U.S. Department
of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Airport Pavement Design and Evaluation

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Initiated by: AAS-100

AC No: 150/5320-6E
Change:

1. PURPOSE. This advisory circular (AC) provides guidance to the public on the design and evaluation of pavements at civil airports.

2. CANCELLATION. This AC cancels AC 150/5320-6D, Airport Pavement Design and Evaluation, dated July 7, 1995.

3. APPLICATION. The FAA recommends the guidelines and standards in this AC for airport pavement design and evaluation. In general, use of this AC is not mandatory. However, use this AC is mandatory for all projects funded with federal grant monies through the Airport Improvement Program (AIP) and with revenue from the Passenger Facility Charge (PFC) Program. See Grant Assurance No. 34, “Policies, Standards, and Specifications,” and PFC Assurance No. 9, “Standards and Specifications.

4. RELATED READING MATERIAL. The publications listed in Appendix 4 provide further guidance and detailed information on the design and evaluation of airport pavements.

5. UNITS. Through this AC, customary English units will be used with soft conversion to metric units for tables and figures and hard conversion for the text.

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FOREWORD

This AC provides guidance on the structural design and evaluation of airport pavements.

Although airplane landing gears play a role in airport pavement design and evaluation, this AC does not dictate any facet of landing gear design. In 1958, the FAA adopted a policy of limiting maximum Federal participation in airport pavements to a pavement section designed to serve a 350,000-pound (158 757 kg) airplane with a DC-8-50 series landing gear configuration. The intent of the policy was to ensure that future airplanes were equipped with landing gears that would not stress pavements more than the referenced 350,000-pound (158 757 kg) airplane.

Throughout the 20th century, airplane manufacturers accepted and followed the 1958 policy and designed airplane landing gears that conformed to it—even though airplane gross weights have long exceeded 350,000 pounds (158 757 kg). Despite increases in airplane weights, manufacturers were able to conform to the policy by increasing the number and spacing of landing gear wheels. Unfortunately, adding extra wheels and landing gears does not contribute to efficiency, and airplane manufacturers are focusing on designing airplane gear configurations to optimize the efficiency of the airplanes. With this change in philosophy and increasing airplane weights, airfield pavements must be designed to withstand increased loading conditions.

Historical pavement design guidance presented in previous versions of this AC was based on methods of analysis that resulted from empirical research and field performance. Although it may have been possible to adjust these methods to address new gear configurations and increased pavement loading, newer design procedures, such as the layered elastic and finite element procedures discussed in Chapter 3, were better adapted for this challenge

The pavement design guidance presented in this AC implements layered elastic theory for flexible pavement design and three-dimensional finite element theory for rigid pavement design. The FAA adopted these methodologies to address the impact of new landing gear configurations and increased pavement load conditions. These procedures are robust and can address future gear configurations without modifying their underlying design procedures.

Chapter 6 presents the pavement evaluation portion of this AC. An airplane operator could be penalized unfairly if an existing facility was evaluated using a method different from that employed in the original design. A slight change in pavement thickness can have a dramatic effect on the payload or range of an airplane. Since a new pavement design methodology might produce different pavement thicknesses, an evaluation of an existing pavement using the new methodology could result in incompatible results. To avoid this situation, airport operators should base the evaluation, whenever possible, on the same methodology as was used for the design.

Where new airplanes are added to the traffic mix at an existing facility, it may not be possible to evaluate the pavement with the original design procedure. For example, when adding a new airplane with a unique gear configuration to the traffic mixture at a facility, it may be impossible to assess the impact of the new airplane using the original design procedures. In these instances, it is necessary to evaluate the pavement with a design procedure capable of addressing the new traffic mixture.

CHAPTER 1. AIRPORT PAVEMENTS— THEIR FUNCTION AND PURPOSES

100. GENERAL. Airport pavements are constructed to provide adequate support for the loads imposed by airplanes and to produce a firm, stable, smooth, all-year, all-weather surface free of debris or other particles that may be blown or picked up by propeller wash or jet blast. In order to satisfactorily fulfill these requirements, the pavement must be of such quality and thickness that it will not fail under the load imposed. In addition, it must possess sufficient inherent stability to withstand, without damage, the abrasive action of traffic, adverse weather conditions, and other deteriorating influences. To produce such pavements requires a coordination of many factors of design, construction, and inspection to assure the best possible combination of available materials and a high standard of workmanship.

a. Types of Pavement. Pavements discussed in this circular are flexible, rigid, hot mix asphalt overlays, and rigid overlays. Various combinations of pavement types and stabilized layers result in complex pavements classified between flexible and rigid. The design and evaluation guidance in this circular can be adapted to any pavement type.

b. Economic Analysis and Design Selection. With proper design and construction, any pavement type (rigid, flexible, composite, etc.) can provide a satisfactory pavement for any civil airplane. However, some designs may be more economical than others and can still provide satisfactory performance. The engineer is required to provide a rationale for the selected design in the engineer's report (see AC 150/5300-9, Predesign, Prebid, and Preconstruction Conferences for Airport Grant Projects). Engineers often base this rationale on economic factors derived from evaluating several design alternatives. Use life-cycle cost analysis if the design selection is based on least cost. Appendix 1 demonstrates an example of a life-cycle cost analysis of alternatives for pavement rehabilitation. Research report FAA-RD-81/078, Economic Analysis of Airport Pavement Rehabilitation Alternatives – An Engineering Manual, provides more details on life-cycle cost analysis. Many new developments in construction have evolved, such as recycling, that can significantly affect pavement costs. Alternate construction bids are appropriate in instances where no clear cost advantage is established in the design process. Economic factors do not always control the design selection. Operational constraints, funding limitations, future expansion, and other issues can override economic factors in the design selection. The engineer's report should address these considerations.

c. Pavement Courses.

(1) Surface. Surface courses include Portland cement concrete (PCC), hot mix asphalt (HMA), sand-bituminous mixture, and sprayed bituminous surface treatments.

(2) Base. Base courses consist of a variety of different materials, which generally fall into two main classes, treated and untreated. An untreated base consists of crushed or uncrushed aggregates. A treated base normally consists of a crushed or uncrushed aggregate mixed with a stabilizer such as cement, bitumen, etc.

(3) Subbase. Subbase courses consist of a granular material, a stabilized granular material, or a stabilized soil.

(4) Geosynthetics. The term geosynthetics describes a range of manufactured synthetic products used to address geotechnical problems. The term is generally understood to encompass four main products: geotextiles, geonets/geogrids, geomembranes and geocomposites. The synthetic nature of the materials in these products makes them suitable for use in the ground where high levels of durability are required. These products have a wide range of applications, including use as a separation between subbase aggregate layers and the underlying subgrade. The need for geosynthetics within a pavement section is dependent upon subgrade soil conditions, groundwater conditions, and the type of overlying pavement aggregate.

101. SPECIFICATIONS AND STANDARDS.

a. Specifications. Reference is made by Item Number throughout the text to construction material specifications contained in AC 150/5370-10, Standards for Specifying Construction of Airports.

b. Geometric Standards. AC 150/5300-13, Airport Design, presents geometric standards for pavement lengths, widths, grades, and slopes.

102. SPECIAL CONSIDERATIONS. Airport pavements should provide a skid resistant surface that will provide good traction during any weather conditions. AC 150/5320-12, Measurement, Construction, and Maintenance of Skid Resistant Airport Pavement Surfaces, presents information on skid resistant surfaces.

103. STAGED CONSTRUCTION OF AIRPORT PAVEMENTS. In some instances, it may be necessary to construct the airport pavement in stages; that is, to build up the pavement profile, layer by layer, as the traffic using the facility increases in weight and number. Lateral staging, i.e., planning for future widening of pavements, is sometimes advantageous to accommodate larger airplanes. If stage construction is to be undertaken, the need for sound planning cannot be overemphasized. It is important to design the complete pavement prior to the start of any stage and to assure that each stage provides an operational surface. The planning of a stage-constructed pavement should recognize a number of considerations.

a. Adequacy of Each Stage. Design each stage to adequately accommodate the traffic that will use the pavement until the next stage is constructed.

b. Drainage. Design and construct the underlying layers and drainage facilities of a pavement constructed in stages to the standards required for the final cross-section. Providing the proper foundation and drainage facilities in the first stage is mandatory, as the underlying layers will not be readily accessible for upgrading in the future.

CHAPTER 2. SOIL INVESTIGATIONS AND EVALUATION

200. GENERAL. The importance of accurate identification and evaluation of pavement foundations cannot be overemphasized. Although it is impossible to explore the entire field of soil mechanics in a publication such as this, the following text will highlight those aspects that are particularly important to the airport paving engineer.

a. Classification System. Use the Unified Soil Classification (USC) system in engineering matters concerning civil airport pavements. To avoid misunderstanding, certain terms employed are defined below:

(1) SOIL Definition. For engineering purposes, and particularly as it applies to airports, soil includes all natural deposits that can be moved with earth moving equipment, without requiring blasting under unfrozen conditions. Harder materials are considered to be rock.

(2) Conditions and Properties. Soil conditions include such items as the elevation of the water table, the presence of water bearing strata, and the field properties of the soil. Field properties of the soil include the density, moisture content, and frost penetration.

(3) Profile. The soil profile is the vertical arrangement soil layers, each of which possesses different physical properties from the adjacent layer.

(4) Subgrade. Subgrade soil is the soil that forms the foundation for the pavement. It is the soil directly beneath the pavement structure.

b. Subgrade Support. It should be remembered that the subgrade soil ultimately provides support for the pavement and the imposed loads. The pavement serves to distribute the imposed load to the subgrade over an area greater than that of the tire contact area. The greater the thickness of pavement, the greater is the area over which the load on the subgrade is distributed. It follows, therefore, that the more unstable the subgrade soil, the greater is the required area of load distribution and consequently the required thickness of pavement is greater. The soils having the best engineering characteristics encountered in the grading and excavating operations should be incorporated in the upper layers of the subgrade by selective grading.

c. Drainage. In addition to the relationship that soil conditions bear to grading and paving operations, they determine the necessity for underdrains and materially influence the amount of surface runoff. Thus, they have a resulting effect on the size and extent of other drainage structures and facilities. (See AC 150/5320-5, Surface Drainage Design.)

201. SOIL INVESTIGATIONS.

a. Distribution and Properties. To provide essential information on the various types of soils, investigations should be made to determine their distribution and physical properties. This information combined with data on site topography and area climatic records, provides basic planning material essential to the logical and effective development of the airport. An investigation of soil conditions at an airport site will include—

(1) Subsurface Soil Profile. An investigation of subsurface soil properties to determine the arrangement of different layers of the soil with relation to the proposed subgrade elevation.

(2) Sampling. Collection of representative samples of the layers of soil.

(3) Testing. Testing of samples to determine the physical properties of the various soil materials with respect to in-place density and subgrade support.

(4) Availability. A review to determine the availability of materials for use in construction of the subgrade and pavement.

b. Procedures. With respect to sampling and surveying procedures and techniques, American Society for Testing and Materials (ASTM) D 420, Standard Guide to Site Characterization for Engineering Design and Construction Purposes, is most frequently used. This method is based entirely on the soil profile. In the field, ASTM D 2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedures), is commonly used to identify soils by such characteristics as color, texture, structure, consistency, compactness, cementation, and, to varying degrees, chemical composition.

(1) Maps. Department of Agriculture soils maps, United States Geodetic Survey (USGS) geologic maps, and USGS engineering geology maps can prove valuable aids in the study of soils at and in the vicinity of the airport. Although the pedological classification, determined from these maps, does not treat soil as an engineering or construction material, data so obtained are extremely useful to the agronomist in connection with the development of turf areas on airports and to the engineer concerned with preliminary investigations of site selection, development costs, and alignment.

(2) Aerial Photography. The practice of determining data on soils with aerial photographs is established and commonly acceptable. Relief, drainage, and soil patterns may be determined from the photographs, and an experienced photo interpreter can define differences in characteristics of soils. By employing this method of investigation, it is possible to expedite soil studies and reduce the amount of effort required to gather data.

202. SURVEYING AND SAMPLING.

a. Subsurface Borings. The initial step in an investigation of subsurface conditions is a soil survey to determine the quantity and extent of the different types of soil, the arrangement of soil layers, and the depth of any subsurface water. These profile borings are usually obtained with a soil auger or similar device. Washed borings are not recommended due to inaccuracies of depth determinations. The intent of the borings is to determine the soil or rock profile and its lateral extent. Inasmuch as each location presents its particular problems and variations, the spacing of borings cannot always be definitely specified by rule or preconceived plan. Suggested criteria for the location, depth, and number of borings for new construction are given in table 2-1. Wide variations in these criteria can be expected due to local conditions.

Nondestructive testing (NDT), as described in AC 150/5370-11, Use of Nondestructive Testing Devices in the Evaluation of Airport Pavement, can be used for computing subgrade strength and to locate soil borings and sampling locations for evaluation of existing pavements. Also, boring logs from original construction and prior evaluations can be used.

TABLE 2-1. TYPICAL SUBSURFACE BORING SPACING AND DEPTH FOR NEW CONSTRUCTION

AREA	SPACING	DEPTH
Runways and Taxiways	Random Across Pavement at 200-foot (60 m) Intervals	Cut Areas - 10' (3 m) Below Finished Grade Fill Areas - 10' (3 m) Below Existing Ground[1]
Other Areas of Pavement	1 Boring per 10,000 Square Feet (930 sq m) of Area	Cut Areas - 10' (3 m) Below Finished Grade Fill Areas - 10' (3 m) Below Existing Ground[1]
Borrow Areas	Sufficient Tests to Clearly Define the Borrow Material	To Depth of Borrow Excavation

[1]For deep fills, boring depths must be sufficient to determine the extent of consolidation and/or slippage the fill may cause.

b. Number of Borings, Locations, and Depths. Obviously, the locations, depths, and numbers of borings must be such that all important soil variations can be determined and mapped. Whenever past experience at the location in question has indicated that settlement or stability in deep fill areas may be a problem or, if in the opinion of the engineer, additional investigations are warranted, more or deeper borings may be required in order to determine the proper design, location, and construction procedures. Conversely, where uniform soil conditions are encountered, fewer borings may be acceptable.

c. Boring Log. A graphic log of soil conditions can be of great value in assessing subgrade conditions. It is recommended that the graphic log be developed, which summarizes the results of the soil explorations. A typical graphic log is included as figure 2-1. The graphic log should include—

(1) Location

(2) Date performed

(3) Type of exploration

(4) Surface elevation

(5) Depth of materials

(6) Sample identification numbers

(7) Classification

(8) Water table

(9) Standard penetration test (SPT)

d. Soil Survey Areas. The soil survey is not confined to soils encountered in grading or necessarily to the area within the boundaries of the airport site. Possible sources of locally available material that may be used as borrow areas or aggregate sources should be investigated.

e. Undisturbed Samples. Samples representative of the different layers of the various soils encountered and various construction materials discovered should be obtained and tested in the laboratory to determine their physical and engineering properties. In-situ properties such as in-place density, shear strength, consolidation characteristics, etc. may necessitate obtaining “undisturbed” core samples. ASTM D 1587, Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes, describes a method of obtaining “undisturbed” soil samples. Because the results of a test can only be as good as the sampling, it is of utmost importance that each sample be representative of a particular type of soil material and not be a careless and indiscriminate mixture of several materials.

f. Inplace Testing. Pits, open cuts, or both may be required for making in-place bearing tests, taking undisturbed samples, charting variable soil strata, etc. This type of supplemental soil investigation is recommended for situations that warrant a high degree of accuracy or when in-situ conditions are complex and require extensive investigation.

203. SOIL TESTS.

a. Physical Soil Properties. To determine the physical properties of a soil and to provide an estimate of its behavior under various conditions, it is necessary to conduct certain soil tests. A number of field and laboratory tests have been developed and standardized. Detailed methods of performing soil tests are completely covered in publications of the ASTM.

b. Testing Requirements. Soil tests are usually identified by terms indicating the soil characteristics that the tests will reveal. Terms that identify the tests considered to be the minimum or basic requirement for airport pavement, with their ASTM designations and brief explanations, follow:

(1) Standard Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants (ASTM D 421). The dry method should be used only for clean, cohesion-less granular materials.

(2) Standard Test Method for Particle-Size Analysis of Soils (ASTM D 422). This analysis provides a quantitative determination of the distribution of particle sizes in soils.

(3) Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils (ASTM D 4318). The plastic and liquid limits of soil define in a standard manner the lowest moisture content at which a soil will change from a semisolid to a plastic state and at which a solid passes from a plastic to a liquid state, respectively. The plasticity index is the numerical difference between the plastic limit and the liquid limit. It indicates the range in moisture content over which a soil remains in a plastic state prior to changing into a liquid. The plastic limit, liquid limit, and plasticity index of soils are used in engineering classification in accordance with the Unified Soil Classification System (ASTM D 2487). In conjunction with particle size analysis, natural moisture content, and other soil properties or conditions, the limits may be used to estimate engineering properties or behavior of soils such as shrink/swell potential, consolidation characteristics, construction/stabilization characteristics, permeability, and strength characteristics.

(4) Moisture-Density Relations of Soils . For purposes of compaction control during construction, tests to determine the moisture-density relations of the different types of soils should be performed.

(i) Heavy Load Pavements. For pavements designed to serve airplanes weighing 60,000 pounds (27 216 kg) or more, use ASTM Method D 1557, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3 (2,700 kN-m/m3)).

(ii) Light Load Pavements. For pavements designed to serve airplanes weighing less than 60,000 pounds (27 216 kg), use ASTM Method D 698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft3 (600 kN-m/m3)).

(5) Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils (ASTM D 1883). This test is used to assign a CBR (California Bearing Ratio) value to subgrade soils for use in the design of flexible pavements.

(6) Modulus of Soil Reaction (AASHTO T 222). This test is used to determine the modulus of soil reaction, *k*, for use in the design of rigid pavements.

c. Supplemental Tests. In many cases, additional soil tests will be required over those listed in paragraph 203b above. It is not possible to cover all the additional tests that may be required; however, a few examples are presented below. This list should not be considered all-inclusive.

(1) Test Method for Shrinkage Factors of Soils by the Mercury Method (ASTM D 427). This test may be required in areas where swelling soils might be encountered.

(2) Standard Test Method for Permeability of Granular Soils (Constant Head) (ASTM D 2434). This test may be needed to assist in the design of subsurface drainage.

(3) Determination of Organic Material in Soils by Wet Combustion (AASHTO T-194). This test may be needed in areas where deep pockets of organic material are encountered or suspected.

(4) Standard Test Method for CBR (California Bearing Ratio) of Soils in Place (ASTM D4429-04). Field bearing tests can be performed when the on site conditions satisfy density and moisture conditions that will exist under the pavement being designed. The method is also described in Manual Series No. 10, Soils Manual (The Asphalt Institute).

204. UNIFIED SOIL CLASSIFICATION. The standard method of classifying soils for engineering purposes is ASTM D 2487, commonly called the Unified System. Table 2-2 provides general soil characteristics pertinent to pavements.

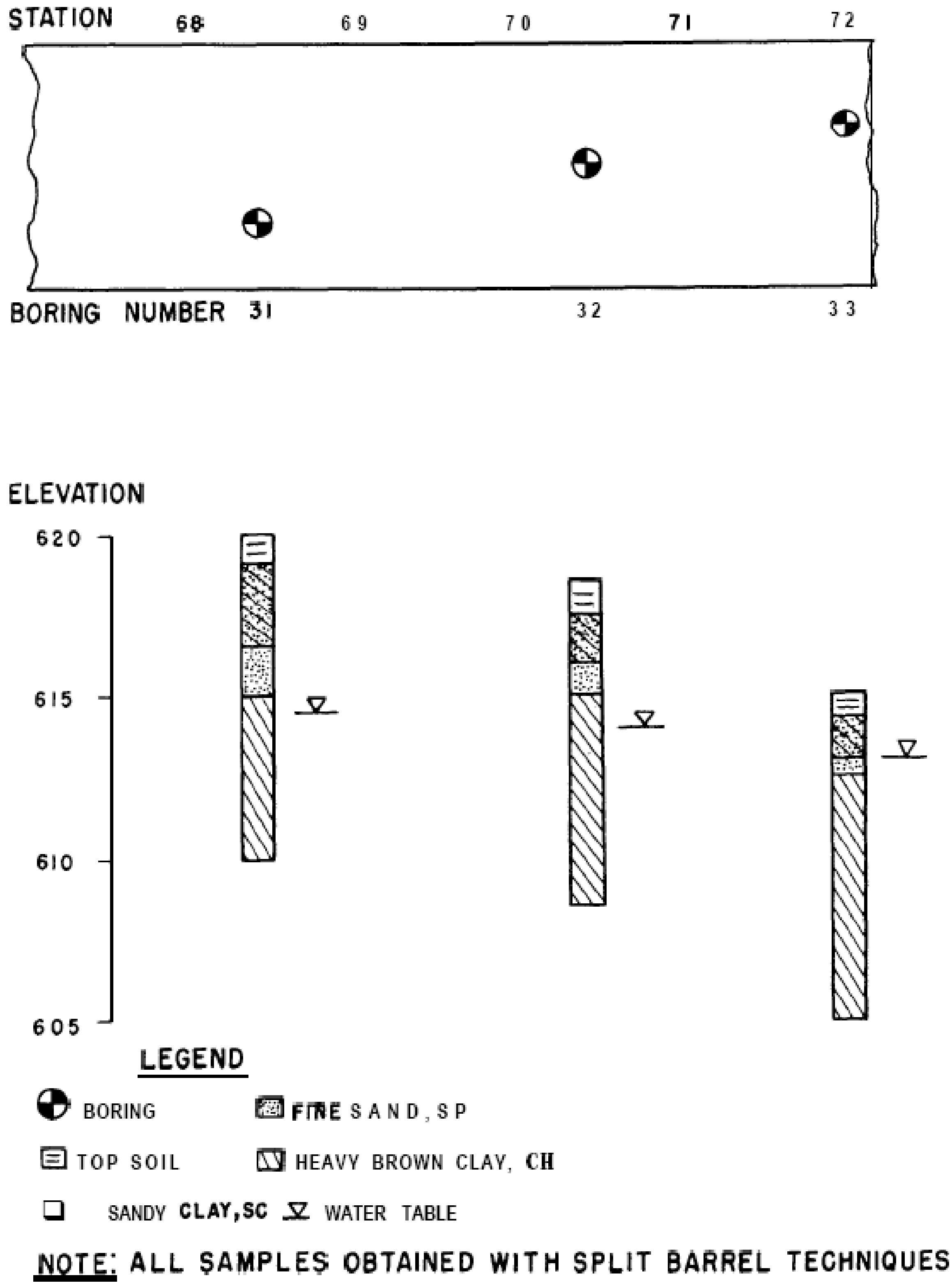


FIGURE 2-1. TYPICAL BORING LOG

TABLE 2-2. SOIL CHARACTERISTICS PERTINENT TO PAVEMENT FOUNDATIONS

Major Divisions		Letter	Name	Value as Foundation When Not Subject to Frost Action	Value as Base Directly under Wearing Surface	Potential Frost Action	Compressibility and Expansion	Drainage Characteristic	Unit Dry Weight (pcf)	CBR	Subgrade Modulus *k* (pci)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Coarse-gravelly soils	Gravel and gravelly soils	GW	Gravel or sandy gravel, well graded	Excellent	Good	None to very slight	Almost none	Excellent	125-140	60-80	300 or more
		GP	Gravel or sandy gravel, poorly graded	Good	Poor to fair	None to very slight	Almost none	Excellent	120-130	35-60	300 or more
		GU	Gravel or sandy gravel, uniformly graded	Good to excellent	Poor	None to very slight	Almost none	Excellent	115-125	25-50	300 or more
		GM	Silty gravel or silty sandy gravel	Good	Fair to good	Slight to medium	Very slight	Fair to poor	130-145	40-80	300 or more
		GC	Clayey gravel or clayey sandy gravel	Good to excellent	Poor	Slight to medium	Slight	Poor to practically impervious	120-140	20-40	200-300
	Sand and sandy soils	SW	Sand or gravelly sand, well graded	Good	Poor to not suitable	None to very slight	Almost none	Excellent	110-130	20-40	200-300
		SP	Sand or gravelly sand, poorly graded	Fair to good	Not suitable	None to very slight	Almost none	Excellent	105-120	15-25	200-300
		SU	Sand or gravelly sand, Poor uniformly Not suitablegraded	Fair to good	Poor	None to very slight	Almost none	Excellent	100-115	10-20	200-300
		SM	Silty sand or silty gravelly sand	Good	Not suitable	Slight to high	Very slight	Fair to poor	120-135	20-40	200-300
		SC	Clayey sand or clayey gravelly sand	Fair to good	Not suitable	Slight to high	Slight to medium	Poor to practically impervious	105-130	10-20	200-300
Fine grained soils	Low compress ibility LL<50	ML	Silts, sandy silts, gravelly silts, or diatomaceous soils	Fair to good	Not suitable	Medium to very high	Slight to medium	Fair to poor	100-125	5-15	100-200
		CL	Lean clays, sandy clays, or gravelly clays	Fair to good	Not suitable	Medium to very high	Medium	Practically impervious	100-125	5-15	100-200
		OL	Organic silts or lean organic clays	Poor	Not suitable	Medium to very high	Medium to high	Poor	90-105	4-8	100-200
	High compress ibility LL<50	MH	Micaceous clays or diatomaceous soils	Poor	Not suitable	Medium to very high	High	Fair to poor	80-100	4-8	100-200
		CH	Fat clays	Poor to very poor	Not suitable	Medium	High	Practically impervious	90-110	3-5	50-100
		OH	Fat organic clays	Poor to very poor	Not suitable	Medium	High	Practically impervious	80-105	3-5	50-100
Peat and other fibrous organic soils		Pt	Peat, humus and other	Not suitable	Not suitable	Slight	Very high	Fair to poor	-	-	-

205. SOIL STRENGTH TESTS. Soil classification for engineering purposes provides an indication of the probable behavior of the soil as a pavement subgrade. This indication of behavior is, however, approximate. Performance different from that expected can occur due to a variety of reasons such as degree of compaction, degree of saturation, height of overburden, etc. The possibility of incorrectly predicting subgrade behavior can be largely eliminated by measuring soil strength. The strength of materials intended for use in flexible pavement structures is measured by the CBR tests. Materials intended for use in rigid pavement structures are tested by the plate bearing method. Each of these tests is discussed in greater detail below. Resilient modulus is used for rigid pavement design because of the variable stress states. Elastic modulus is estimated from CBR and k using the correlations $E = 1500 \times$ CBR and $E = 26 \times k^{1.284}$

a. California Bearing Ratio. The CBR test is basically a penetration test conducted at a uniform rate of strain. The force required to produce a given penetration in the material under test is compared to the force required to produce the same penetration in a standard crushed limestone. The result is expressed as a ratio of the two forces. Thus a material with a CBR value of 15 means the material in question offers 15 percent of the resistance to penetration that the standard crushed stone offers. Laboratory CBR tests should be performed in accordance with ASTM D 1883, Bearing Ratio of Laboratory-Compacted Soils. Field CBR tests should be conducted in accordance with the ASTM D 4429, Standard Test Method for Bearing Ratio of Soils in Place.

(1) Laboratory. Laboratory CBR tests are conducted on materials that have been obtained from the site and remolded to the density that will be obtained during construction. Specimens are soaked for 4 days to allow the material to reach saturation. A saturated CBR test is used to simulate the conditions likely to occur in a pavement that has been in service for some time. Pavement foundations tend to reach nearly complete saturation after about 3 years. Seasonal moisture changes also dictate the use of a saturated CBR design value since traffic must be supported during periods of high moisture such as spring seasons.

(2) Field. Field CBR tests can provide valuable information on foundations that have been in place for several years. The materials should have been in place for a sufficient time to allow for the moisture to reach an equilibrium condition. An example of this condition is a fill that has been constructed and surcharged for a long period of time prior to pavement construction.

(3) Gravelly Materials. CBR tests on gravelly materials are difficult to interpret. Laboratory CBR tests on gravel often yield CBR results that are too high due to the confining effects of the mold. The assignment of CBR values to gravelly subgrade materials may be based on judgment and experience. The FAA pavement design procedure recommends a maximum subgrade *E* value of 50,000 psi (345 MPa) (CBR=33.3) for use in design.

(4) Number of Tests. The number of CBR tests needed to properly establish a design value cannot be simply stated. Variability of the soil conditions encountered at the site will have the greatest influence on the number of tests needed. As an approximate “rule of thumb”, three CBR tests on each different major soil type should be considered. The preliminary soil survey will reveal how many different soil types will be encountered. The design CBR value should be conservatively selected. Common paving engineering practice is to select a value that is one standard deviation below the mean. As a rule, a design CBR value of 3 is the lowest practical value that should be assigned. In instances where the subgrade strength is lower than CBR equals 3, the subgrade should be improved through stabilization or other means to raise the design CBR value. The following formula can be used to convert CBR to *k* value for the subgrade. However, this is only an approximate relationship and it is the recommended appropriate testing to establish design values.

$$k = \left[\frac{1500 \times \text{CBR}}{26}\right]^{0.7788}, \ (k \text{ in pci})$$

(5) Lime Rock Bearing Ratio. Some areas of the country use the lime rock bearing ratio (LBR) to express soil strength. To convert LBR to CBR, multiply LBR by 0.8.

b. Plate Bearing Test. As the name indicates, the plate bearing test measures the bearing capacity of the pavement foundation. The result, *k* value, can be envisioned as the pressure required to produce a unit deflection of the pavement foundation. The plate bearing test result, *k* value, has the units of pounds per cubic inch (Mega-Newton per cubic meter). Plate bearing tests should be performed in accordance with the procedures contained in AASHTO T 222.

(1) Test Conditions. Plate bearing tests must be conducted in the field and are best performed on test sections that are constructed to the design compaction and moisture conditions. A correction to the *k* value for saturation is required to simulate the moisture conditions likely to be encountered by the in-service pavement.

(2) Number of Tests. Plate bearing tests are relatively expensive to perform and thus the number of tests that can be conducted to establish a design value is limited. Generally only two or three tests can be performed for each pavement feature. The design *k* value should be conservatively selected.

(3) Plate Size. The rigid pavement design presented in this circular is based on the elastic modulus (*E*) or *k* value. The *k* value can be determined by a static plate load test using a 30-inch (762 mm) diameter plate. Use of a plate of smaller diameter will result in a higher *k* value than is represented in the design and evaluation curves.

c. Additional Soil Strength Tests. Where stability of the underlying section is questionable, additional soil strength tests may be necessary. Direct shear tests (ASTM D 3080) or field vane tests (ASTM D 2573) may be required to adequately design the pavement structure.

206. SUBGRADE STABILIZATION. Subgrade stabilization should be considered if one or more of the following conditions exist: poor drainage, adverse surface drainage, frost, or need for a stable working platform. Subgrade stabilization can be accomplished through the addition of chemical agents or by mechanical methods.

a. Chemical Stabilization. Different soil types require different stabilizing agents for best results. The following publications are recommended to determine the appropriate type and amount of chemical stabilization for subgrade soils: Unified Facilities Criteria (UFC) Manual Pavement Design for Airfields, UFC 3-260-02; Soil Cement Construction Handbook, Portland Cement Association; and The Asphalt Institute Manual Series MS-19, Basic Asphalt Emulsion Manual (see Appendix 4).

b. Mechanical Stabilization. In some instances, subgrades cannot be adequately stabilized through the use of chemical additives. The underlying soils may be so soft that stabilized materials cannot be mixed and compacted over the underlying soils without failing the soft soils. Extremely soft soils may require bridging in order to construct the pavement section. Bridging can be accomplished with the use of thick layers of shot rock or cobbles. Thick layers of lean, porous concrete have also been used to bridge extremely soft soils. Geosynthetics should be considered as mechanical stabilization over soft, fine-grained soils. Geosynthetics can facilitate site access over soft soils and aid in reducing subgrade soil disturbance due to construction traffic. Geosynthetics will also function as a separation material to limit long-term weakening of pavement aggregate associated with contamination of the aggregate with underlying fine-grained soils. FHWA-HI-95-038, Geosynthetic Design and Construction Guidelines, provides more information about construction over soft soils using geosynthetics (see Appendix 4).

207. SEASONAL FROST. The design of pavements in areas subject to seasonal frost action requires special consideration. The detrimental effects of frost action may be manifested by non-uniform heave and in loss of soil strength during frost melting. Other related detrimental effects include possible loss of compaction, development of pavement roughness, restriction of drainage, and cracking and deterioration of the pavement surface. Detrimental frost action requires that three conditions be met simultaneously: first, the soil must be frost susceptible; second, freezing temperatures must penetrate into the frost susceptible soil; third, free moisture must be available in sufficient quantities to form ice lenses.

a. Frost Susceptibility. The frost susceptibility of soils is dependent to a large extent on the size and distribution of voids in the soil mass. Voids must be of a certain critical size for the development of ice lenses. Empirical relationships have been developed correlating the degree of frost susceptibility with the soil classification and the amount of material finer than 0.02 mm by weight. Soils are categorized into four groups for frost design purposes: Frost Group 1 (FG-l), FG-2, FG-3, and FG-4. The higher the frost group number, the more susceptible the soil, i.e., soils in FG-4 are more frost susceptible than soils in frost groups 1, 2, or 3. Table 2-3 defines the frost groups.

b. Depth of Frost Penetration. The depth of frost penetration is a function of the thermal properties of the pavement and soil mass, the surface temperature, and the temperature of the pavement and soil mass at the start of the freezing season. In determining the frost penetration depth, primary consideration should be given to local engineering experience. Residential construction practice, including the experience of local building departments, is generally the best guide to frost penetration depth.

c. Free Water. The availability of free water in the soil mass to freeze and form ice lenses is the third consideration that must be present for detrimental frost action to occur. Water can be drawn from considerable depths by capillary action, by infiltration from the surface or sides, or by condensation of atmospheric water vapor. Generally speaking, if the degree of saturation of the soil is 70 percent or greater, frost heave will probably occur. For all practical purposes, the designer should assume that sufficient water to cause detrimental frost action will be present.

d. Frost Design. The design of pavements to offset seasonal frost effects is presented in Chapter 3. A more detailed and rigorous discussion of frost action and its effects can be found in Research Report No. FAA-RD-74-030, Design of Civil Airfield Pavement for Seasonal Frost and Permafrost Conditions (see Appendix 4).

TABLE 2-3. SOIL FROST GROUPS

FROST GROUP	KIND OF SOIL	PERCENTAGE FINER THAN 0.02 mm BY WEIGHT	SOIL CLASSIFICATION
FG-1	Gravelly Soils	3 to 10	GW, GP, GW-GM, GP-GM
FG-2	Gravelly Soils Sands	10 to 20 3 to 5	GM, GW-GM, GP-GM, SW, SP, SM, SW-SM, SP-SM
FG-3	Gravelly Soils Sands, except very fine silty sands Clays, PI above 12	Over 20 Over 15 -	GM, GC SM, SC CL, CH
FG-4	Very fine silty sands All Silts Clays, PI = 12 or less Varved Clays and other fine grained banded sediments	Over 15 - - -	SM ML, MH CL, CL-ML CL, CH, ML, SM

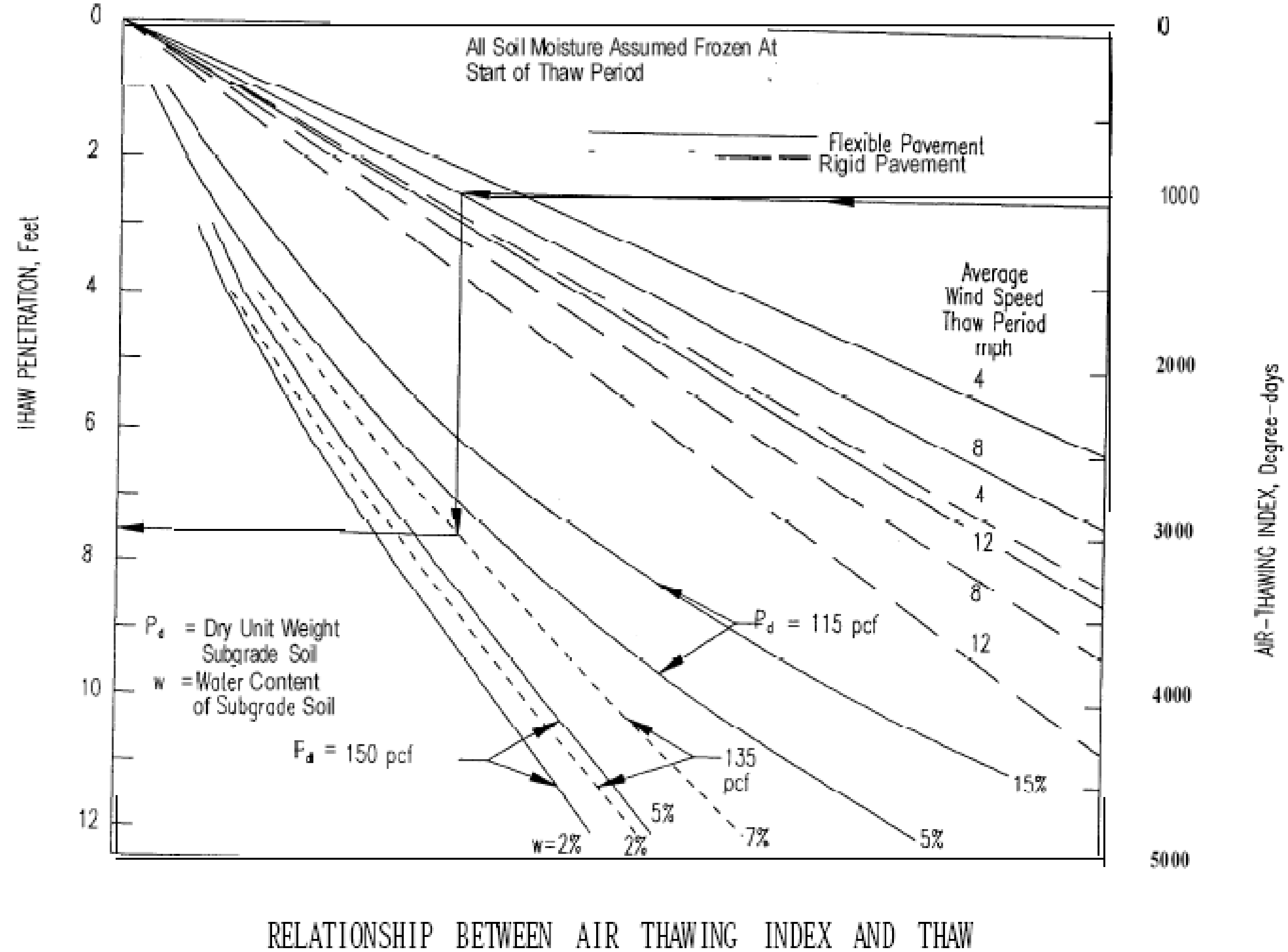
208. PERMAFROST. In arctic regions, soils are often frozen at considerable depths year round. Seasonal thawing and refreezing of the upper layer of permafrost can lead to severe loss of bearing capacity and/or differential heave. In areas with continuous high-ice-content permafrost at shallow depths, satisfactory pavements are best ensured by restricting seasonal thawing to the pavement and to a non-frost susceptible base course. This approach is intended to prevent degradation (thawing) of the permafrost layer.

a. Susceptibility. The frost susceptibility of soils in permafrost areas is classified the same as given above in paragraph 207.

b. Depth of Thaw Penetration. Pavement design for permafrost areas must consider the depth of seasonal thaw penetration. Although the Modified Berggren equation (see reference 18, Appendix 4) can theoretically be used with local climatic data to approximate the depth of thawing in permafrost, there are currently no software programs available to do this. However, the depth to which thawing temperatures penetrate into permafrost may be estimated using figure 2-2. Use of figure 2-2 requires inputs of air thawing index, average wind speed during the thaw period, pavement type, and density of the permafrost layer. The air thawing index is expressed in degree days and is the difference between average daily temperature and 32 degrees Fahrenheit (0 degrees Celsius) multiplied by the number of days the temperature exceeds freezing. The thawing index used for design (design thawing index) should be based on the three warmest summers in the last 30 years of record. If 30-year records are not available, data from the warmest summer in the latest 10-year period may be used.

c. Muskeg. Muskeg is sometimes encountered in arctic areas. Muskeg is a highly organic soil deposit that is essentially a swamp. Every effort should be made to avoid pavement construction on this material. If construction in areas of muskeg is unavoidable and the soil survey shows the thickness of muskeg is less than 5 feet (1.5 m), the muskeg should be removed and replaced with granular fill. If the thickness of muskeg is too great to warrant removal and replacement, a 5-foot (1.5 m) granular fill should be placed over the muskeg. These thicknesses are based on experience and it should be anticipated that differential settlement will occur and considerable maintenance will be required to maintain a smooth surface. Use of a geosynthetic between the muskeg surface and the bottom of granular fill is recommended to prevent migration of the muskeg up into the granular till. In this application, the geosynthetic is considered to perform the function of separation. Additional information on the design and construction of geosynthetics performing the separation function within pavement sections is provided in FHWA-HI-95-038 (see Appendix 4).

d. Permafrost Design. Design of pavements in areas of permafrost is discussed in Chapter 3. Further information on permafrost can be found in Research Report No. FAA-RD-74-030 (see Appendix 4).



Note:
1 foot = 0.3048 m
1 pcf = 16.02 kg/m³
1 mph = 1.609 km/h

FIGURE 2-2. RELATIONSHIP BETWEEN AIR THAWING INDEX AND THAW PENETRATION INTO GRANULAR, NON-FROST SUSCEPTABLE SUBGRADE SOIL