuel spillage. It is not necessary to heat a cold mix in hot weather unless it has hardened. In cold weather, however, the material must be heated until it can be handled satisfactorily.

Compact the patching material thoroughly with a pneumatic tamper. If cold mix is used, swab the surface with liquid asphalt and cover it with small aggregate. Use a smooth-wheeled or pneumatic roller over the surface.

LABORATORY TESTS

Laboratory tests provide data with which to classify materials and determine their strength characteristics. In the laboratory, materials can be reworked or their moisture conditions adjusted to arrive at an estimate of the strength expected under future conditions of increased density or moisture. The following tests apply to both satisfactory and failed areas.

Pavement Tests

Where a pavement consists of more than one course, the cores obtained for testing should be split at the interfaces of the various courses so that each course can be tested separately. Test the cores of each course in the laboratory for Marshall stability; flow; percentage of asphalt; aggregate type, shape, and gradation; specific gravity of bitumen and aggregate; and density. Compute the voids in the total mix and the percentage of voids filled with asphalt from the test results.

Use parts of the chunk samples to determine aggregate gradation; specific gravity of asphalt and aggregate; and penetration, ductility, and softening point of the asphalt. Disintegrate and recompact other chunk samples, and test the recompacted specimens for Marshall stability, flow, and density. Compute their void relationships.

The stability of cores cut from the pavement may be lower than that of the recompacted sample. Part of this difference is due to differences in density because field cores seldom have a density as high as the laboratory-compacted samples. Most variation in stability is attributed to differences in structure of the field and laboratory samples. Another factor is that the asphalt hardens during reheating.

Remove and replace the mix if results are totally unfavorable (for example, if stability is under 500 based on 50 blows or if flow is greater than 20 based on 50 blows). Sometimes, additional compaction increases the stability. (For voids total mix, tolerance is within 1 percent of specifications; for voids filled with asphalt, tolerance is within 5 percent of specifications.)

No standard tests have been developed to determine resistance to spillage. However, a small amount of jet fuel should be spilled on one chunk from each test pit to see if the fuel penetrates the sample quickly or if it puddles on the surface.

Base-Course, Subbase, and Subgrade Tests

Obtain classification data consisting of Atterberg limits, gradation, and specific gravity determinations from design and construction-control tests or tests performed on samples of base-course, subbase, and subgrade materials remolded at three compaction efforts. Develop the moisture density and CBR relationships for the CE 55 compaction test. Where available, include results of tests made on the soaked and unsoaked condition for possible future use.

MAKING THE EVALUATION

Evaluation of expedient pavement requires less effort than evaluation of flexible pavement. Expedient-pavement evaluation procedures are similar to expedient-pavement design procedures covered previously in this chapter.

Evaluation of a flexible pavement consists of two principle determinations—the load-carrying capacity of the entire pavement structure and the quality of the bituminous pavement. The load-carrying capacity is evaluated by applying the proper criteria to the factors of pavement thickness; the CBR of the base course, CBR of subbase, or combined thickness of all courses above the subgrade; and the CBR of the subgrade. The quality of bituminous pavement is judged by its ability to withstand traffic loads, fuel spillage, and jet blast.

Evaluation of rigid pavements requires an understanding of its characteristics, which are beyond the scope of this chapter. The actual procedure, however, is very similar to flexible-pavement evaluation. Essentially, the strength of the subgrade and the condition of the rigid pavement determine whether an existing airfield requires additional overlays to support certain aircraft. (Rigid pavement evaluation is covered in Chapter 3, TM 5-826-3/AFM 88-24.)

EXPEDIENT- AND AGGREGATE-SURFACED AIRFIELDS

The evaluation of unsurfaced, mat-surfaced, and aggregate-surfaced pavements to determine the number of allowable traffic cycles is conducted using the appropriate design aircraft (C-130 or C-17). Since these are the only major aircraft that can operate on small, semiprepared, austere airfields, the curves used in the design process can be used in the evaluation. The procedure is very similar to the actual design procedure.

DESIGN STEPS

1. Determine the airfield location.

2. Determine the aircraft type and weight that will use the pavement.

3. Determine the CBR by using the airfield cone penetrometer or DCP test (found in Appendices I and J, respectively), or estimate the CBR based on soil classification (see FM 5-410).

4. Determine the number of required passes.

5. Knowing the airfield surface type (light-mat, medium-mat, or unsurfaced), use the appropriate curve by entering the left side of Figure 12-6, page 12-11, with the CBR. Follow horizontally to the gross aircraft weight. Then, follow downward to determine the allowable aircraft passes.

Example 11

Given an unsurfaced airfield with a CBR of 9 and soil type ML, determine the number of allowable aircraft passes for a C-130 aircraft with a weight of 130,000 pounds.

Solution 11

The aircraft, weight, and CBR are all given. Using Figure 12-6, page 12-11, enter the left side at CBR = 9 and read right (horizontally) to the C-130 curve. Follow downward and determine that there are 740 allowable aircraft passes.

FLEXIBLE-PAVEMENT AIRFIELDS

The evaluation of flexible pavements should be based on existing conditions. Do not consider the minimum allowable design thickness and maximum allowable design CBR values in Table 12-8, page 12-23, in the evaluation. The evaluation to determine the number of passes allowable is conducted using Figures K-1 through K-40, pages K-1 through K-40, because the evaluation may or may not be based on the C-141 (the design aircraft for flexible pavements). Use the following procedure:

- Determine the aircraft type and weight that will use the pavement. If the aircraft operating weight is unknown, use the weight for the design aircraft (C-141/345 kips).
- Determine the traffic area to evaluate (see Figure 12-5, page 12-7). Do not include overrun areas, Type D traffic areas, blast pads, and other nonload-carrying pavements in the evaluation. However, prepare a statement of their condition (as determined by visual inspection) and record the thickness and quality of the various layers.
- Determine the layer thickness of the select, subbase, base, and AC surface according to the procedure for the DCP or this chapter.
- Determine the CBR of the subgrade, select, subbase, and base. The CBR test can be conducted using test pits described previously in this chapter.

Another method for determining subgrade CBR is to use the DCP (Appendix J). The CBR of the select, subbase, and base also could be established from construction drawings, the AFCESA, or the Corps of Engineers' evaluation reports. The CBR also can be estimated based on soil classification (see FM 5-410). The physical properties on which the evaluation is based are presented in Table 12-18. The evaluation for the runway is based on the pavement thickness in the central 100-foot width for all gear configurations.

- Select the appropriate evaluation curve from Figures K-1 through K-40, pages K-2 through K-41. If there is no curve for the aircraft considered, use the curve for the controlling aircraft (C-141).
- Use the appropriate curve by entering the top with the cover thickness above the subgrade (total thickness of higher CBR material existing above the top of the subgrade). Follow downward to the gross aircraft weight. Then, move horizontally (left or right) to the subgrade CBR. Finally, move downward to determine the number of allowable aircraft passes. Repeat this procedure for each pavement layer (select, subbase, and base) using the cover thickness on top of the layer being considered. Once the number of allowable aircraft passes has been determined for each pavement layer, the most conservative (that is, the lowest) number will control the evaluation.

Table 12-18. Summary of physical property data

Facility Number and Identification	Pavement		Base			Subgrade	
	Thick (in)	Description	Thick (in)	Classification	CBR	Classification	CBR
Primary runway, taxiway, and parking apron	4	Asphaltic concrete	8 15	GW crushed stone GP stabilized gravel	100 50	CL lean clay	15

Example 12

Determine the number of allowable aircraft passes for all F-4 aircraft with a weight of 62,000 pounds. The test pit evaluation of a captured enemy airfield indicates the following conditions:

- Type B traffic area (primary taxiway).
- 4 inches of AC.
- 6 inches of base course, CBR = 80 (GW).
- 4 inches of subbase course, CBR = 40 (GM).

Subgrade, CBR = 10 (CL).

Solution 12

The aircraft type (F-4), weight (62 kips), traffic area (B), layer thicknesses, and CBR values have all been provided. Using Figure K-38, page K-38, enter the top with a cover thickness (above the subgrade) of 14 inches. Read downward to a gross aircraft weight of 62 kips. Then, read right to reach the subgrade CBR value of 10. Finally, read downward to determine a subgrade allowable pass level of 10^4, or 10,000 passes. Repeat these steps for the subbase. Enter the cover thickness = 10 inches, gross aircraft weight = 62 kips, and subbase CBR = 40. The allowable subbase pass level is greater than 100,000. Now, evaluate the base course. Enter the cover thickness = 4 inches, weight = 62 kips, and base CBR = 80. The allowable base pass level is greater than 100,000. The subgrade controls the evaluation with 10,000 passes.

Example 13

Evaluate the airfield described in the previous example for a C-5A weighing 700,000 pounds.

Using the same steps as in the previous example, the allowable passes are as follows:

- Subgrade = 140.
- Subbase = 100,000+.
- Base = 100.000+.

Solution 13

The subgrade controls the evaluation with 140 allowable passes.

Selection of Strength and Thickness values

Carefully select CBR values for use in an evaluation. Thickness values are selected from design or actual measured thickness for the base and subbase layers.

CBR test results from an individual test pit are seldom uniform. Therefore, study the data carefully to determine reasonable values for the evaluation. There are no rules or formulas for the number of values needed. This is a matter of engineering judgment. The following guidelines may assist in determining the number needed. A minimum of five CBR values per facility is required even when the material is known to be uniform, when control tests indicate that placement is uniform, and when available values cover a narrow range. When the uniformity of material and construction are not known, the number of test values should be sufficient to establish a good statistical distribution.

To select values for an evaluation, plot test results on profiles or arrange them in tabular form to show the range of the data. In most cases, the value selected should be a low average, but it should not be the lowest value in a range.

When conditions are uniform, the lower quartile value from a cumulative distribution plot may be used. Where conditions are not uniform, the following example may be helpful.

The subgrade material beneath a facility being evaluated varies so that the facility may be divided into several large areas of differing subgrade material. The in-place CBR values for the entire facility, arranged in ascending order, are as follows: 7, 7, 8, 9, 9, 10, 14, 14, 15, 16, 20, 21, 21, 22, 28, 30, 30, and 31. A study of in-place conditions reveals the degree of saturation of the subgrade is about the same for the entire area covered by the facility, and the degree of saturation is high enough that in-place CBR values can be used for evaluation.

Preliminary analysis of this data shows the statistical distribution for the whole facility is not good, and the values logically fall into four groups. Each group represents one of the areas of different material. The most critical area is that represented by the range of values from 7 to 10 because more of the values fall in that group than in any other. Thus, the evaluation should be based on this area.

Because the range is narrow, a formal statistical analysis is not necessary. A visual inspection of the figures indicates a value of 8 or 9 should be selected.

Regardless of the number of values available and the method used to select the evaluation figure, the number of values and the analytical process used should be described in the evacuation report in sufficient detail to be easily understood later.
Because of certain inherent difficulties in processing samples for laboratory tests and in performing in-place tests on base course materials, it is advisable to assign arbitrary CBR values to certain materials based on their service behavior (see Table 5-3, page 5-12, FM 5-430-00-l/AFPAM 32-8013, Vol 1). Use these CBR values for base-course material when the material meets quality requirements of the specification.

When evaluation tests are made less than three years after construction and indicate plasticity index values greater than 5, consider in-place CBR values but assign no value greater than 50. When tests are made three years or more after construction and indicate plasticity index values greater than 5, use in-place values.

When evaluation tests on subbase materials are made less than three years after construction and tested materials meet the suggested requirements, consider in-place CBR values, but assign no value greater than 50. When tests are made three years or more after construction, use in-place values.

Sometimes, CBR tests tend to underrate certain cohesionless, nonplastic materials that are not confined. If records show adequate performance and service behavior for these materials, use judgment to assign an arbitrary CBR value for evaluation.

Quality Of Bituminous Pavement

The condition of a bituminous pavement, either surface or binder course, is evaluated at the time of sampling by comparing the test data from the core samples with design criteria in TM 5-337. Future behavior of the pavement under additional traffic is predicted by comparing the test data from the recompacted laboratory specimens with the design criteria. The following example shows the prediction of behavior from tests on cores and on recompacted laboratory surface course specimens.

Assume the thickness and aggregate gradation are satisfactory. The current density (cores) is relatively low, the flow is approaching the upper limit, the voids' relationship is outside the acceptable ranges, and the stability is satisfactory.

Data from the recompacted specimens indicate additional compaction from traffic will tend to improve the quality of the pavement. Thus, the pavement probably will adjust itself to heavier loads and tire pressures than it has sustained in the past and will be satisfactory under either high- or low-pressure traffic. At CE 55, the voids' total mix value is below the midpoint of the acceptable range, and the flow is at the upper limit, indicating a mix slightly richer than ideal. However, no danger from flushing (bleeding) is expected.

Ability to withstand fuel spillage. ACs are readily soluble in jet fuels, but tars are not. Maximum distress is caused to AC pavements by fuel frequently dripping on a given area or by the pavement mix being so pervious that it allows considerable fuel penetration. Voids in the total mix control the rate at which penetration occurs. Fuels will penetrate very little into pavements with about 3 percent voids but will rapidly penetrate pavements with high (over 7 percent) voids.

Weathering appears to increase the pavement's resistance to penetration of jet fuels. Pavements about one year old or older usually perform better in this respect than new pavements.

Tar concretes and rubberized-tar concretes are not readily soluble in jet fuel, but saturation with jet fuel is detrimental to the life of such pavements. A low-void, total-mix value in a surface course indicates that it is sufficiently impervious to forestall damage.

Determine the type binder in the surface course, and study the surface course characteristics for resistance to jet fuel. Note poorly bonded thin layers. Use Table 12-19 as a guide for evaluating the types of bituminous pavements from the standpoint of fuel spillage for use in areas throughout the airfield.

Ability to withstand jet blast. Tests have shown that about 300°F is the critical temperature for AC and rubberized-tar concrete. About 250°F is the critical temperature for tar concrete. Field tests simulating pretakeoff checks at the ends of runways indicate the maximum temperatures induced in pavement tests; simulating maintenance checkups were 315°F. Rubberized-tar concretes usually withstand these temperatures. No bituminous pavement resists erosion if afterburners are turned on when the plane is standing still.

Thin surface courses that are not bonded well to the underlying layers may be picked up or flayed by high-velocity blasts even though the binder is not melted. All jet aircraft currently in use produce blasts of sufficient velocity to flay such courses. Surface courses less than 1 inch thick with poor bond to the underlying layers are, therefore, rated as unsatisfactory for all jet aircraft. This rating applies only to parking areas and the ends of runways.

Effects of traffic compaction. When evaluating effects of future traffic on the behavior of the paving mix, compare existing conditions with results of laboratory tests mentioned previously. If the pavement is constructed so voids fall at or about the lower limit of the specified allowable range, planes with high-pressure tires probably will produce sufficient densification to reduce voids in the total mix. When voids fall below the specified minimum, there is no internal air in the asphalt mix for the asphalt to flow into. Such pavement is considered to be in a critical condition. These conditions cannot be translated into numerical evaluations, but they should be discussed and summarized in the evaluation report.

To evaluate the base, subbase, and subgrade from the standpoint of future compaction, compare in-place densities (in percentage of CE 55 maximum density) with design requirements for the various loads and gear configurations the pavement is expected to support. If the in-place density of a layer is appreciably lower than required, remove the surface, base course, and subbase courses and apply proper compaction.

Low-density materials combined with low moisture content permit densification.

Table 12-19. Guidance for evaluating pavement types

Type Pavement	**Texture**	**Uses**
Asphalt concrete	NA	Runway and taxiway interiors
Tar and rubberized-tar concrete	Dense	All areas
Tar and rubberized-tar concrete	Open	Runway interiors, runway ends, taxiway interiors, and taxiway ends

Include statements of the possible amount of settlement due to densification in the evaluation of pavements subjected to channelized traffic.

If cohesive materials develop pore pressures, study the possible loss in strength and estimate the lowest probable CBR. Consider this estimated value when selecting the evaluation CBR for that material.

Actual and estimated pavement behavior. Study the traffic history to learn the weights of planes that have been using the field, then compare the behavior of the facilities under actual plane weights with that indicated by the evaluations of the pavement's load-carrying capacities. In making these comparisons, consider the number of coverages produced by each type of plane and the effects of mixed traffic.

No criteria exists for judging the effects of mixed traffic. However, flexible pavements probably can withstand a few applications of loads well in excess of the load they can withstand for full operation. Also, numerous applications of loads below the full operation load (50 percent or less) are not detrimental; in fact, they are probably beneficial.

Exact agreement between behavior of facilities as shown by the evaluation and behavior that occurs under traffic is not expected. This is primarily caused by the difficulties in determining the exact traffic that produced the behavior and because conditions change with time. Study major differences in the evaluation based on the test data and data indicated from behavior under traffic. Discuss the differences in the evaluation report.

As a minimum, the evaluation of an airfield should allow loads and intensity of traffic equal to those previously sustained, provided this traffic does not produce distress. As an operating procedure, frequently inspect the pavements after heavier planes are introduced during the frost-melting period. Limit loads or reduce traffic intensity when high deflections are observed during traffic.

Evaluation for Arid Regions

The danger of saturation beneath flexible pavements is reduced when the annual rainfall is less than 15 inches, the water table (including perched water table) is at least 15 feet below the surface, and the water content of the subgrade does not increase above the optimum determined by the CE 55 compaction test. Under such conditions, reduce the total design thickness of the pavement, base, and subbase courses by 20 percent. Apply this reduction to the select material or to the subbase course having the lowest design CBR value.

Conversely, when evaluating flexible pavements under these conditions, increase the total thickness above the subgrade by 25 percent before entering the evaluation curves. Apply this increase to the select material or the subbase course having the lowest bearing ratio or to the same layer in which the reduction was made in the design analysis.

FLEXIBLE OVERLAY OVER FLEXIBLE PAVEMENTS

An evaluation of a flexible-pavement airfield may determine that the traffic areas do not meet the cover requirements for a particular mission. In this case, it is possible to overlay the existing pavement with additional material to make it satisfactory for use.

An example of the design procedure for applying a flexible overlay to flexible pavement follows.

Example 14

The evaluation of an existing airfield pavement indicates the conditions shown below. Tests on the AC indicate that it is adequate. The directive states the field will be used as a rear area 10,000-foot airfield for 1,000 passes.

4" AC Pavement

6" Base Course CBR = 80

6" Select Material CBR = 20

Subgrade CBR = 7

Solution 14

The critical aircraft for the rear area 10,000-foot airfield is the C-141, which has a gross weight of 345,000 pounds. The pavement being considered is a Type B traffic area. To design the overlay, check the existing airfield against the thickness design requirements in Figure 12-12, page 12-41. This indicates whether the airfield is satisfactory as is or whether an overlay is needed.

Enter Figure 12-12 with the CBR of each soil layer of the pavements, and read the thickness required above that layer from the curve. The value from the curve is compared with the existing thickness.

If the thickness from the curve is less than the existing thickness, the airfield pavement is satisfactory. If the required thickness is greater than the existing thickness, an overlay is required. The overlay thickness must be equal to the difference between the design thickness and the existing thickness. The results of this example are shown below:

Soil Layer	Existing Thickness Above Soil Layer (in)	Design Thickness (in)	Overlay Thickness Requirement
CBR 7 subgrade	16	24	8
CBR 20 select material	10	11.2	1.2
CBR 80 base	4	3.2	0

Use the largest overlay thickness requirement. An overlay thickness of 8 inches will satisfy the thickness requirement for operating on this pavement for 1,000 passes as a heavy lift, rear-area pavement. It is possible to overlay 8 inches of AC on the existing surface, but this would be prohibitively expensive. A better alternative is to overlay 6 inches (minimum lift thickness) of CBR = 100 base course and 3 inches of AC. The overlay is shown following:

3" AC Pavement

6" Base Course CBR = 100

4" AC Pavement

6" Base Course CBR = 80

6" Select Material CBR = 20

Subgrade CBR = 7

Another method to determine an overlay requirement is to use the evaluation curves, Figures K-1 through K-40, pages K-1 through K-40. Enter these curves at the bottom with the number of aircraft passes and read upward to the layer's CBR value. Then, read horizontally to the aircraft gross weight. Finally, read upward to determine the required thickness above that soil layer. Using the same example as above yields the following information:

Soil Layer	Existing Thickness Above Soil Layer (in)	Design Thickness (in)	Overlay Thickness Requirement
CBR 7 subgrade	16	24	8
CBR 20 select material	10	11.1	1.1
CBR 80 base	4	3.2	0

Thus, this method also would result in an overlay.

NONRIGID OVERLAYS OVER RIGID PAVEMENTS

In the rear areas of the TO, it may be necessary to evaluate existing rigid pavements and to bring them to required strengths by adding nonrigid overlays. Use the following design procedure to determine the nonrigid overlay thickness needed to increase the load-carrying capacity of existing concrete pavements. This design procedure is also used to evaluate existing concrete pavements with nonrigid overlay.

Nonrigid overlays may be AC or flexible. The type of nonrigid overlay used for a given condition depends on the required overlay thickness. In general, the flexible overlay is used when the required overlay is of sufficient thickness to incorporate a minimum 4-inch compacted layer of high-quality, base-course material, plus the required thickness of AC surface course. The AC overlay will be used when less overlay thickness is needed.

The method used assumes the nonrigid overlay on rigid pavement to be a flexible pavement, with the rigid-base pavement assumed to be a high-quality base course with CBR = 100. This is a very conservative assumption. The nonrigid overlay on rigid pavement is designed and evaluated in the same manner as a flexible pavement, the procedure for which was described earlier in this chapter. Thus, when designing and evaluating, it will be necessary to determine the physical constants that are required for flexible pavements.

If an existing flexible overlay has already been placed, the quality of the AC portion of the overlay and the CBR values of the subgrade and base course beneath the rigid base pavement will have to be established. As mentioned above, the rigid-base pavement will be assumed to have CBR = 100.

Example 15

Assume a runway with uniform thickness of nonrigid overlay on rigid pavement throughout its entire width and length must be evaluated. The overlay composed of AC for full depth is 2 inches, the thickness of the rigid base pavement is 6 inches, the base course thickness under rigid pavement is 8 inches, the base course CBR is 40, and the subgrade CBR is 7.

2" AC Pavement

6" Portland Cement Concrete

8" Base Course CBR = 80

Subgrade CBR = 7

This sample airfield is to be used by C-141 aircraft for 5,000 passes. The design load is 345,000 pounds. Tests of the AC indicate that it meets design requirements for stability, density, gradation, voids relations, and other design requirements.

Solution 15

A design curve for traffic area Type B will be required. Enter Figure 12-12, page12-41, with this design load (in kips). It is found that the CBR = 7 subgrade requires 28 inches of cover, CBR = 40 requires 7.3 inches of cover, and CBR = 100 (Portland cement (PC) concrete) requires no cover.

The total cover over the CBR = 7 subgrade is only 16 inches, whereas 28 inches is required. Therefore, the overlay must be 28 - 16 inches, or 12 inches thick.

PAVEMENT AND AIRFIELD CLASSIFICATION NUMBERS

After an airfield pavement has been designed, constructed, or evaluated, aircraft other than the critical aircraft probably will land on the pavement. (These can include foreign national aircraft.) Due to these constraints, it will be extremely difficult to account for all traffic loads in relation to the design life of the airfield. One method to account for this is to set a pavement classification number (PCN) based on the design aircraft, assign an aircraft classification number (ACN) to aircraft based on their load, and then compare the two. The ACN expresses the relative structural effect of an aircraft on different pavement types for specified standard subgrade strengths in terms of a standard single-wheel load. The PCN expresses the relative load-carrying capacity of a pavement in terms of a standard single-wheel load.

The system is structured so that a pavement with a particular PCN value can support, without weight restrictions, an aircraft that has an ACN value equal to or less than the pavement's PCN value. This is possible because ACN and PCN values are computed using the same technical basis.

DETERMINATION OF VALUES

Pavement Classification Numbers

The PCN numerical value for a particular pavement is determined from the allowable load rating, which is usually based on the design aircraft. Once the allowable load rating is established, determining the PCN value js a process of converting that rating to a standard relative value. Curves for converting allowable load ratings to PCN values are presented in Appendix O. The PCN value is usable for reporting the pavement strength only.

Rigid pavement PCN—allowable load curves. For rigid pavements, aircraft landing gear flotation requirements are determined by the Westergaard solution for a loaded elastic plate on a dense liquid foundation (interior load case), assuming a concrete working stress of 399 psi. Four different subgrade strengths are considered: high, 554 pounds per cubic inch (pci); medium, 296 pci: low, 148 pci: and ultralow, 74 pci. Using these parameters, a standard single-wheel load at a tire pressure of 181 psi is computed for each subgrade strength. The standard single-wheel load is expressed in kilograms and divided by 500 to obtain the PCN. Division by 500 is a rounding-off process to make the numbers smaller and more manageable.

Flexible-pavement PCN—allowable load curves. For flexible pavements, aircraft landing gear flotation requirements are determined by the CBR method. As with the rigid pavement, four different subgrade strengths are considered: high, CBR = 15; medium, CBR = 10; low, CBR = 6; and ultralow, CBR = 3. A standard single-wheel load at a tire pressure of 181 psi is computed for each of these subgrade strengths. The standard single-wheel load is expressed in kilograms and divided by 500 to obtain the PCN.

Reporting the PCN. The PCN should be reported in whole numbers, rounding off any fractional parts to the nearest whole number. For pavements of variable strength, the controlling PCN numerical value for the weakest feature of the pavement should be reported as the strength of the pavement. Besides their PCN number, data coded in Table 12-20 must be provided.

ACN values are determined the same way as PCN values because they are relative to the aircraft load and subgrade strength. A set value has not been selected for aircraft since this can vary based on the aircraft load and can be different from takeoff and landing due to full expenditure.

Guidance on Overload Operations

Pavement overload can result from loads that are too large, from a substantially increased application rate, or from both. Loads larger than the defined (design or evaluation) load shorten the design life while smaller loads extend it. Except for massive overloading, pavements in their structural behavior are not subject to a particular limiting load above which they suddenly or catastrophically fail. Their behavior is such that a pavement can sustain a definable load for an expected number of repetitions during its design life. As a result, occasional minor overloading is acceptable, when expedient, with only limited loss in pavement life expectancy and small acceleration of pavement deterioration. For those operations in which the magnitude of overload or the frequency of use does not justify a detailed analysis, the following criteria are suggested:

- For flexible pavements, occasional movements by aircraft with ACN not exceeding 10 percent above the reported PCN should not adversely affect the pavement.

- For rigid or composite pavements where a rigid pavement layer provides a primary element of the structure, occasional movements by aircraft with ACN not exceeding 5 percent above the reported PCN should not adversely affect the pavement.
- If the pavement structure is unknown, the 5-percent limitation should apply.
- The annual number of overload movements should not exceed approximately 5 percent of the total annual aircraft movements.

Such overload movements should not normally be permitted on pavements exhibiting signs of distress or failure. Furthermore, overloading should be avoided during any periods of thaw following frost penetration or when the strength of the pavement or its subgrade could be weakened by water. Excessive repetition of overloads can cause severe shortening of pavement life or require major rehabilitation of pavement. Therefore, where overload operations are conducted, the appropriate authority should review the relevant pavement condition regularly and review the criteria for overload operations periodically.

NOTE: Thickness design for rigid, flexible, and unsurfaced pavement (with or without matting) can be accomplished with computer programs developed by WES. The programs are available from the US Army Transportation Center, ATTN: CEMRD-ED-TT, 12565 West Center Road, Omaha, NE 68144-3869.

Table 12-20. PCN five-part code

PCN	Pavement Type	Subgrade Strength*	Tire Pressure**	Method of PCN Determination
Numerical value	R = rigid	A	W	T = technical evaluation
		B	X	
	F = flexible	C	Y	
		D	Z	U = using aircraft

*Code	Category	Flexible Pavement (CBR)	Rigid Pavement (k) (Pavement Condition Index)
A	High	Over 13	Over 400
B	Medium	8-13	201-400
C	Low	4-8	100-200
D	Ultralow	<4	<100

**Code	Category	Tire Pressure (psi)
W	High	No limit
X	Medium	146-217
Y	Low	74-145
Z	Ultralow	0-73