Airport Engineering

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SUBGRADES AND SUBBASES

Concrete pavement is very rigid in comparison to the soil that is placed upon. It is this rigidity that allows the pavement to distribute a large gear load to the supporting medium with a minimal pressure increase on the soil.

- A very thick pavement is very rigid, Therefore, a load placed at the center of a panel will be distributed to the supporting medium over the entire bottom of the pavement. As an example, a thick pavement panel will distribute the load over the soil in much the same fashion as does the foundation of a building. A very thin pavement, with the same load, will upwards resulting in a smaller contact area with the supporting soil. The smaller contact area results in higher deformation of the concrete.

- The critical element in pavement performance is the consistency of the supporting soil. A pavement that is designed for a stiff support will have early failure in those areas where the support is significantly less than the design assumptions. It is for the purpose of attaining that continuity that pavements are developed as layered construction.

- Therefore, most design standards include a minimum of a four-inch thickness of gravel or crushed stone as a subbase for pavements 6 inches and thicker. For granular materials, a thicker subbase results in increased uniformity but the effective improvement in support is limited. Figure 1.1 is reproduced from the results of early testing of pavements constructed on granular material.

SUBBASE

- **A subbase is the soil layer (or layers) between the subgrade and pavement. The subbase improves uniformity of the supporting medium, and it also provides a firm surface that will support the operation of construction equipment. In some cases, the weight and track characteristics of the construction equipment may control the thickness and quality of the subbase.**

- There are numerous materials and combinations of material that can used to construct a subbase for airfield pavement.
- They Include:
  - Open graded gravels and crushed stone
  - Dense graded gravels and crushed stone
  - Sands and sandy clays
  - Soil cement
  - Cement-stabilized sands, gravels and crushed stone
  - Asphalt-stabilized sands, gravels and crushed stone
  - Lean concrete or econocrete
  - Flowable fill, recycled, crushed and graded concrete pavement

- **The Federal Aviation Adminstration (FAA) requires a stabilized subbase be used for those pavements that support aircraft traffic greater than 100,000 pounds (45,360 kg).**

- **CONCRETE STRENGTH : Flexural Strength of Concrete**

- GRASP THE IMPLICATIONS OF THE ASSUMPTIONS
- DO NOT MISTAKE SOPHISTICATED ANALYSIS FOR THE TRUTH
- PAVEMENT MATERIALS – ITS MORE THAN JUST STRENGTH
- NO PAVEMENT IS ANY BETTER THAN ITS CONSTRUCTION

CHAPTER 3. PAVEMENT DESIGN
ADVISORY CIRCULAR A/C 150-5320-6D
SECTION 1. DESIGN CONSIDERATIONS

- **DESIGN PHILOSOPHY**

  a. **FLEXIBLE PAVEMENTS**
  b. **RIGID PAVEMENT**

- **BACKGROUND**

  a. **VARIABLES**

- **DETERMINATION OF EQUIVALENT ANNUAL DEPARTURES BY THE DESIGN AIRCRAFT**

  a. **CONVERSIONS**

THE FOLLOWING CONVERSION FACTORS SHOULD BE USED TO CONVERT FROM ONE LANDING GEAR TYPE TO ANOTHER:

TO CONVERT FROM	TO	MULTIPLY DEPARTURES BY
Single wheel	Dual wheel	0.8
Single wheel	Dual tandem	0.5
Dual wheel	Single wheel	1.3
Dual wheel	Dual tandem	0.6
Dual tandem	Single wheel	2.0
Dual tandem	Dual wheel	1.7
Double Dual tandem	Dual tandem	1.0
Double Dual tandem	Dual wheel	1.7


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IAH EIS

Areas of Special Interest

- Wetlands
- Air quality
- Drainage and water quality
- Biotic communities

IAH EIS Findings-
"Preferred Alternative"

- **Noise impacts** – Noise levels decrease
- **Land use** – 1,685 acres of land to be acquired
- **Social** – One small subdivision relocated
- **Air quality** – All build alternatives reduce emissions when compared to "no-build"
- **Historic/ archeological** – No significant impacts

IAH EIS Findings- "Preferred Alternative"

- **Endangered/ threatened species –** No Impacts
- **Biotic communities** – 2,896 acres affected
- **Wetlands** – 100 acres
- **Floodplains** – Detention required
- **Farmlands** – No impacts
- **Hazardous materials** – 1 abandoned land fill to be removed, no known hazardous materials

FAA Record of Decision

- Issued September 8, 2000
- Approved, with conditions, the decision to participate in the proposed Federal actions
- Completes the EIS process

Sustainable Airport Development

Materials, Practices, and Principles for Environmentally Sustainable Airport Development

Sustainable
Airport Development

Definition – Sustainable Development

“- - development that maintains or enhances economic opportunity and community well-being while protecting and Restoring the natural environment upon which people and economies depend.

Sustainable development meets the needs of the present without compromising the ability of future generations to Meet their own needs.

Sustainability Factors to be Considered

- Site Planning and Design
- Construction Practices
- Water Resources
- Landscaping
- Building Material Selection
  Life Cycle Assessment

Sustainability Factors to be Considered

- Building Materials
- Waste Reduction
- Energy Effiency
- Indoor Air Quality
- Chemical Use

Recommended reference

Leadership in Energy and Environmental (LEED), US Green Building Council - **www.usgbc.org**

Notify FAA -

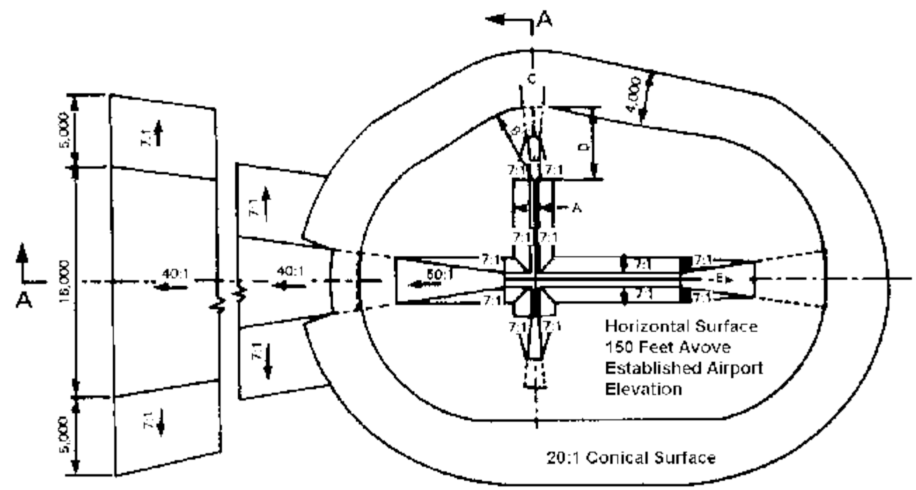
More than 200’ above ground

Above imaginary surface

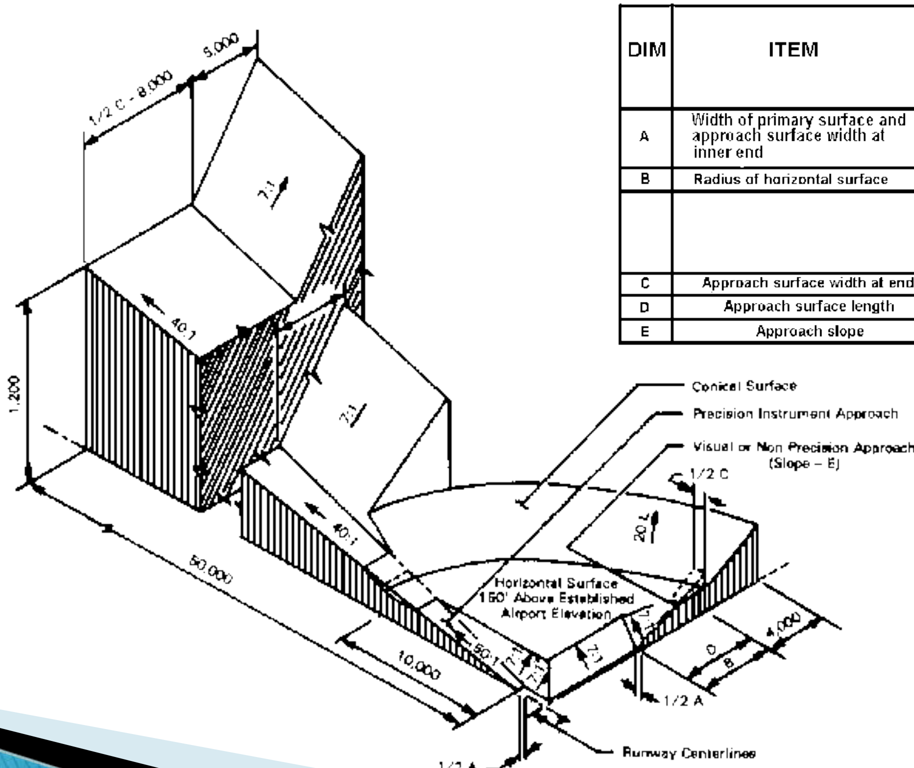
- 100:1 slope from runway > 3,200’
- 50:1 slope from runway < or = 3,200’
- 25:1 slope – heliports

Construction ON a public – use airport

FAR Part 77 Airport Imaginary Surfaces



DIM	ITEM	Dimensional Standards (Feet)					
		Visual Runway		Non-Precision Instrument Runway			Precision Instrument Runway
		A	B	A	B		
					C	D	
A	Width of primary surface and approach surface width at inner end	250	500	500	500	1,000	1,000
B	Radius of horizontal surface	5,000	5,000	5,000	10,000	10,000	10,000
		Visual Approach		Non-Precision Instrument Approach			Precision Instrument Approach
		A	B	A	B		
					C	D	
C	Approach surface width at end	1,250	1,500	2,000	3,500	4,000	16,000
D	Approach surface length	5,000	5,000	5,000	10,000	10,000	*
E	Approach slope	20:1	20:1	20:1	34:1	34:1	*



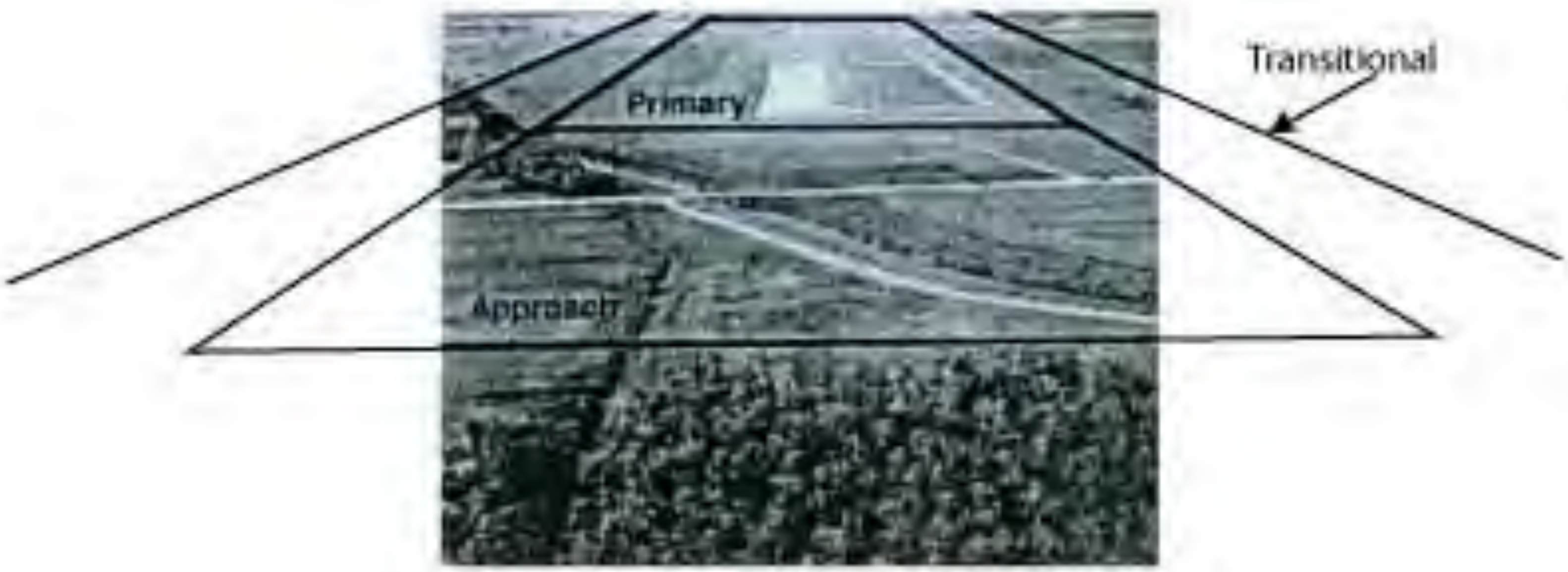
Airport Imaginary Surfaces

Approach Surface
- Slopes: 20:1, 34:1, 50:1
- Length: 5000', 10,000', 50,000'

Primary Surface
- Runway Elevation, extends 200' beyond runway end

Transitional Surface
- Slope 7:1 to Horizontal Surface

Airport Imaginary Surfaces



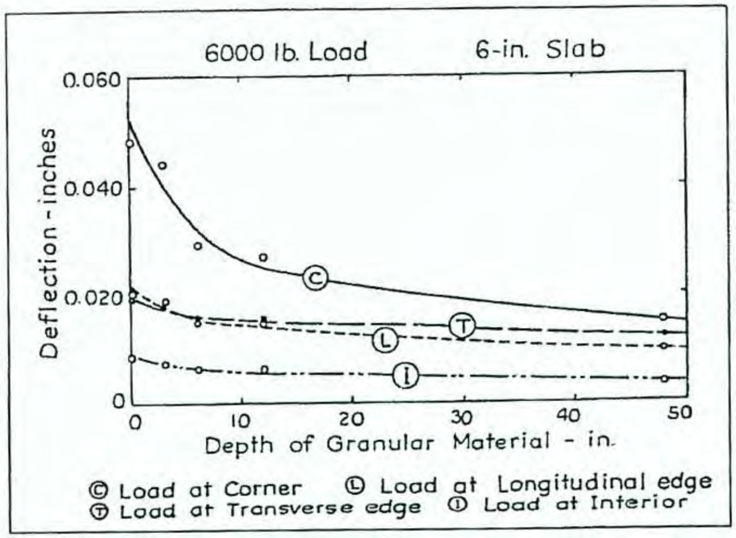


Figure 1.1 Influence of granular subbase thickness on panel deflection [1]

Using chemical or mineral stabilization for both subgrade and/or subbase will significantly increase both consistency and support. Figure 1.2 is reproduced from early research results on stabilized subbases under concrete pavement [2]. In a similar fashion, the combination of stabilized materials and drainage layers improve consistency, improve subbase support, and minimize the potential for the development of soft spots which are the result of standing water. The combinations of materials that are available to the designer and constructor are numerous.

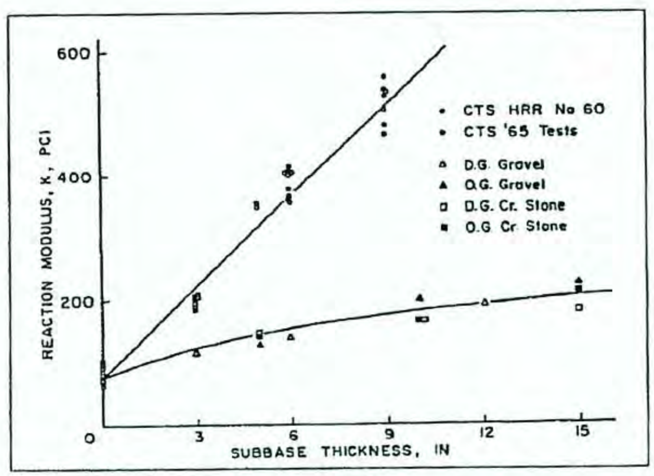


Figure 1.2 Effect of cement-treated and granular subbase thickness on k-value [2]
(subgrade k-value = 80)

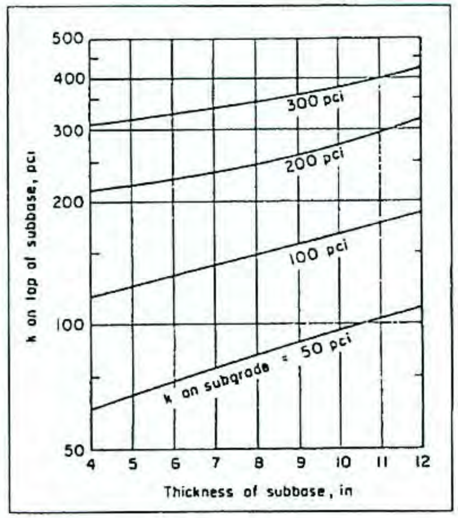


Figure 1.3 Effect of granular subbase thickness on k-value
(subgrade k-value = 50, 100, 200, 300)

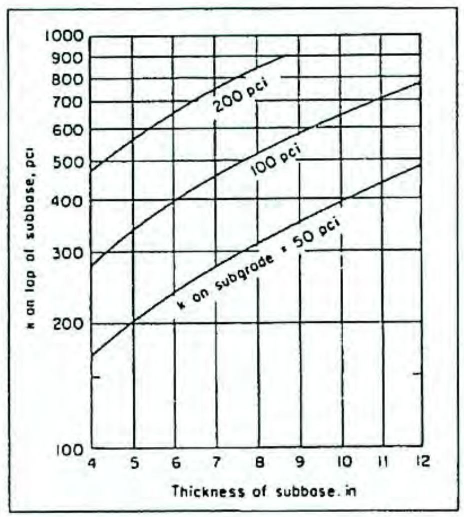


Figure 1.4 Effect of cement-treated subbase thickness on k-value
(subgrade k-value = 50, 100, 200, 300)

The following information is provided to give the user knowledge about how subgrade and subbase improvement techniques can be used to achieve the best performance of concrete pavement and achieve the most economical cross section. The user should understand that the use of standard details for the design of subgrade, subbase and pavement is limited to single geographic locations where the optimum combination of pavement layers has already been developed.

Subbase

A subbase is the soil layer (or layers) between the subgrade and pavement. The subbase improves uniformity of the supporting medium, and it also provides a firm surface that will support the operation of construction equipment. In some cases, the weight and track characteristics of the construction equipment may control the thickness and quality of the subbase.

There are numerous materials and combinations of materials that can be used to construct a subbase for airfield pavement. They include:

- Open graded gravels and crushed stone
- Dense graded gravels and crushed stone
- Sands and sandy clays
- Soil cement
- Cement-stabilized sands, gravels and crushed stone
- Asphalt-stabilized sands, gravels and crushed stone
- Lean concrete or econocrete
- Flowable fill, and
- Recycled, crushed and graded concrete pavement

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Measurement of Supporting Stiffness

The quantitative value of the support provided by the subgrade was quantified by Westergaard under the term "Modulus of Subgrade Reaction." [3] The modulus is expressed in equations as "k" and the units are pounds per square inch per inch (lbs/in^3 or pci). The units are derived from the method used to determine the value of "k." The standard test for determining "k" is to place a load on a standard 30-inch diameter steel plate, calculating the pressure [load divided by area of the plate] and measuring the rate of deformation (ASTM D 1196).

The pavement is designed based upon the "k" value on top of the supporting medium. The subgrade may have a value of "k" = 100, but the improved "k" that results from the placement of the subbase is used as the design value. All pavement design procedures that use Westergaard's analysis of concrete pavement stress [3] limit the maximum value of "k" to be 500 pci. This is because of the difficulty in measuring (and the resultant variability) "k" on very rigid subbase material. However, the designer must be cautious about using the maximum allowable value for "k" when doing pavement detailing. As an example, the calculations that are accomplished to establish the joint spacing are directly variable to the "k" value. Using the value of 500 pci could easily result in a design error when the actual "k" will exceed 750 pci when rigid subbase materials are used. Figure 1.5 is an example of the change in joint spacing that occurs as a result of increased "k" values.

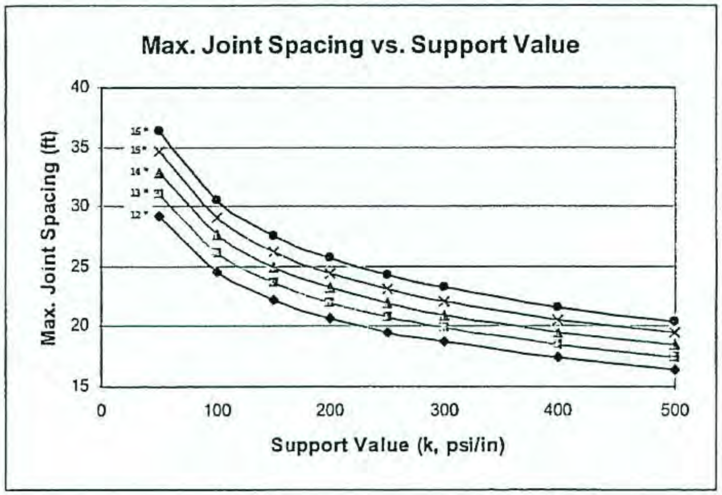


Figure 1.5 Maximum joint spacing (6ℓ) vs. support value

The standard method of determining "k" is by loading the 30-inch plate placed upon the subgrade. However, this standard test is very seldom utilized. The testing procedure is invasive, cumbersome, and literally cannot be accomplished at an active airport. There are, however, other ways to determine the subgrade value of "k." Empirical relationships are available through many sources that equate "k" to the soil type based upon classification or California Bearing Ratio (CBR) correlations. The most convenient method for determing "k" is by backcalculation from the evaluation of existing pavements using the Falling Weight Deflectometer (FWD) and the associated software.

The value of "k" used for the subgrade need not be exact. The value of "k" used for design is an "improved" value that is based upon the type and thickness of subbase. The design of the pavement is accomplished using the "k" measured on top of the subbase. It is nearly impossible to measure the improved "k" because the subbase is constructed and the pavement immediately follows. It is nor reasonable to design the subbase, build it, and then measure "k."

Since the "improved" value is estimated, it is usually adequate to round the subgrade "k" to the nearest 10 when the "k" is less than 100 and to the nearest 25 when the "k" exceeds 100. This approximation of "k" is not detrimental to the design thickness determination, because a change of 100 pci for a multiple-wheel aircraft impacts the required thickness by less than one-half inch. And, in most cases, the design thickness is rounded up to the nearest full inch for the actual construction.

Special Subgrade Conditions

There are three subgrade soil conditions resulting in variable support that must be controlled by subgrade improvement.

- Expansive Soils
- Frost Action
- Soils Vulnerable to Pumping

Effective mitigation of expansive soil conditions and frost action is achieved through special subgrade preparation techniques. The prevention of pumping requires the use of a subbase layer.

Expansive Soils

Excessive differential shrink and swell of expansive soils cause non-uniform subgrade support. As a result, concrete pavements usually become distorted enough to adversely affect pavement smoothness. Several conditions can lead to variable support:

1. When expansive soils are compacted when too dry or are allowed to dry out prior to paving, variable expansion may occur after the pavement is placed and cause pavement roughness.
2. When expansive soils are too wet prior to paving, subsequent variable shrinkage may leave the slab edges unsupported.
3. When concrete pavements are placed on expansive soils with widely varying moisture contents, subsequent shrink and swell may cause bumps, depressions, or waves in the pavement surface.

Variable support and pavement roughness caused by shrink and swell of expansive soils are most likely to occur in arid, semi-arid, or sub-humid regions. Objectionable distortion can also occur in humid climates during periods of drought or during dry periods in the summer months.

In all climatic areas, expansion and softening of the subgrade during wet periods occurs more rapidly at joints and along pavement edges because of moisture infiltration. The resultant differential support often results in pavement distress because the subgrade soils beneath the pavement cannot adjust to the changing moisture content and climatic environment.

The following measures provide effective and economical control of expansive soils:

1. Subgrade grading operations. Selective grading, cross-hauling, and mixing of subgrade soils make it possible to have reasonably uniform conditions in the upper part of the subgrade, with gradual transitions between soils of varying volume-change properties.

2. Non-expansive cover. In areas with prolonged periods of dry weather, highly expansive subgrades may require a cover layer of low-volume-change soil placed full width over the subgrade. This layer minimizes changes in the moisture content of the underlying expansive soil and also has some surcharge effect. If the low-volume-change layer has low to moderate permeability, it is not only more effective but usually less costly than a permeable, granular soil. Highly permeable, open-graded subbase materials are not recommended as cover for expansive soils since they permit greater changes in subgrade moisture content.

3. Cement or Lime Modified Subgrade. The treatment of expansive clay soils with cement, fly ash, cement kiln dust and/or lime is very effective not only in reducing volume changes, but also in increasing the bearing strength of subgrade soils. Because of this, it may be desirable and economical in some cases to modify existing soils instead of importing subbase material or cross-hauling. Local experience with stabilization should be validated because some expansive soils react to chemical changes by differential swelling.

The amount of stabilizing agent for the control of volume change and increase in strength must be based on laboratory test results.

Frost-susceptible Soils

Frost-action damage can result in two conditions; frost heave – an abrupt, differential heave, or reduced support due to spring thaw and resultant saturated subgrade.

Frost damage to concrete pavement is controlled by reducing the variability of the subgrade soil, reducing the exposure of frost susceptible soils, and controlling the moisture conditions that lead to objectionable differential heaving – especially where subgrade soils change abruptly from non-frost-susceptible soils to the highly frost-susceptible fine sands and silts.

Criteria and soil classifications used for identifying frost-susceptible soils usually reflect susceptibility to both heaving and softening during thaw. Therefore, soil data must be reviewed to distinguish between data for soils susceptible to heave and data for soils susceptible to softening after thaw.

The degree of frost susceptibility can be approximated by the hydraulic properties of soils: (1) capillarity – the soil's ability to pull moisture by capillary forces; and (2) permeability – the soil's ability to transmit water through its voids. The worst heaving usually occurs in fine-grained soils subject to capillary action. Low-plasticity soils with a high percentage of silt-size particles are particularly susceptible to frost heave. These soils have pore sizes small enough to develop capillary potential but large enough for passage of water to the frozen zone. Coarser soils have higher rates of flow, but not the capillary potential to lift enough moisture for the formation of ice lenses. More cohesive soils such as clays, although developing high capillarity, have low permeability and water moves too slowly for growth of the thick ice lenses that cause damage.

As in the case of expansive soils, a large degree of control of frost action is accomplished most economically by appropriate grading operations and by controlling subgrade compaction and moisture. These methods include:

1. Selective grading and mixing. These operations are used to replace localized areas of highly frost-susceptible soils and to transition soils to correct abrupt changes in soil types. Where soils

Table 1 Typical Analytical Models Used For Concrete Pavement Analysis And Design		
Model	Characteristics	Selected References
Westergaard Interior Load Model	Load at the interior of an infinite elastic plate resting on a bed of springs (Winkler foundation)	Westergaard 1926, Packard 1973, Yoder and Witczak 1975, Huang 1993
Westergaard Edge Load Model	Load adjacent to a free edge of an elastic plate infinite in the other three horizontal directions and resting on a bed of springs (Winkler foundation)	Westergaard 1948, Yoder and Witczak 1975, Rollings 1989, Rollings and Pittman 1992
Layered Elastic Model	Circular surface loads on a sequence of homogeneous, horizontal, elastic layers that, depending on specific solution used, may have varying interface conditions (Burmister foundation)	Yoder and Witczak 1975, Parker et al 1979, Rollings 1988, Huang 1993
Finite Difference Model	Finite difference representation of pavement slab on springs (Winkler foundation) or elastic solid (Boussinesq foundation)	Hudson and Matlock 1966, Saxena 1973
Prismatic Finite Element Model	Finite element model of pavement using 2-D prismatic solid elements with loads applied as a Fourier series	Pichumani 1973, Crawford and Pichumani 1975
Finite Element Models with a Spring Foundation	Finite element model of one or more slabs, typically using four-node plate elements, with material under the slab represented by a bed of springs (Winkler foundation)	Eberhardt 1973, Eberhardt and Willmer 1973, Tabatabie 1978 Ioannides et al 1985b, Tayabji and Colley 1986, Huang 1993
Hybrid Finite Element Models	Finite element model of one or more slabs, typically using four-node plate elements, with material under the slab represented by the continuous elastic solid (Boussinesq foundation) or layered elastic model (Burmister foundation).	Chou and Huang 198 1, Huang 1993
Generalized 3-D Finite Element Models	Pavement structure modeled using finite elements either completely or using spring foundation for deeper material; some recent work has used 20 to 27 node, reduced integration, isoparametric elements	Kuo 1994, Hammons 1997

During the 1970's, the military elected to develop the layered elastic approach rather than the available finite element methods as the next generation design model to supplement existing design methods. The reasons for this selection were (1) the same model could be used for both rigid and flexible pavements, (2) layered elastic theory was already in use to analyze falling weight deflectometer data for military pavement evaluations, (3) the model had the ability to analyze variable interface friction and layer stiffness which was felt to be particularly desirable for overlay design, (4) it was supportable on existing computers routinely available in military design offices, and (5) the basic design technology and theory was within the grasp of practicing engineers working with military pavements. Layered elastic cannot analyze discontinuities such as joints which is a major disadvantage. However, considering all of the simplifying assumptions currently used in the design process, we in effect only calculate nominal design stresses reflecting the interaction of material properties, thicknesses, and load magnitudes and geometries rather than actual in-situ stresses, this disadvantage did not outweigh the other advantages of the layered elastic model. However, inherent in the Corps of Engineers use of the layered elastic model is the requirement that existing types and qualities of joints capable of load transfer will continue to be used. In 1988 guidance and software were officially issued in the Corps of Engineers and Air Force allowing use of layered elastic theory as an alternative design method to the previous Westergaard based design method for concrete airfield pavements.

of more simple tests such as the compressive or splitting tensile tests on cylinders. This simply reflects the empirical nature of concrete strength testing and how these empirical tests are influenced

Table 2. Methods of Estimating Concrete Tensile Strength Properties

Test	Description	Standard	Comments
Direct Tension	Metal end plates bonded to ends of cylindrical concrete specimen are loaded in direct axial tension	Adaptation of ASTM D 2936 for rock cores	Extremely difficult to fabricate and test specimens; not widely used; other variants of direct tensile testing have been used in the past.
Third-Point Beam	Simply supported beam with a span of three times its depth is loaded at third points which induces a uniform moment over center portion of beam. Simple beam theory is used to calculate stress at bottom of the beam.	ASTM C 78	Probably the most widely used test to estimate flexural strength of concrete; also commonly referred to as modulus of rupture; test results are very sensitive to drying and proper testing procedures.
Center-Point Beam	Simply supported beam with a span of three times its depth is loaded at the center which induces a maximum moment at the center of the beam. Stress calculation is same as for third-point beam.	ASTM C 293	Results are typically 10 to 15% higher than third-point beam test; coefficient of variation of test results is typically also higher; very sensitive to drying and proper testing procedures.
Splitting Tensile	A cylindrical concrete specimen is subjected to a diametral compressive force along its length which induces a tensile zone over most of the specimen's diameter	ASTM C 496	Gives results lower than third-point beam test; over estimates true tensile strength because of deviations between theory and testing conditions; specimens easier to fabricate and test than beams; coefficient of variation usually lower than beam tests.
Ring	Hydrostatic pressure applied to the inside of a concrete ring specimen, and inner wall stress is calculated as for an elastic medium thick cylinder.	Malhotra et a 1966	Because of deviations from theory used to calculate stresses, over estimates true tensile strength; not widely used.
Double Punch	Compressive load applied to ends of cylindrical specimen through bearing blocks smaller than specimen inducing tensile zone similarly to splitting tensile test.	Chen 1970	Does not preselect failure plane so results are lower than splitting tensile test; results are sensitive to specimen size; not widely used.

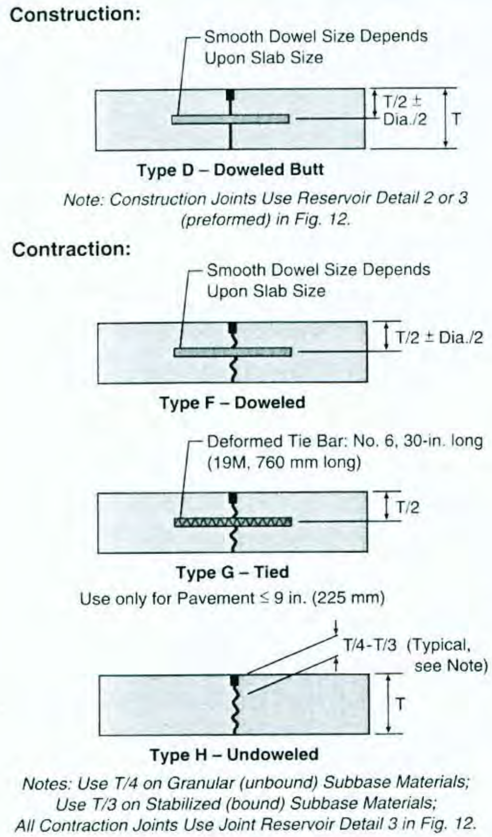
differently by various concrete parameters. For example, whether aggregate is crushed or uncrushed has negligible impact on concrete compressive strength, but crushing aggregate increases concrete strength determined from beam tests. Therefore the commonly used general relationships between beam flexural strength and compressive strength must be a function of aggregate (as well as other parameters).

A commonly used relationship is of the form

$$f_t = C\,(f'_c)^{1/2}$$

where

f_t = flexural strength determined from beam tests



Construction Joints — Construction joints separate abutting construction placed at different times, such as at the end of a day's placement, or between paving lanes. Load transfer at construction joints is achieved through the use of dowel bars. Figure 1, Type D shows a standard construction joint detail.

Contraction Joints — Contraction joints control the location of pavement cracking caused by drying shrinkage and/or thermal contraction. Contraction joints are also used to reduce the stress caused by slab curling and warping. Load transfer is usually accomplished by aggregate interlock. However, dowel bars may be used for load transfer at contraction joints under certain conditions. Figure 1, Types F, G and H show contraction joint details.

Isolation Joints — The purpose of an isolation joint is to separate intersecting pavements and to isolate embedded fixtures within the pavement (pavement penetrations) such as for in-pavement drains. There are two types of isolation joints: Figure 1, Type A and B.

Type A doweled isolation joints provide load transfer with dowel bars. A 0.75-in (19-mm) non-extruding compressible material provides the separation between two abutting pavements.

Type B isolation joints do not use dowel bars, but use increased thickness along the joint to reduce tensile stresses in the slab and bearing stresses on the subbase or subgrade. This type of isolation joint is preferable where a pavement carrying active traffic abuts a structure (i.e., building) or where horizontal and vertical differences in movement of the pavements are anticipated. Separation is provided with a non-extruding compressible material.

Type B undoweled isolation joints allow the pavement freedom of movement laterally and an embedded fixture freedom of movement vertically, with no mechanical interconnection.

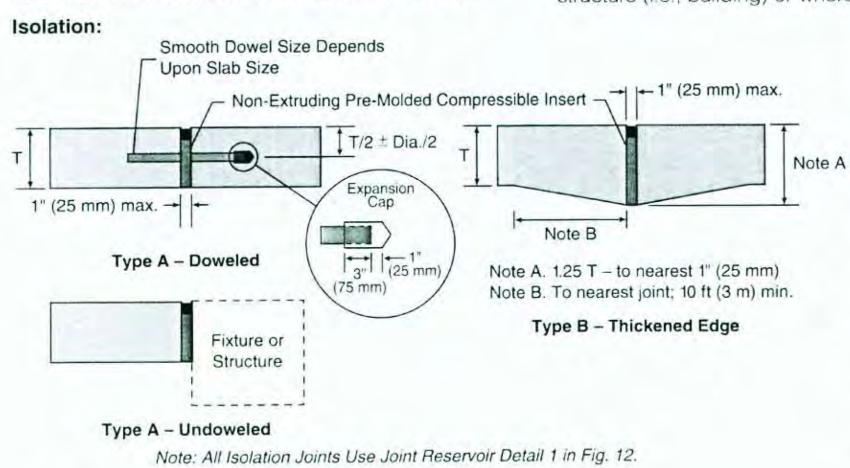


Figure 1. Joint Types for Airfields.

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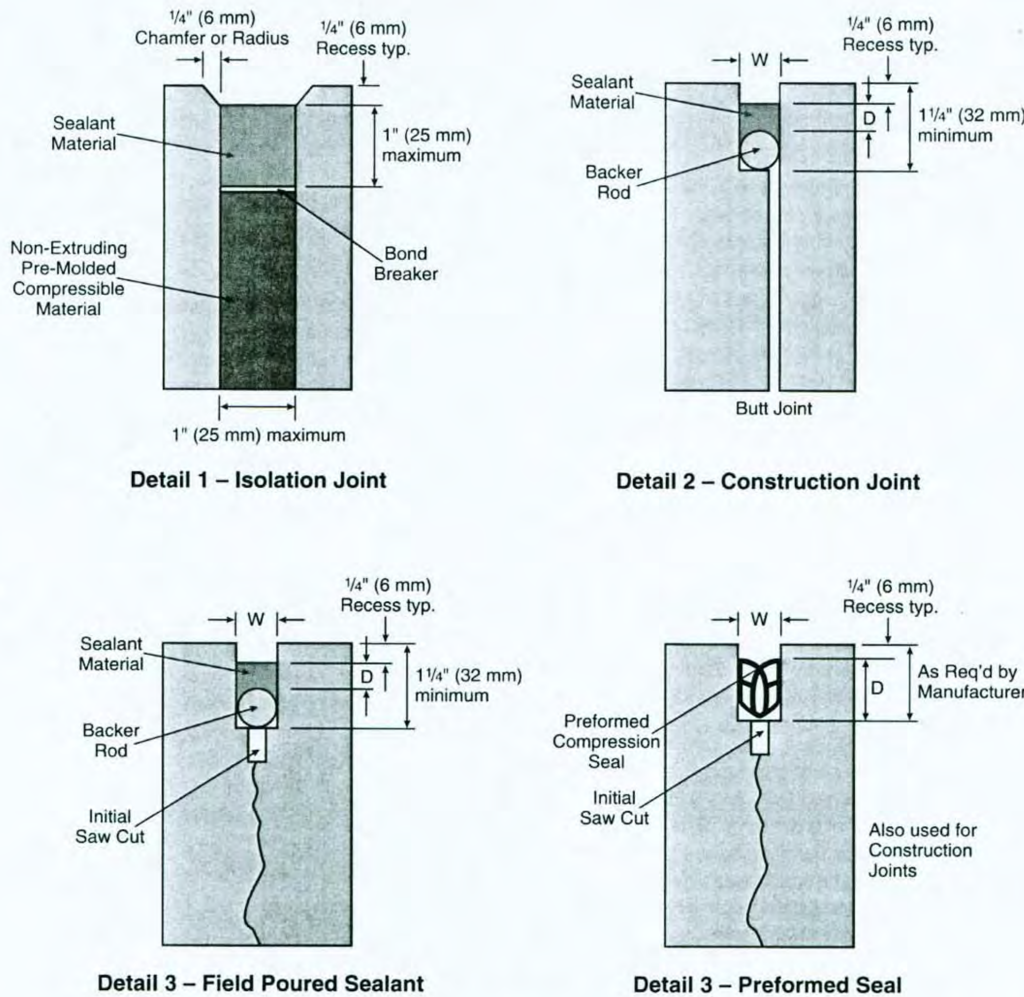

Hot-Poured Sealant – W/D = 1 (typical)
Silicone Sealant – W/D = 2 (typical)
Two-Component Cold Poured Sealant – W/D = 2 (typical)
Preformed Compression Seal – W Sized for Slab & Climate

Figure 12. Joint sealant reservoir design options for airfield pavement.

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NEW ACs

- **April 16, 2004:** Updated Addendum to 150/5345-53B, Airport Lighting Equip Program.
- **April 13, 2004:** Added 150/5380-8, Handbook for Indentification of Alkali-Silic Airfield Pavements.
- **April 9, 2004:** Added Change 7 of 150/5200-30A, Airport Winter Safety and updating Appendix 4.
- **February 15, 2004:** Replaced Appendices 12 and 13 of 150/5300-13, Airpor Aircraft Characteristics Database.

AIRPORT PLANNING

150/5000-5C Designated U.S. International Airports (12-4-96). (AAS-3) Explains the categories of U.S. airports designated to serve international air traffic and provides a airports.

150/5000-7 Announcement of Availability Report No. DOT/FAA/PP/87-1, Measuring Economic Significance of Airports (5-12-87). (APP-400)

150/5000-9A Announcement of Availability Report No. DOT/FAA/PP/92-5, Guideline Insulation of Residences Exposed to Aircraft Operations (7-2-93). (APP-510)

150/5000-10A Announcement of Availability Report No. DOT/FAA/PP/-92-6, Estimat Economic Significance of Airports (7-2-93). (APP-400)

150/5000-11 Announcement of Availability: All Cargo Carrier Activity Report (FAA Fo

Revised) (3-34-93). (APP-400) Provides guidance for the submission of the All Carg
Report (revised as of March 1993).

150/5000-12 Announcement of Availability: Passenger Facility Charge (PFC) Applic
5500-1) (7-15-94). (APP-530) Provides guidance for the submission of the PFC appl
recent versions of the PFC application.

150/5000-13 Announcement of Availability: RTCA Inc., Document RTCA-221, Guida
Recommended Requirements for Airport Surface Movement Sensors (9-7-94). (AAS

150/5020-1 Noise Control and Compatibility Planning for Airports (8-5-83). (APP-60
guidance for noise control and compatibility planning for airports as well as specific
preparation of airport noise exposure maps and airport noise compatibility programs
operators for submission under Federal Aviation Regulation Part 150 and the Aviatic
Abatement Act of 1979. Contains an expanded Table of Land Uses Normally Comp
Levels of Noise.

150/5050-3B Planning the State Aviation System (1-6-89). (APP-400) Provides gene
preparing a State airport system plan. ($3.75 Supt. Docs.) SN 050-007-00813-9.

150/5050-4 Citizen Participation in Airport Planning (9-26-75). (APP-600). Provides
involvement in airport planning. Although not mandatory for airport grant programs, i
for early citizen participation.

150/5050-7 Establishment of Airport Action Groups (6-23-87). (AAS-300). Provides
establishment of airport action groups.

150/5060-5 Airport Capacity And Delay (9-23-83). (AAS-100). (Consolidated reprint
Explains how to compute airport capacity and aircraft delay for airport planning and

> 150/5060-5 Change 2 (12-1-95). (AAS-100). Reflects the increased capacity
> from a change in parallel runway separation criteria, adds a procedure far cal
> savings associated with a reduction in aircraft delay, and updates the capacit
> computer program references.

150/5070-5 Planning the Metropolitan Airport System (5-22-70). (APP-400). Gives g
developing airport-system plans for large metropolitan areas. It may be used by met
agencies and their consultants in preparing such system plans and by the FAA in re
($5.50 Supt. Docs.) SN 050-008-00003-7.

150/5070-6A Airport Master Plans (6-85). (APP-400). Provides guidance for the pre
master plans, pursuant to the provisions of the Airport and Airway Improvement Act
Supt. Docs.) SN 050-007-00703-5.

FEDERAL-AID AIRPORT PROGRAMS

150/5100-6D Labor Requirements for the Airport Improvement Program (AIP) (10- 1
Encompasses the basic labor and associated requirements for the Airport Improvem
(ADAP). It is intended for sponsors using program assistance and for contractors an
working on projects under the program.

150/5220-17A Design Standards for an Aircraft Rescue and Firefighting Training Fa((AAS-100). Contains standards, specifications, and recommendations for the design rescue and firefighting training facility utilizing either propane or a flammable liquid h as the fuel.

150/5220-17A Chg. 1 (11-24-98). Change 1 to Design Standards for an Aircr and Firefighting (ARFF) Training Facility.

150/5220-18 Buildings For Storage and Maintenance of Airport Snow and Ice Contrc Materials (10-15-92). (AAS- 100). Provides guidance for site selection, design and c buildings used to store and maintain airport snow and ice control equipment and ma

150/5220-19 Guide Specification for Small Agent Aircraft Rescue and Fire Fighting \ (AAS-100). Contains performance standards, specifications, and recommendations construction, and testing of a family of small, dual agent aircraft rescue and fire fight vehicles.

150/5220-20 Airport Snow and Ice Control Equipment (6-30-92). (AAS-100). Provide assist airport operators in the procurement of snow and ice control equipment for air

150/5220-20 Chg. 1 (3-1-94). This change provides guidance to airport opera involved in the procurement of snow sweepers to control ice and snow at airp inclement weather.

150/5220-21B Guide Specification for Devices Used to Board Airline Passengers wi Impairments (3-17-00). (AAS- 100). Contains performance standards, specifications recommendations for the design, construction, and testing of devices used to assist airline passengers with mobility Impairments.

150/5220-22 Engineered Materials Arresting Systems (EMAS) for Aircraft Overruns 100). Contains standards for the planning, design, and installation of EMAS in runw

150/5220-22 Chg 1 (10/06/00). Guidance in installing EMAS where the area a no longer than required, based on stopping the designed aircraft exiting the ru knots, has been added to paragraph 6.b.

150/5230-4 Aircraft Fuel Storage, Handling, and Dispensing On Airports (8-27-82). ((Consolidated reprint includes changes 1 and 2). Provides information on aviation fu airport storage and the handling, cleaning, and dispensing of fuel into aircraft.

DESIGN CONSTRUCTION, AND MAINTENANCE--GENERAL

150/5300-7B FAA Policy on Facility Relocations Occasioned by Airport Improvemen 8-72). (ABU-10). Reaffirms the aviation community of the FAA policy governing resp funding relocation, replacement and modification to air traffic control and air navigati made necessary by improvements or changes to the airport.

150/5300-9A Predesign, Prebid, and Preconstruction Conferences for Airport Grant (AAS-100). Provides guidance for conducting predesign, prebid, and preconstructior projects funded under the FAA airport grant program.

150/5300-13 Airport Design (9-29-89). (AAS- 110). (Consolidated reprint includes ch Contains the FAA's standards and recommendations for airport design. ($20.00 Sup 007-01046-0. This AC is very large and therefore is broken into the following sectior downloading: Chapters [1-8] Appendices [1-11] [12] [13-18]

Aircraft Characteristic Database (2-13-04). This replaces Appendices 12 and AC 150/5300-13.

150/5300-13 Chg 5 (2-14-97). Provides guidance to assist airport sponsors in evaluation and preparation of the airport landing surface to support instrumen procedures and incorporates change 4 criteria into the airport layout plan pre guidance.

150/5300-13 Chg 6 (9-30-00). Provides expanded guidance for new approach and incorporates new Flight Standards requirements.

150/5300-13 Chg 7 (10-1-02). Provides new guidance consistent with Runwa Area Program requirments, clarifies nighttime threshold siting requirements, a new instrument approach procedures and requirements for preparing airport l [HTML version]

150/5300-14 Design of Aircraft Deicing Facilities (8-23-93). (AAS-100). Provides sta specifications, and guidance for designing aircraft deicing facilities.

150/5300-14 Change 1 (8-13-99). Design of Aircraft Deicing Facilities, Chang change updates the definitions of aircraft deicing facilities and holdover times design criteria for aircraft de/anti-icing fluid storage and transfer systems, info concerning recycling of glycols, and references.

150/5300-14 Change 2 (8-31-00). Design of Aircraft Deicing Facilities, Chang change provides standards and recommendations to build infra-red aircraft de facilities and adds anaerobic bioremediation as an alternative method to mitig runoff effects of de/anti-icing products. (AAS-100)

150/5300-15 Use of Value Engineering for Engineering and Design of Airport Grant (AAS-100). Provides guidance for the use of value engineering (VE) in airport projec Airport Grant Program.

150/5320-5B Airport Drainage (7-1-70).(AAS-100). Provides guidance for engineers, and the public in the design and maintenance of airport drainage systems. This docu five parts for easier downloading. [1] [2] [3] [4] [5]. ($5.50 Supt. Docs.) SN 050-007-C

150/5320-6D Airport Pavement Design and Evaluation (1-30-96). (AAS-100). Provid public for the design and evaluation of pavements at civil airports. This AC is very la broken into the following sections for downloading: [1] [2] [3] [4] [5]

150/5320-6D Change 1 (1-30-96). Corrects errors in the graph for Figure 2-4, Subbase on Modulus of Subgrade Reaction, and changes a typographical err paragraph 339b.

150/5320-6D Change 2 (6-3-02). Incorporates recent changes and correction version]

150/5320-12C Measurement, Construction, and Maintenance of Skid Resistant Airp Surfaces (3-18-97). (AAS-100). Contains guidelines and procedures for the design a skid-resistant pavement; pavement evaluation, without or with friction equipment; an high skid-resistant pavements.

150/5320-14 Airport Landscaping for Noise Control Purposes (1-31-78). (APP-400). to airport planners and operators in the use of tree and vegetation screens in and ar

150/5320-15 Management of Airport Industrial Waste (2-11-91). (AAS-100). Provide on the characteristics, management, and regulations of industrial wastes generated

150/5320-15 Change 1 (4-22-97). This change provides guidance on best ma practices to eliminate, prevent, or reduce pollutants in storm water runoff ass airport industrial activities.

150/5320-16 Airport Pavement Design for the Boeing 777 Airplane Provides thickne standards for pavements intended to serve the Boeing 777 airplane. Download Pave Computer Program.

150/5325-4A Runway Length Requirements for Airport Design (1-29-90). (AAS-110) reprint includes Change 1 dated 3-11-91). Provides design standards and guidelines recommended runway lengths. This AC is very large and therefore is broken into th for downloading: [1] [2] [3] [4] [5] [6] [7]

150/5335-5 Standardized Method of Reporting Airport Pavement Strength PCN (6- 1 Provides guidance for using the standardized International Civil Aviation Organizatio to report airport pavement strength. The standardized method is known as the ACN/ AC is very large and therefore is broken into the following sections for downloading:

150/5335-5 Change 1 (3-6-87).

150/5340-1H Standards for Airport Markings (8-31-99). (AAS-300). Describes the s markings used on airport runways, taxiways, and aprons. NOTE: This AC has three [Figures 1-10], [Figures 11-20], and [Appendix 1 (Figures 1-5)].

150/5340-1H Change 1 Standards for Airport Markings (12-01-00). (AAS-300 increase the size of various holding position markings to improve conspicuity thereby, reduce surface incidents, including runway incursions.

150/5340-4C Installation Details for Runway Centerline Touchdown Zone Lighting S (AAS-100). (Consolidated reprint includes Changes 1 and 2). Describes standards f installation of runway centerline and touchdown zone lighting systems.

150/5340-5B Segmented Circle Airport Marker System (12-21-84). (AAS-100). (Con includes change 1). Sets forth standards for a system of airport marking consisting c and traffic control devices.

150/5340-14B Economy Approach Lighting Aids (6-19-70). (AAS-100). (Consolidate Changes 1 and 2). Describes standards for the design selection, siting, and mainten approach lighting aids.

150/5340-14B Change 3 Updates AC 150/5340-14B.

150/5340-17B Standby Power for Non-FAA Airport Lighting Systems (1-6-86). (AAS standards for the design, installation, and maintenance of standby power for non-ag visual aids associated with the National Airspace System (NAS) and the national sys

150/5340-18C Standards for Airport Sign Systems (7-31-91). (AAS-4). Contains the Administration standards for the siting and installation of signs on airport runways ar

150/5340-18C Change 1 (11-13-91).

150/5340-19 Taxiway Centerline Lighting System (11-14-68) is cancelled as of 9-1-9 150/5340-28.

150/5340-21 Airport Miscellaneous Lighting visual Aids (3-25-71). (AAS-100). Descr the system design, installation, inspection, testing, and maintenance of airport misce aids; i.e., airport beacons, beacon towers, wind cones, wind tees, and obstruction lig

150/5340-23B Supplemental Wind Cones (5-11-90). (AAS-100). Describes criteria fc performance of supplemental wind cones.

150/5340-24 Runway and Taxiway Edge Lighting System (9-3-75). (AAS-100). (Con includes change 1). Describes standards for the design, installation, and maintenanc taxiway edge lighting.

150/5340-26 Maintenance of Airport Visual Aid Facilities (8-26-82). (Spanish Langua Available). (AAS-100). Provides recommended guidelines for maintenance of airport

150/5340-27A Air-to-Ground Radio Control of Airport Lighting Systems (3-4-86). (AA the FAA standard operating configurations for air-to-ground radio control of airport li

150/5340-28 [Appendix 2 (figures 1-15)] [Appendix 2 (figures 16-30)] Low Visibility Systems (9-1-98). (AAS-100). Describes the standards for design, installation, and low visibility taxiway lighting systems, including taxiway centerline lights, stop bars, r and clearance bars. *NOTE: This AC is provided in 3 files due to the size of the files. 12 are intended as 11"x17" foldouts. For best results, print these drawings on legal copier to enlarge to 11"x17" (121%).*

150/5340-29 [Appendix 2- Figures] Installation Details for Land and Hold Short Light 30-99). (AAS-100). Describes standards for the design, installation, and maintenanc short lighting systems.

150/5345-1V Approved Airport Equipment (6-6-97). (AAS-100). AC 150/5345-1U is reference to AC 150/5345-1...shall be replaced with AC 150/5345-53.

150/5345-3E Specification for L-821 Panels for Control of Airport Lighting (9-1-98).

Provides the specified manufacturing requirements for panels used for remote contr and auxiliary systems.

150/5345-5A Circuit Selector Switch (3-23-82). (AAS-100). This advisory circular co specification for a circuit selector switch for use in airport lighting circuits.

150/5345-7E Specification for L-824 Underground Electrical Cable for Airport Lightin (AAS-100). Describes the specification requirements for L-824 electrical cables. (HT

150/5345-10E Specification for Constant Current Regulators Regulator Monitors (10 100). Contains a specification for constant current regulators used on airport lighting monitor that reports on the status of the regulator. Airport Technical Advisory on Ele Interference (EMI).

150/5345-12C Specification for Airport and Heliport Beacon (1-9-84). (AAS-100). Co specifications for light beacons which are used to locate and identify civil airports, se heliports.

150/5345-13A Specification for L-841 Auxiliary Relay Cabinet Assembly for Pilot Co Lighting Circuits (8-8-86). (AAS-100). Contains the specification requirements for a r to control airfield lighting circuits. The L-841 consists of an enclosure containing a D control circuit protection and 20 pilot relays.

150/5345-26C FAA Specification for L-823 Plug and Receptacle, Cable Connectors 100). Describes the subject specification requirements.

150/5345-27C Specification for Wind Cone Assemblies (7-19-85). (AAS-100). This a contains a specification for wind cone assemblies to be used to provide wind inform aircraft.

150/5345-28D Precision Approach Path Indicator (PAPI) Systems (5-23-85). Reprin Change 1. (AAS-100). Contains the Federal Aviation Administration (FAA) standard Approach Path Indicator (PAPI) systems which provide pilots with visual glideslope approach for landing.

> 150/5345-28D Change 1 (11-1-91). (AAS-250).

150/5345-39B FAA Specification L-853, Runway and Taxiway Centerline Retroreflec 80). (AAS-100). (Consolidated reprint includes changes 1). Describes specification 853 Runway and Taxiway Retroreflective markers, for the guidance of the public.

150/5345-42C Specification for Airport Light Bases, Transformer Houses, Junction E Accessories (6-8-89). (AAS-100). Contains specification for containers designed to s bases, transformer housings, junction boxes and related accessories (Incorporates (

> 150/5345-42C Change 1 (10-29-91). (AAS-100). Corrects, clarifies, and revis of the specification and corrects drafting errors.

150/5345-43E Specification for Obstruction Lighting Equipment (10-19-95). (AAS-10 FAA specification for obstruction lighting equipment.

150/5345-44F Specification for Taxiway and Runway Signs (1-5-94). (Consolidated change 1). (AAS-100). Contains a specification for lighted and unlighted signs to be and runways.

150/5345-44F Change 1 (8-23-94) Adds a requirement to the qualification tes deletes the prohibition on unlighted swinging signs.

150/5345-45A Lightweight Approach Light Structure (12-9-87). (AAS-100). Presents for lightweight structures for supporting lights as used in visual navigational aid syste

150/5345-46B Specification for Runway and Taxiway Light Fixtures (9-1-98). (AAS- FAA specifications for light fixtures to be used on airport runways and taxiways.

150/5345-47A Isolation Transformers for Airport Lighting Systems (12-9-87). (AAS-1 specifications requirements for series-to-series isolation transformers for use in airpc

150/5345-49A Specification L-854, Radio Control Equipment (8-8-86). (AAS-100). C specification for radio control equipment to be used for controlling airport lighting fac

150/5345-50 Specification for Portable Runway Lights (10-16-78). (AAS-100). (Cons includes change 1). Creates a standard and specification for a battery operated light outline a runway area temporarily.

150/5345-51 Specification for Discharge-Type Flasher Equipment (8-14-81). (AAS-1 reprint includes change 1). Contains the specifications for discharge-type flashing lig used for runway end identifier lights (REIL) and for an omnidirectional approach light (ODALS).

150/5345-52 Generic Visual Glideslope Indicators (CVGI) (6-21-88). (AAS-100). Cor standards for generic visual glideslope indicators systems. GVGI systems provide pi glideslope guidance during approaches for landing at general aviation airports.

150/5345-53B (Including Change 1) Airport Lighting Equipment Certification Prograr 100). Describes the Airport Lighting Equipment Certification Program (ALECP).

150/5345-53B Addendum (4-15-04) (AAS-100). Airport Lighting Equipment C Program. Addendums to Appendices 3 & 4 of AC 150/5345-53B. [HTML vers

150/5345-53B Chg. 1 (09-08-00) This change reinstates L-824, Underground Cable for Airport Lighting Circuits (AC 150/5345-7D) and adds L-884, Power a Unit for Land and Hold Short Lighting Systems (AC 150/5345-54) to the Airpo Equipment Certification Program.

150/5345-54A (08-09-00) Specification for L-884 Power and Control Unit for Land a Lighting Systems. **A consolidated version of 150/5345-54A (including change 1) available online. For more information, contact Richard Smith at 202-267-9529.**

150/5345-54A chg. 1 (06-29-01) (AAS-100). Provides a correction to paragra Painting and Finishing. (HTML version)

IAH

FIVE RUNWAYS

8L/26R - 9000 feet by 150 feet, R/W 26 ILS Category III

8R/26L - 9,400 feet by 150 feet, R/W 26 - ILS Category I/III
9/27 - 10,000 feet by 150 feet, R/W 27 - ILS Category I/III
15L/33R - 12,000 feet by 150 feet - R/W 33 ILS Category I
15R/33L - 10,000 feet by 150 feet, R/W 15 - ILS Category I

IAH

Navigational aids and other FAA-operated facilities which include:

- Instrument Landing System for each major runway
- Airport Surveillance Radar
- Other navigational aids and lighting systems for all runways
- Low Level Alert Wind Shear System
- Doppler radar to enhance weather prediction
- Aircraft rescue and firefighting facility
- Runway 8L/26R - utilizes LED Taxiway Edge Light Fixtures
- Three parallel Category III runways at IAH permit triple independent simultaneous all-weather flight operations

ILS COMPONENTS

ILS COMPONENTS

- LOCALIZER AND GLIDE SLOPE
  - Localizer – indicates alignment w/ runway
  - Glideslope – indicates correct descent path

ILS COMPONENTS

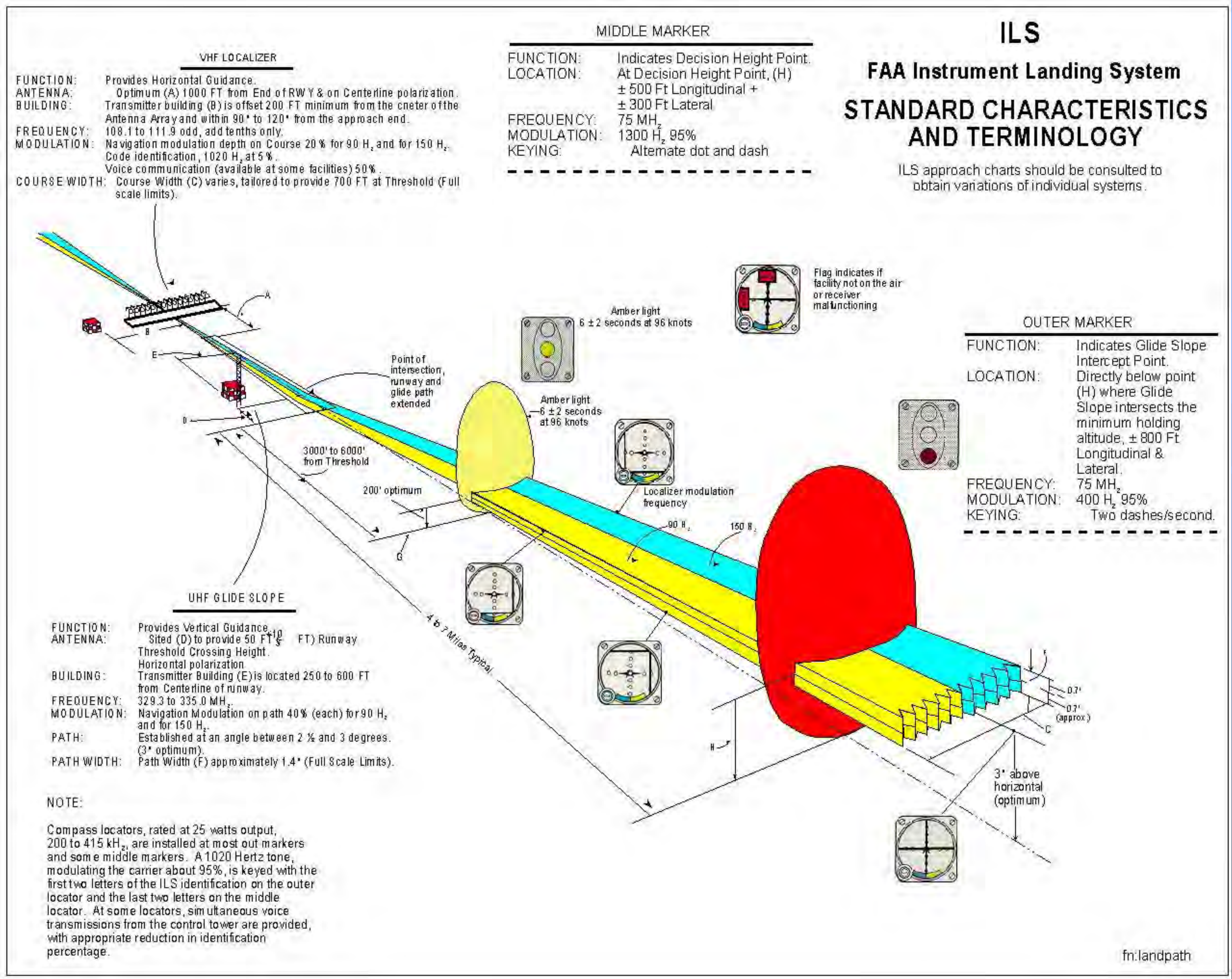
- OUTER AND MIDDLE MARKERS

  - OM – Denotes beginning of final approach segment (Final Approach Fix).

  - MM – Denotes Missed Approach Point (MAP)
    - Usually placed at decision height on glidepath.

ILS COMPONENTS

DMJM Aviation



ILS COMPONENTS

1. Compass locators located at the Outer Marker (OM) or Middle Marker (MM) may be substituted for marker beacons. DME, when specified in the procedure, may be substituted for the OM.

2. Where a complete ILS system is installed on each end of a runway; (i.e. the approach end of Runway 9 and the approach end of Runway27) the ILS systems are not in service simultaneously.

ILS COMPONENTS

DMJM Aviation

- ILS LOCALIZER

LOCALIZER PROVIDES GUIDANCE
FOR HORIZONTAL POSITION

LOCALIZER

1. The localizer transmitter operates on one of 40 ILS channels within the frequency range of 108.10 to 111.95 mHz. Signals provide the pilot with course guidance to the runway centerline.

2. The approach course of the localizer is called the front course and is used with other functional parts, e.g., glide slope, marker beacons, etc.

3. The localizer signal is transmitted at the far end of the runway. It is adjusted for a course width of (full scale fly-left to a full scale fly-right) of 700 feet at the runway threshold.

ILS COMPONENTS

- ILS GLIDE SLOPE

GLIDE SLOPE AND GENERATOR ON CONSTANT POWER RUNWAY

GLIDE SLOPE

1. The glide slope transmitter is located between 750 feet and 1,250 feet from the approach end of the runway (down the runway) and offset 250 to 450 feet from the runway centerline. It transmits a glide path beam 1.4 degrees wide. The signal provides descent information for navigation down to the lowest authorized decision height (DH) specified in the approved ILS approach procedure.

2. The glide path projection angle is normally adjusted to 3 degrees above horizontal so that it intersects the MM at about 200 feet and the OM at about 1,400 feet above the runway elevation. The glide slope is normally usable to the distance of 10 NM.

DMJM Aviation

ILS COMPONENTS

- ILS MARKERS

INNER AND MIDDLE MARKER

MARKERS

1. ILS marker beacons have a rated power output of 3 watts or less and an antenna array designed to produce a elliptical pattern with dimensions, at 1,000 feet above the antenna, of approximately 2,400 feet in width and 4,200 feet in length.

2. Ordinarily, there are two marker beacons associated with an ILS, the OM and MM. Locations with a Category II and III ILS also have an Inner Marker (IM).

ILS COMPONENTS

- OUTER MARKERS

CAT III INSTRUMENT LANDING SYSTEM COMPONENT LOCATED 5 MILES OFF RUNWAY THRESHOLD DESIGNED TO MEET LOCAL BUILDING AND ZONING CODES

CONSTRUCTION COSTS

DMJM Aviation

			MATERIALS		LABOR		EQUIP			TOTAL
ITEM DESCRIPTION	UNITS	HOW MANY	UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	MAN DAYS	
RUNWAY35				$0		$0		$0		$0
LOC	EA	1	$32,000	$32,000	$44,700	$44,700	$17,500	$17,500		$94,200
LOC equipment	EA	1	$0	$0	$0	$0	$120,000			$0
GS	EA	1	$18,900	$18,900	$38,750	$38,750	$0	$0		$57,650
GS Equipment	EA	1	$0	$0	$0	$0	$45,000	$45,000		$45,000
MM	EA	1	$7,500	$7,500	$10,500	$10,500	$3,500	$3,500		$21,500
MALSR	EA	1	$365,000	$365,000	$435,000	$435,000	$22,000	$22,000		$822,000
MALSR Equipment	EA	1	$0	$0	$0	$0	$735,000	$735,000		$735,000
PAPI	EA	1	$8,900	$8,900	$11,385	$11,385	$1,500	$1,500		$21,785
PAPI Equipment	EA	1	$0	$0	$0	$0	$10,500	$10,500		$10,500
Ductbank LOC to GS	LF	9000	$12	$108,000	$13	$117,000	$2	$18,000		$243,000
Ductbank MALSR to GS	LF	2500	$12	$30,000	$13	$32,500	$2	$5,000		$67,500
Shelter LOC	EA	1	$0	$0	$0	$0	$30,000	$30,000		$30,000
Shelter GS	EA	1	$0	$0	$0	$0	$25,000	$25,000		$25,000
Shelter MALSR/MM	EA	1	$0	$0	$0	$0	$30,000	$30,000		$30,000
RUNWAY17			$0							
PAPI	EA	1	$8,900	$8,900	$11,386	$11,386	$1,500	$1,500		$21,786
PAPI Equipment	EA	1	$0	$0	$0	$0	$10,500	$10,500		$10,500
				$0		$0		$0		$0
TOTAL				**$579,200**		**$701,221**		**$955,000**		**$2,235,421**
TOTAL COST ESTIMATE FOR THIS SHEET IS										**$2,235,421**
Material Tax		0.06		$34,752.00						$34,752.00
Laber Burden		0.12				$84,147				$84,147
								TOTAL		**$2,354,320**

Pavement Types

Rigid – PCC

- Joined Plain Concrete Pavement – JPCP (JCP)
- Joined Reinforced Concrete Pavement – JRCP
- Continuously Reinforced Concrete Pavement - CRCP
- Prestressed Concrete Pavement - PCP

Flexible – ACP/HMA

- Full Depth
- Layered
  - Granular
  - Bound Layers
- Surface Treatment

Composite

Pavement Types

Rigid Pavement

- Portland Cement Concrete Slab
- Base
- Subgrade

Flexible Pavement

- Layered System
- Asphaltic Wearing Surface
- Base
- Subbase
- Subgrade

Major Factors Affecting Pavement Design

Types of aircraft, maximum loads and the anticipated frequency

Type of facility considered

- Runway
- Taxiway
- Apron
- Hangar Floor

Supporting value of the subgrade

Principal characteristics of available construction

- Material

Gear configuration

Fundamental Design Concepts

Wheel Loading

- Pavement Thickness
- Pavement Stiffness

Environmental Loading – Temperature and Moisture

- Joint Spacing
- Reinforcement
- HMA Stiffness


nwa
NORTHWEST AIRLINES

Fundamental Design Concepts

Application
Load and Environment
Principle of Superposition

Stress Dependent On:

- Gear Spacing
- Magnitude and tire pressure
- Number of wheels

Fatigue
Layered Concept

317. DESIGN INPUTS. Use of the design curves for flexible pavements requires a CBR value for the subgrade material, a CBR value for the subbase material, the gross weight of the design aircraft, and the number of annual departures of the design aircraft. The design curves presented in Figures 3-2 through 3-15 indicate the total pavement thickness required and the thickness of hot mix asphalt surfacing. Table 3-4 gives the minimum thicknesses of base course for various materials and design loadings. For annual departures in excess of 25,000 the total pavement thickness should be increased in accordance with Table 3-5. l-inch (25 mm) of the thickness increase should be hot mix asphalt surfacing; the remaining thickness increase should be proportioned between base and subbase.

TABLE 3-4. MINIMUM BASE COURSE THICKNESS

Design Aircraft	Design Load Range		Minimum Base Course Thickness	
	lbs.	(kg)	in.	(mm)
Single Wheel	30,000 - 50,000 50,000 - 75,000	(13600 - 22 700) (22700 - 34 000)	4 6	(100) (150)
Dual Wheel	50,000 - 100,000 100,000 - 200,000	(22700 - 45 000) (45 000 - 90 700)	6 8	(150) (200)
Dual Tandem	100,000 - 250,000 250,000 - 400,000	(45 000 - 113 400) (113400 - 181 000)	6 8	(150) (200)
757 767	200,000 - 400,000	(90700 - 181000)	6	(150)
DC-10 L1011	400,000 - 600,000	(181 000 - 272000)	8	(200)
B-747	400,000 - 600,000 600,000 - 850,000	(181 000 - 272000) (272 000 - 385 700)	6 8	(150) (200)
c-130	75,000 - 125,000 125,000 - 175,000	(34 000 - 56 700) (56700 - 79 400)	4 6	(100) (150)

Note: The calculated base course thicknesses should be compared with the minimum base course thicknesses listed above. The greater thickness, calculated or minimum, should be specified in the design section.

318. CRITICAL AND NONCRITICAL AREAS. The design curves, Figures 3-2 through 3-15, are used to determine the total critical pavement thickness, "T", and the surface course thickness requirements. The 0.9T factor for the noncritical pavement applies to the base and subbase courses; the surface course thickness is as noted on the design curves. For the variable section of the transition section and thinned edge, the reduction applies only to the base course. The 0.7T thickness for base shall be the minimum permitted. The subbase thickness shall be increased or varied to provide positive surface drainage of the subgrade surface. Surface course thicknesses are as shown in Figure 3-l. For fractions of an inch of 0.5 or more, use the next higher whole number; for less than 0.5, use the next lower whole number.

TABLE 3-5. PAVEMENT THICKNESS FOR HIGH DEPARTURE LEVELS

Annual Departure Level	Percent of 25,000 Departure Thickness
50,000	104
100,000	108
150,000	110
200,000	112

Note:
The values given in Table 3-5 are based on extrapolation of research data and observations of in-service pavements. Table 3-5 was developed assuming a logarithmic relationship between percent of thickness and departures.

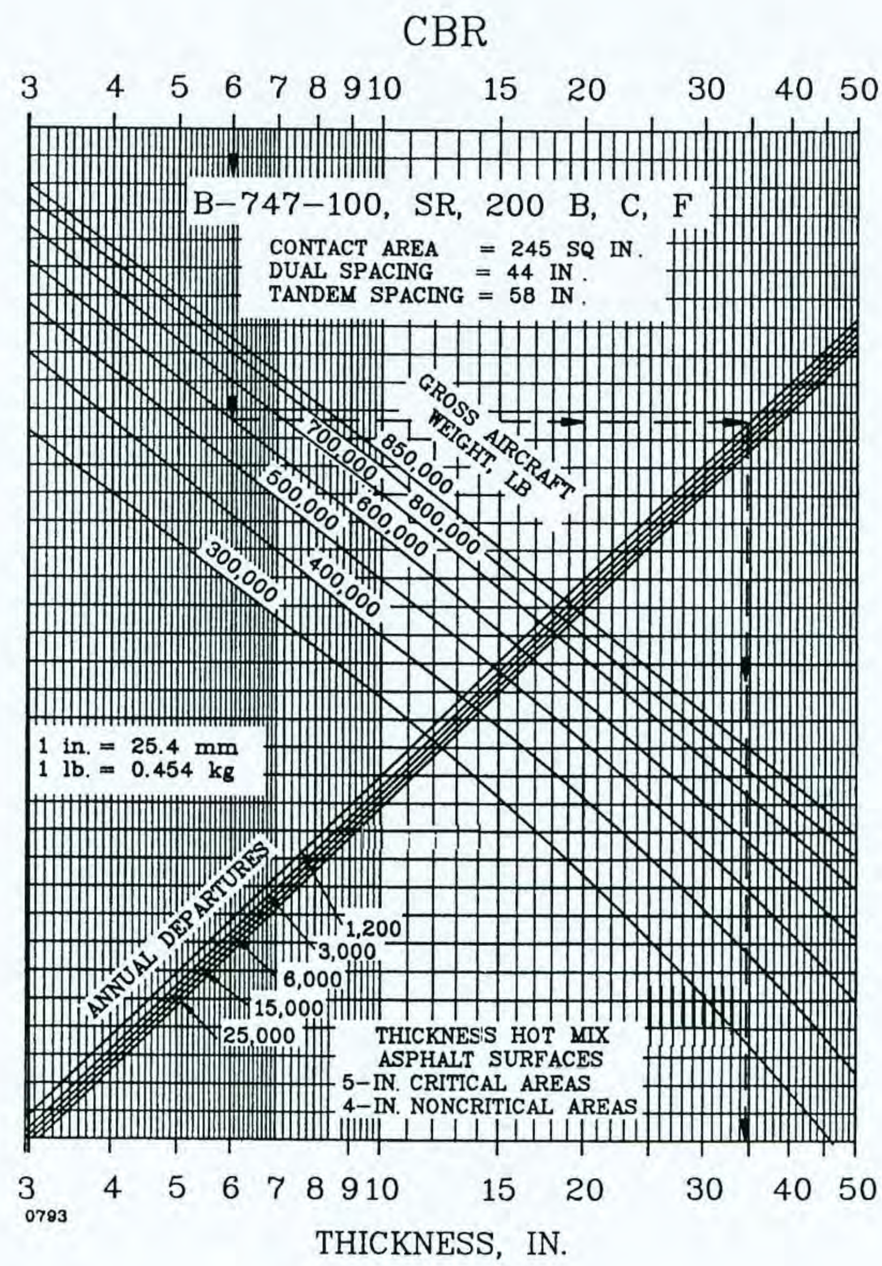


FIGURE 3-7 FLEXIBLE PAVEMENT DESIGN CURVES, B-747-100,SR, 200 B, C, F

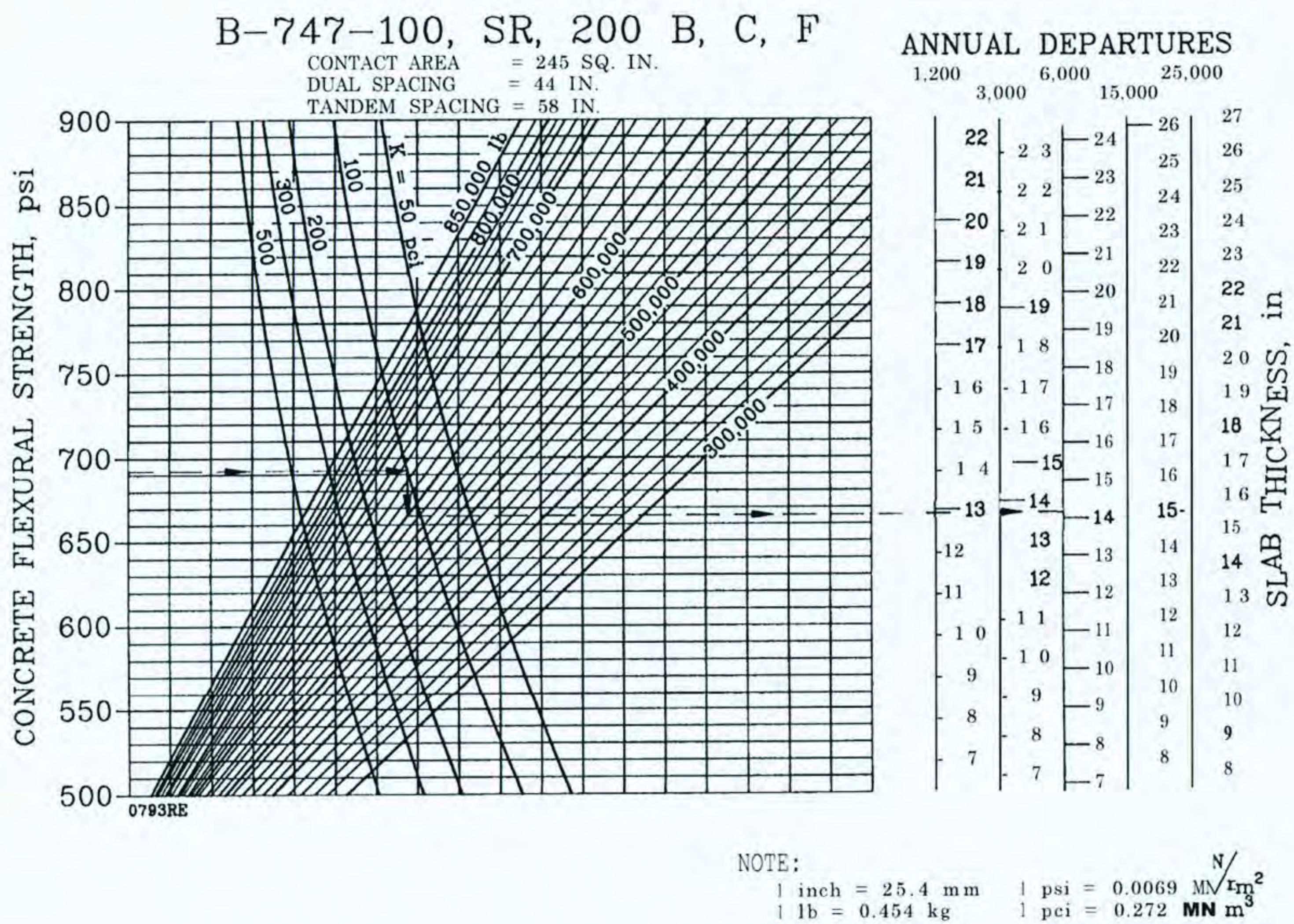


FIGURE 3-33. OPTIONAL RIGID PAVEMENT DESIGN CURVES, B-747-100, SR, 200 B, C, F

LEDFAA - Layered Elastic Airport Pavement Design (V 1.3, June 2004)

Section NewFlexible in Job QuitoRunway.
Working directory is C:\Program Files\Ledfaa13\

The structure is New Flexible.
Design Life = 20 years.
A design has not been completed for this section.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness inches	Modulus psi	Poisson's Ratio	Strength R, psi
1	P-401 AC Surface	5.00	200,000	0.35	0
2	P-401 St (flex)	8.00	400,000	0.35	0
3	P-209 Cr Ag	10.00	75,000	0.35	0
4	Subgrade	0.00	15,000	0.35	0

Total thickness to the top of the subgrade = 23.00 in

Aircraft Information

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	DC-10-10	458,000	2,263	0.00
2	B-747-400	873,000	832	0.00
3	B-777-200ER	634,500	425	0.00

Additional Aircraft Information

No.	Name	CDF Contribution	CDF Max for Aircraft	P/C Ratio
1	DC-10-10	0.00	0.00	0.00
2	B-747-400	0.00	0.00	0.00
3	B-777-200ER	0.00	0.00	0.00

NOTES

NewFlexible

LEDFAA - Layered Elastic Airport Pavement Design (V 1.3, June 2004)

Section QuitoRunway in Job QuitoAirportRunway.
Working directory is C:\Program Files\Ledfaa13\

The pavement structure includes an undefined layer.
This constitutes a deviation from standards and
requires FAA approval.

The structure is New Rigid.
Design Life = 20 years.
A design for this section was completed on 04/14/08 at 09:31:04.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness inches	Modulus psi	Poisson's Ratio	Strength R, psi
1	PCC Surface	19.81	4,000,000	0.15	700
2	P-401 St (flex)	4.00	400,000	0.35	0
3	P-304 CTB	14.00	500,000	0.20	0
4	Undefined	8.00	80,000	0.35	0
5	Subgrade	0.00	5,000	0.40	0

Total thickness to the top of the subgrade = 45.81 in

Aircraft Information

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	A300-B2	333,000	800	0.00
2	A320-opt	170,000	3,700	0.00
3	A340-200/300	600,000	500	0.00
4	340-200/300 Belly	600,000	500	0.00
5	C-5	960,000	1,000	0.00
6	B-727	210,000	1,240	0.00
7	B-737-500	134,000	24,000	0.00
8	B-737-900	179,000	40,000	0.00
9	B-747-400ER	970,000	4,000	0.00
10	B-757	250,000	5,800	0.00
11	B-767-200	410,000	5,000	0.00
12	B-777-300ER	776,000	4,000	0.00
13	DC-10-30	583,000	460	0.00
14	DC-10-30 Belly	583,000	460	0.00
15	MD-83	161,000	4,620	0.00

Additional Aircraft Information

No.	Name	CDF Contribution	CDF Max for Aircraft	P/C Ratio
1	A300-B2	0.00	0.00	0.00
2	A320-opt	0.00	0.00	0.00
3	A340-200/300	0.00	0.00	0.00
4	340-200/300 Belly	0.00	0.00	0.00
5	C-5	0.00	0.00	0.00
6	B-727	0.00	0.00	0.00
7	B-737-500	0.00	0.00	0.00
8	B-737-900	0.00	0.00	0.00
9	B-747-400ER	0.00	0.00	0.00
10	B-757	0.00	0.00	0.00
11	B-767-200	0.00	0.00	0.00
12	B-777-300ER	0.00	0.00	0.00
13	DC-10-30	0.00	0.00	0.00
14	DC-10-30 Belly	0.00	0.00	0.00
15	MD-83	0.00	0.00	0.00

NOTES

QuitoRunway

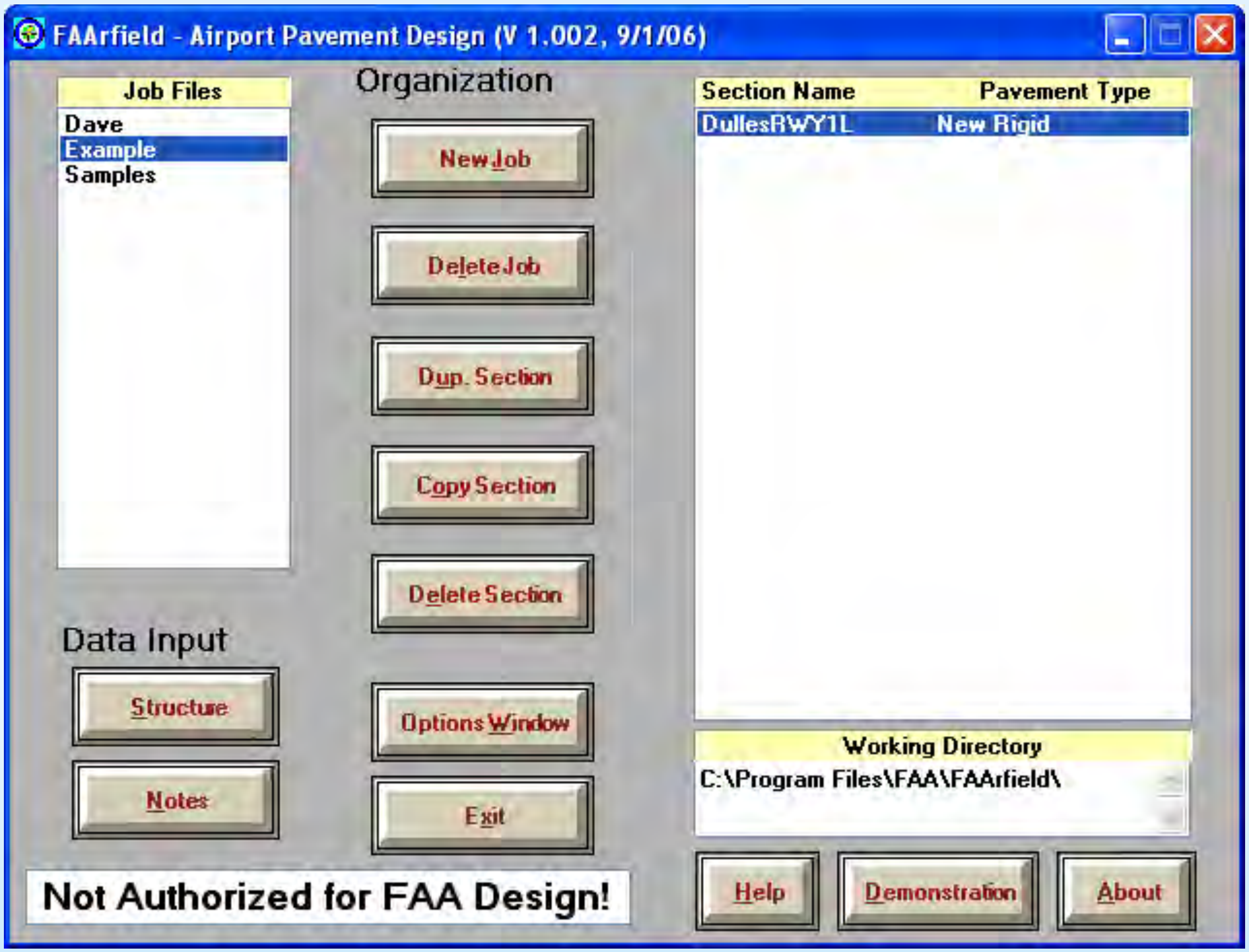
Example Design #1: New Rigid Pavement

- Pavement Structure:
  - PCC Slab (R = 700 psi)
  - Econocrete (6 in. thick)
  - Crushed Aggregate Base (6 in. thick)
  - Subgrade (E = 15,000 psi)
- Traffic Mix:
  - Washington Dulles RWY 1L
  - 14-Aircraft Mix includes B777, A340

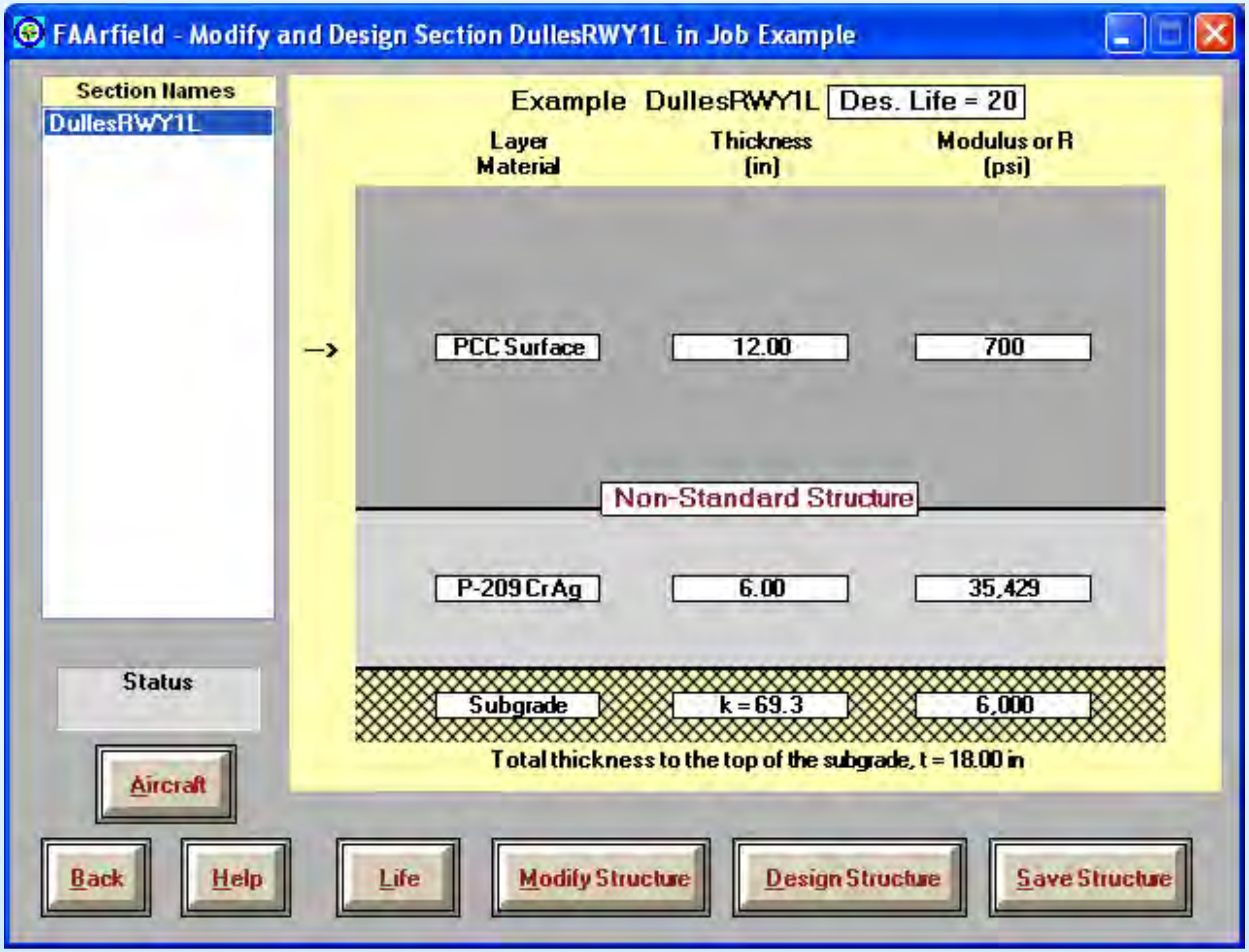
Traffic Mix, Dulles Airport RWY 1L

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	A340-300 std	621,000	1,239	0.00
2	A340-300 std Belly	621,000	1,239	0.00
3	B737-700	160,000	51,632	0.00
4	Sngl Whl-30	35,000	10,710	0.00
5	Adv. B727-200C Basic	210,000	4,779	0.00
6	MD11ER	621,000	2,216	0.00
7	MD11ER Belly	621,000	2,216	0.00
8	Sngl Whl-60	55,000	98,759	0.00
9	B737-800	173,000	10,238	0.00
10	B757-200	250,000	13,212	0.00
11	DC8-63/73	355,000	156	0.00

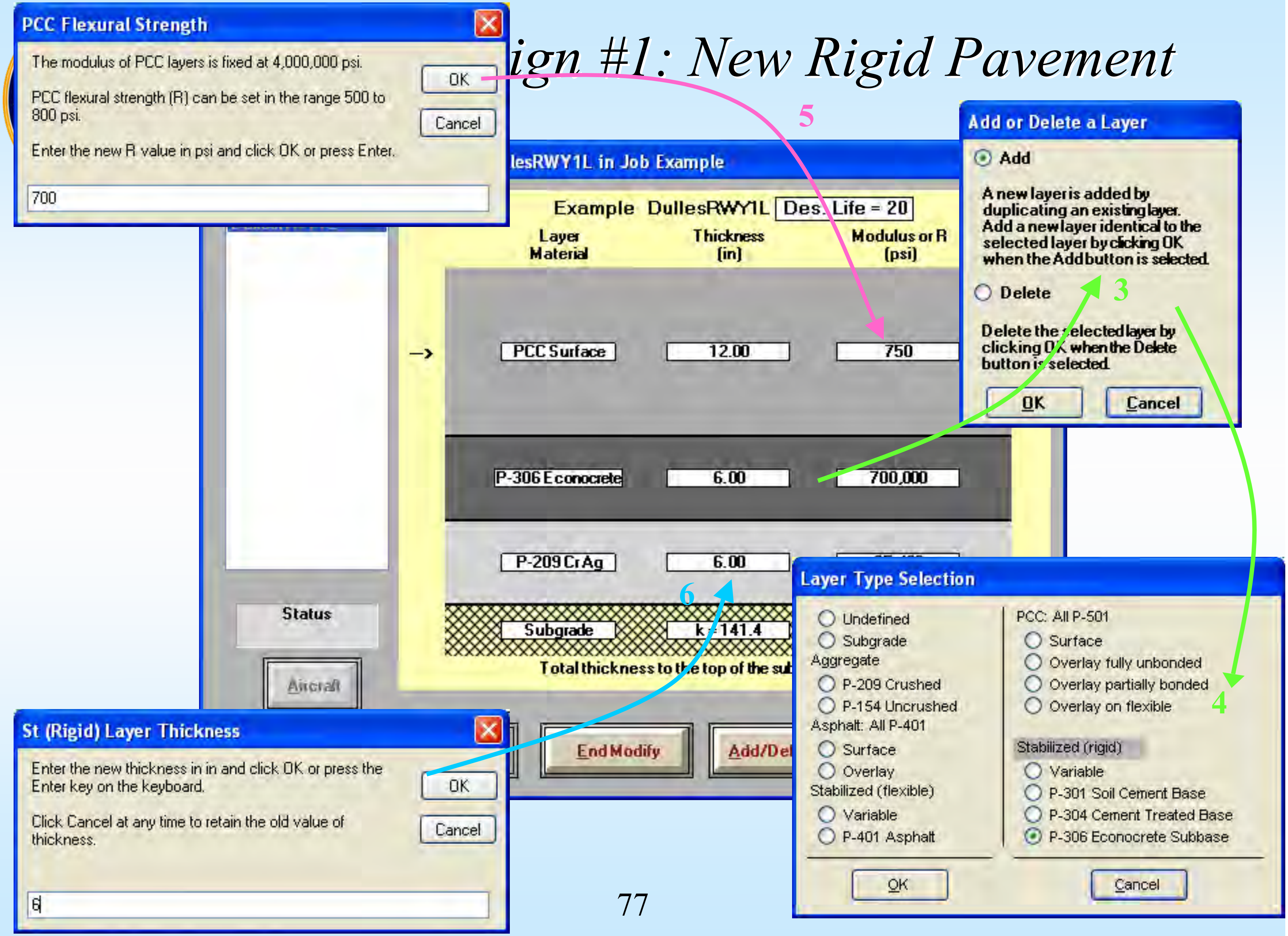
Example Design #1: New Rigid Pavement Startup Window



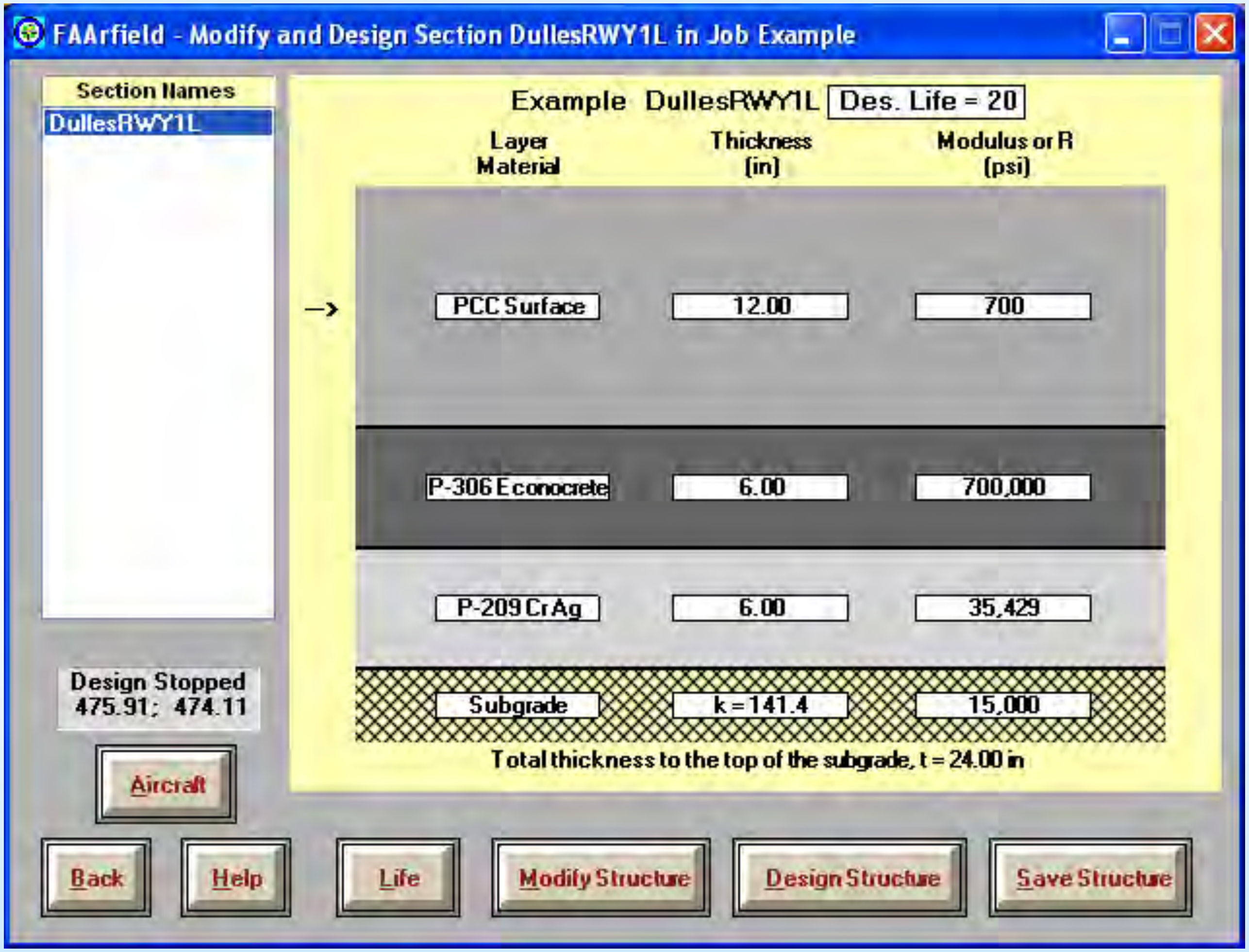
Example Design #1: New Rigid Pavement Structure Window



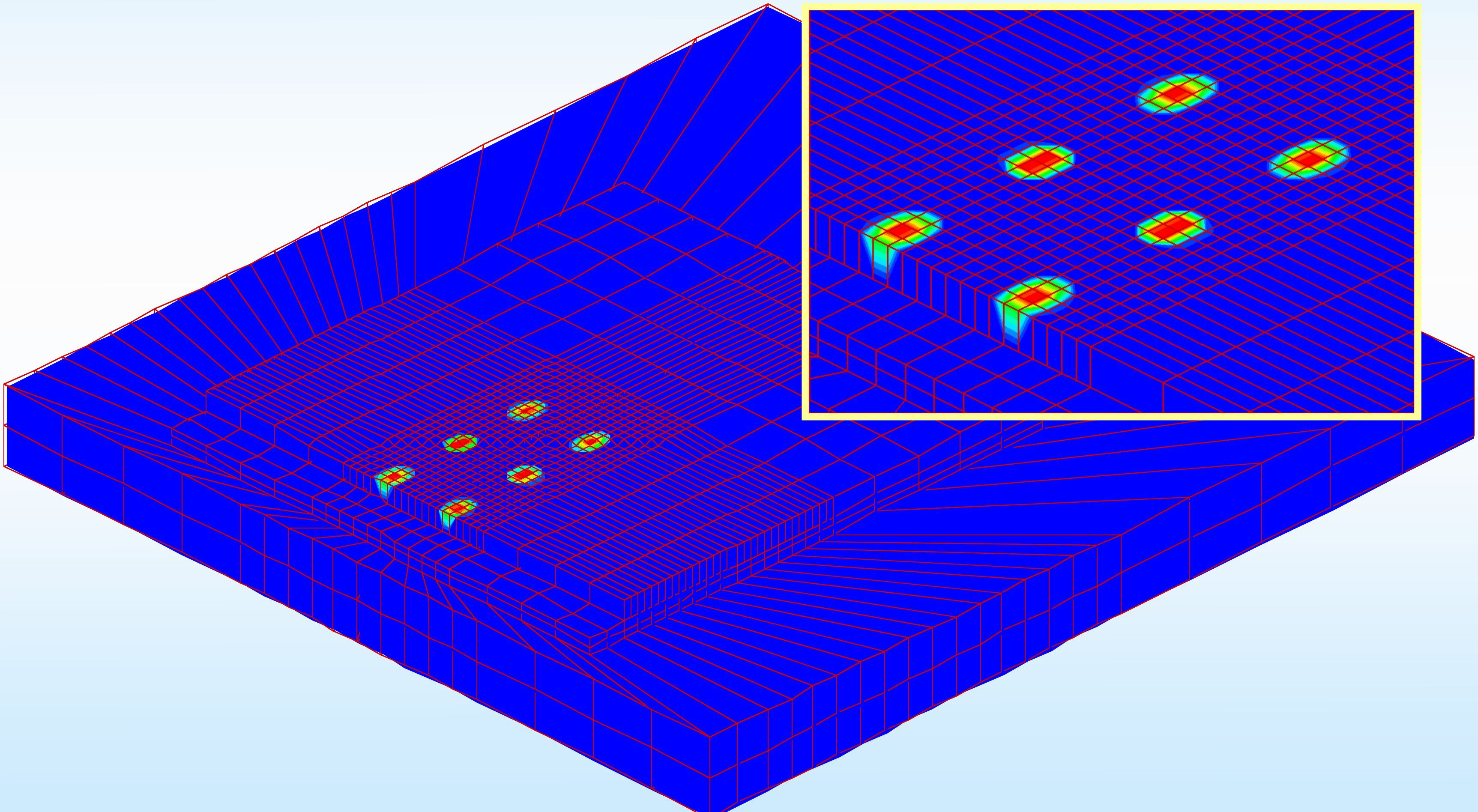
...ign #1: New Rigid Pavement



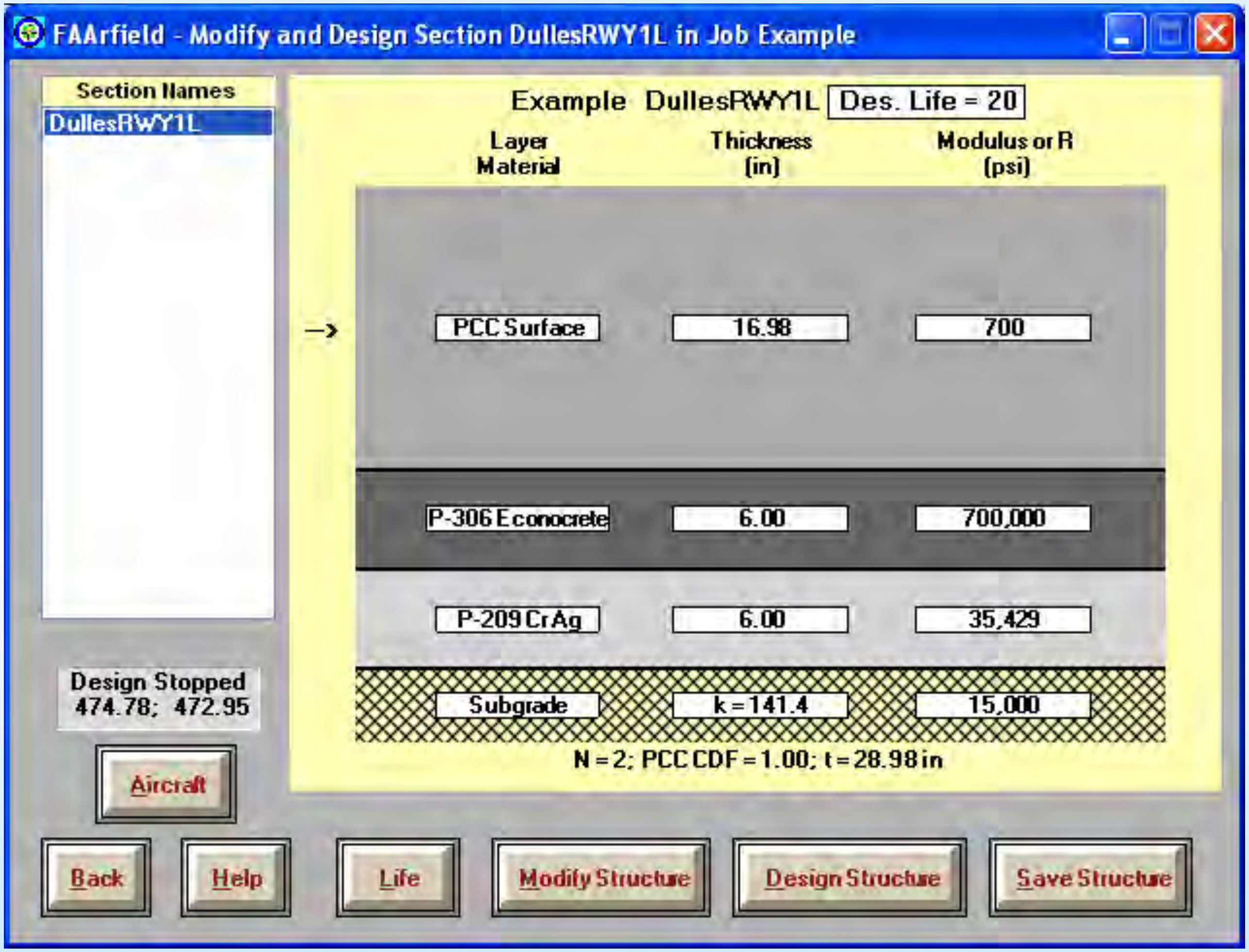
Example Design #1: New Rigid Pavement Final Structure Window



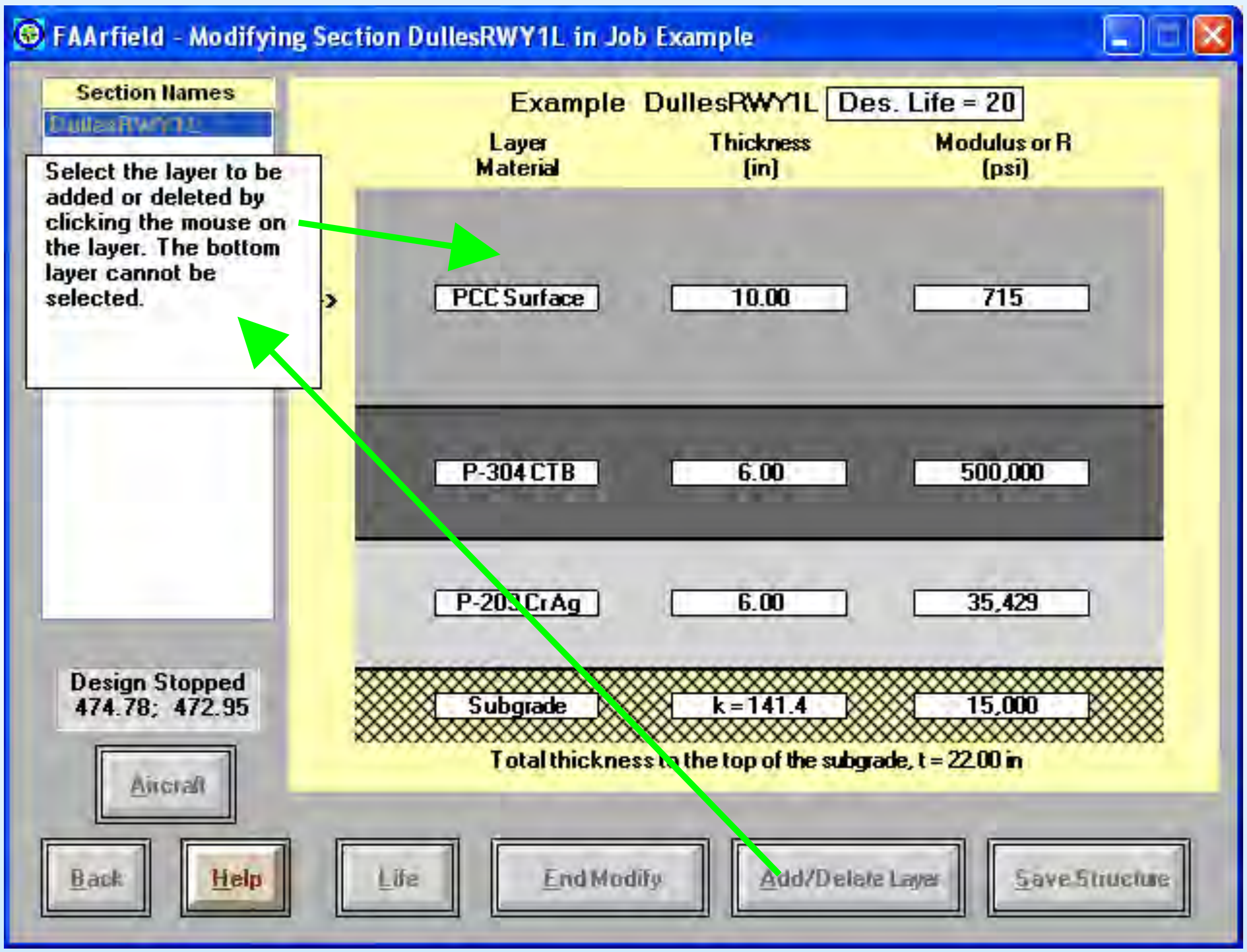
Example Design #1: New Rigid Pavement
FEDFAA Rigid Pavement Model



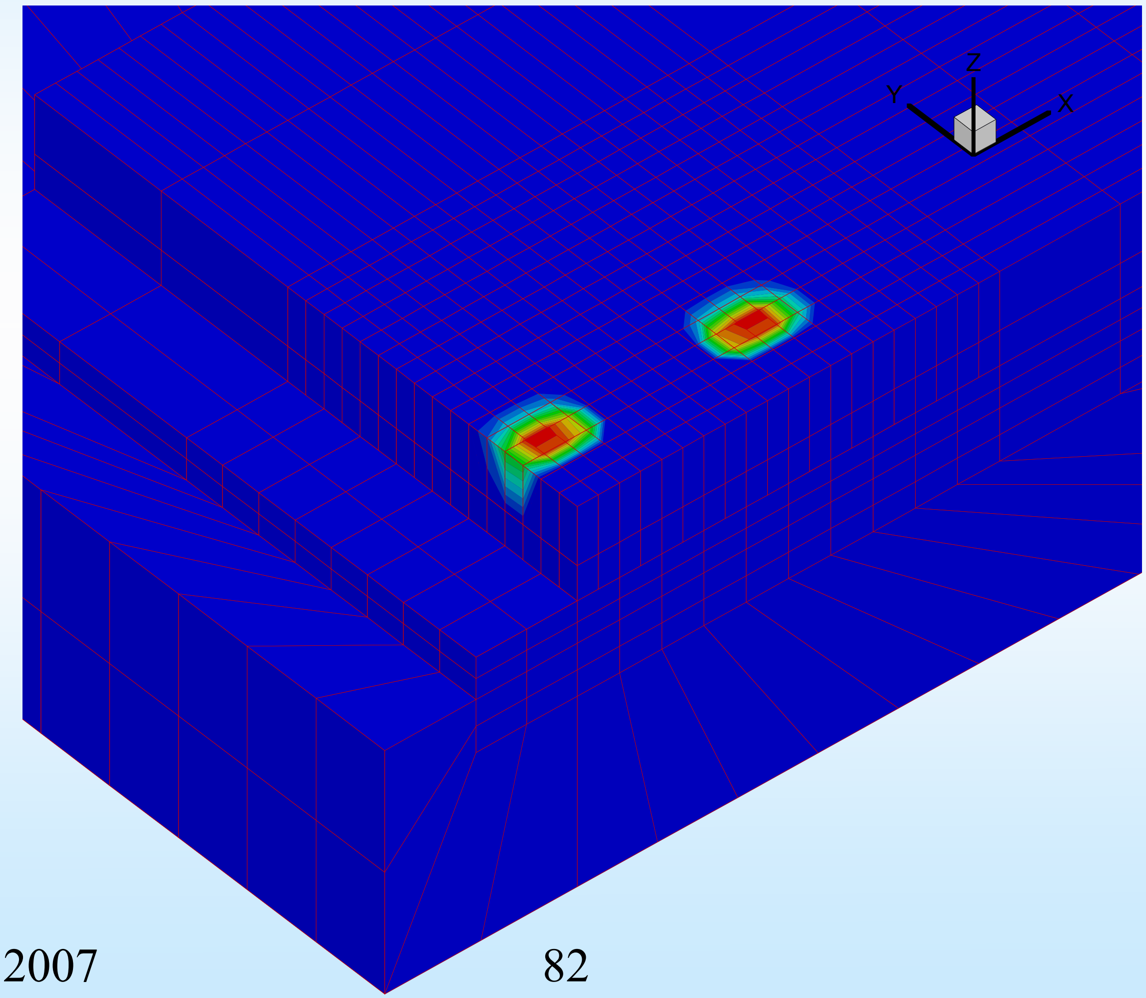
Example Design #1: New Rigid Pavement Final Thickness Design



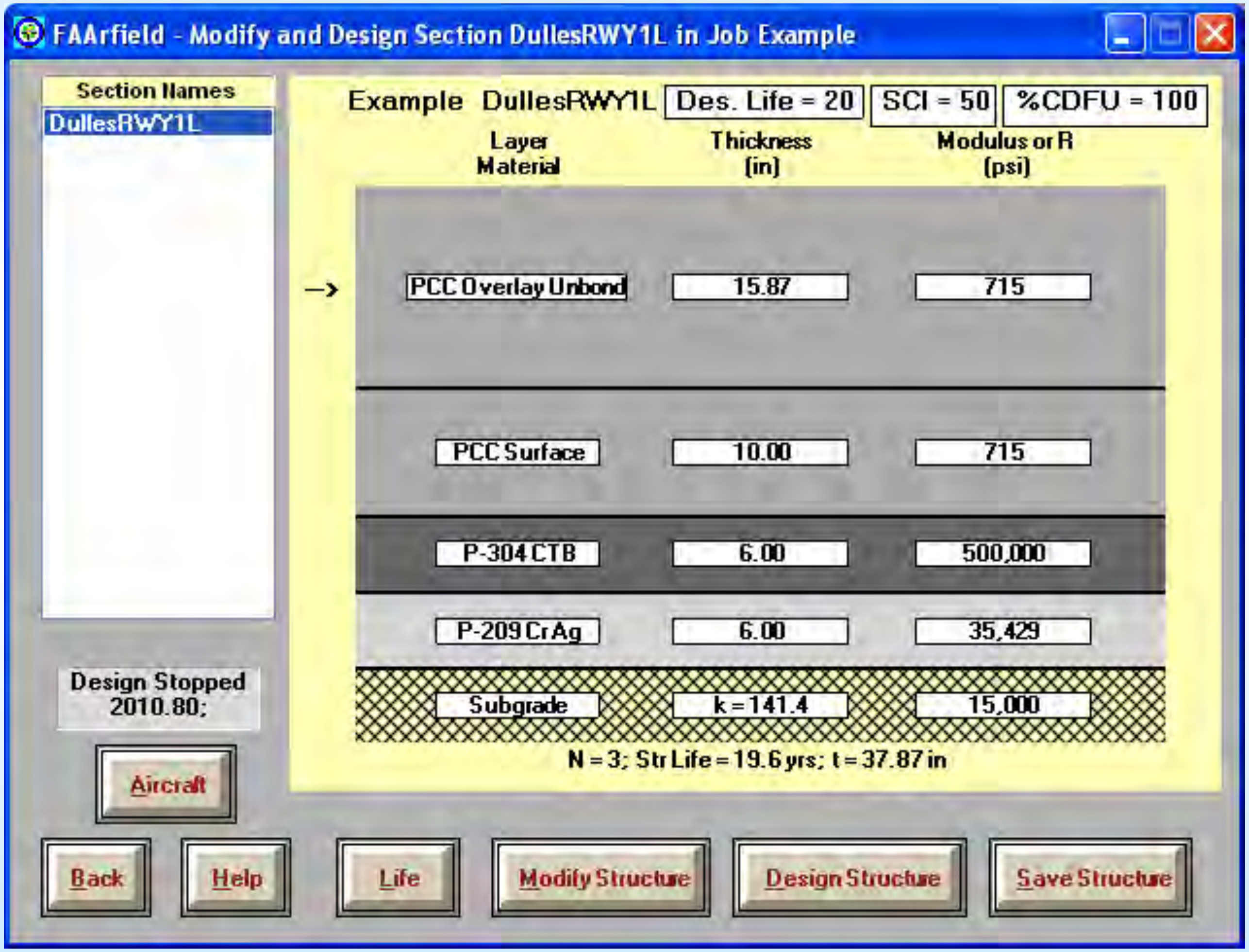
Example Design #2: Rigid on Rigid Overlay Structure Window



Example Design #2: Rigid on Rigid Overlay
FEDFAA Rigid Overlay Model



Example Design #2: Rigid on Rigid Overlay Final Thickness Design (U.S. Units)



Example Design #2: Rigid on Rigid Overlay 3D FE Solution - Notes & Information

FAArfield - Notes and Information for Job Example

Section Names

DullesRWY1L

Design Information for Section DullesRWY1L

Section DullesRWY1L in Job Example.
Working directory is C:\Program Files\FAA\FAArfield\

Section DullesRWY1L in Job Example.
The structure is Unbonded PCC Overlay on Rigid.
SCI of the existing pavement = 50.
Design Life = 20 years.
A design for this section was completed on 01/10/07 at 15:37:56.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	PCC Overlay Unbond	15.87	4,000,000	0.15	715
2	PCC Surface	10.00	4,000,000	0.15	715
3	P-304 CTB	6.00	500,000	0.20	0
4	P-209 Cr Ag	6.00	35,429	0.35	0
5	Subgrade	0.00	15,000	0.40	0

Total thickness to the top of the subgrade = 37.87 in

Aircraft Information

		Gross Wt	Annual	% Annual

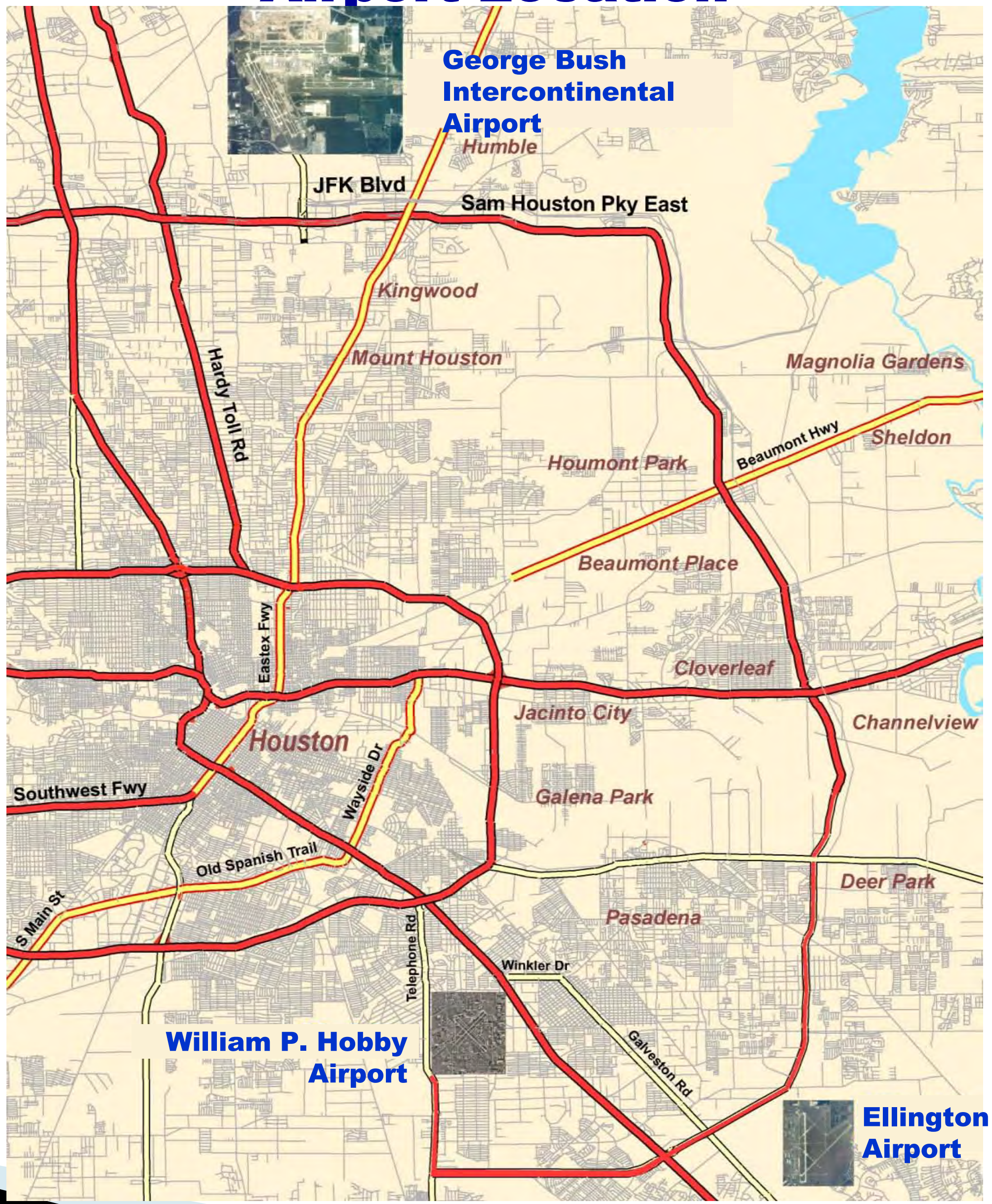
Help

Back | Save | Print | Design Info | Notes | Copy

Example Design #2: Rigid on Rigid Overlay Additional Aircraft Information

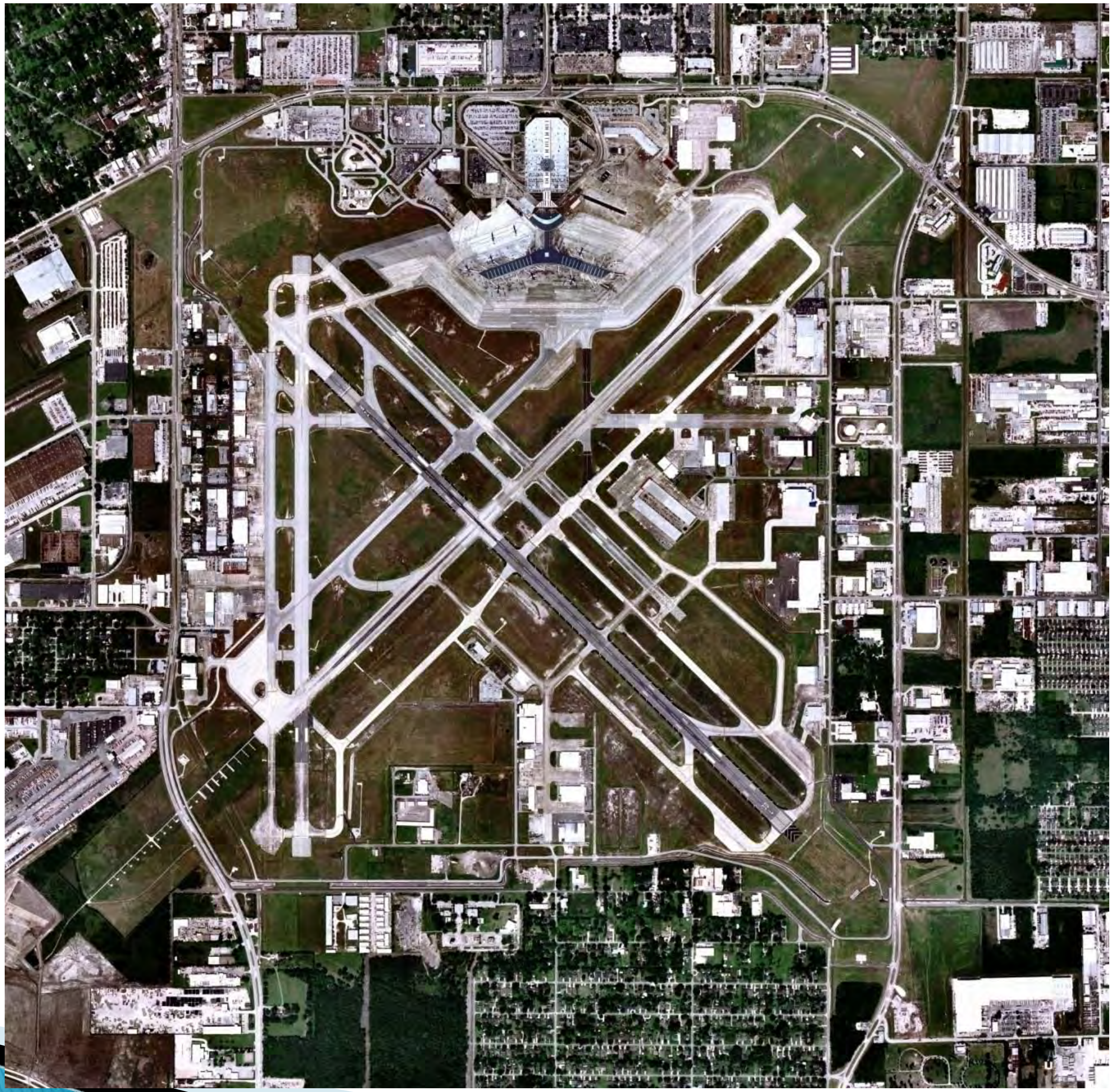
No.	Name	CDF Contribution	CDF Max for Aircraft	P/C Ratio
1	B737-700	0.24	0.24	3.69
2	Sngl Whl-30	0.00	0.00	5.87
3	Adv. B727-200C Basic	0.42	0.42	2.75
4	MD11ER	0.00	0.15	3.71
5	MD11ER Belly	0.00	0.55	3.04
6	Sngl Whl-60	0.00	0.00	5.54
7	B737-800	0.18	0.18	3.55
8	B757-200	0.00	0.00	3.95
9	DC8-63/73	0.01	0.01	3.38
10	B777-200 Baseline	0.00	0.11	3.91
11	B767-200	0.00	0.01	3.83
12	B777-200LR	0.00	0.17	3.90
13	B747-400	0.14	0.24	3.47
14	[illegible]	[illegible]	[illegible]	[illegible]

George Bush Intercontinental Airport Location



George Bush Intercontinental Airport, Houston, Texas

William P. Hobby Airport
Houston, Texas



Novophalt Hot Mix Asphaltic Concrete
(Polyethylene Additive)

I. SUMMARY

Novophalt Asphalt improves the following properties of the Hot Mix Asphaltic Concrete:

1) Better Viscosity
2) Improvement in Temperature Susceptibility
3) Higher Marshall Stability
4) Higher Modules of Elasticity
5) Higher Tensile strength
6) Better Moisture Resistance
7) Better Fatigue Resistance
8) Better Resistance to Permanent Deformation
9) Better dynamic modulus, creep resistance, resilient modulus, flexural modulus
10) Less Damage to Pavement
11) Less Rutting
12) Less Cracking

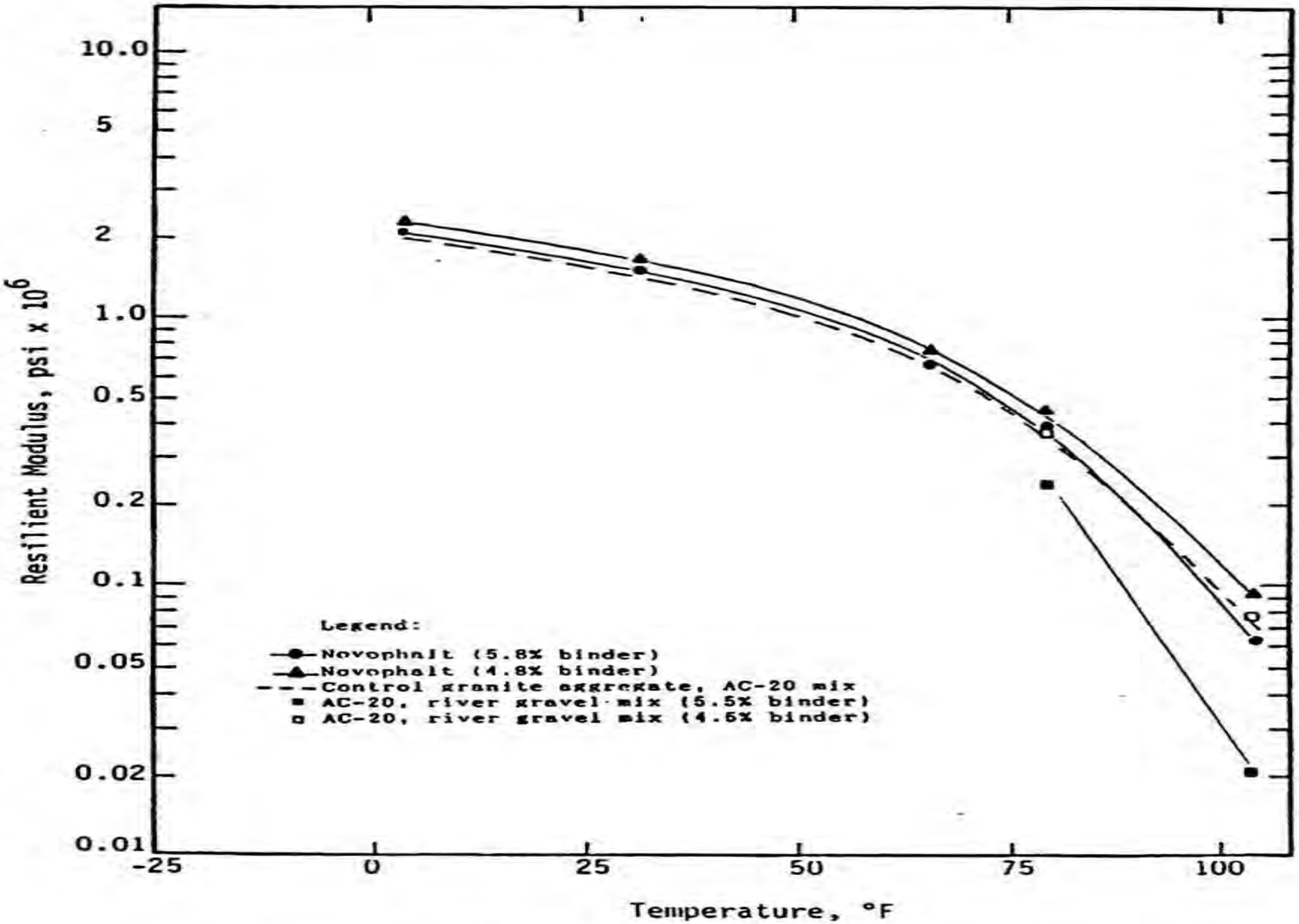


Figure 11. Resilient Modulus Versus Temperature Relationships for Novophalt Mixture Groups (5.8 and 4.8 percent binder) and for Traditional Mixtures Using AC-20 Asphalt Cement without Polyeythelene.

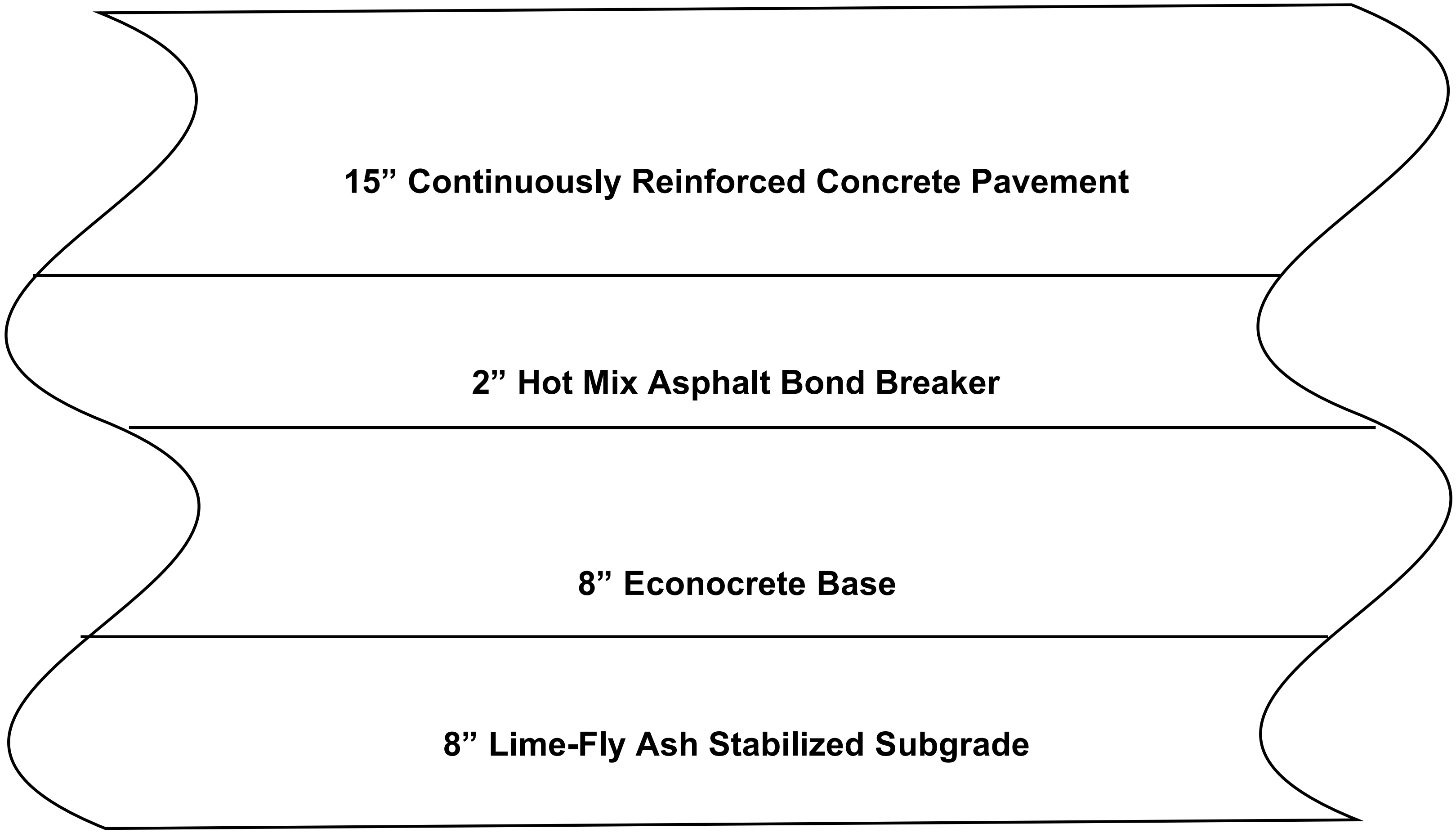

15” Continuously Reinforced Concrete Pavement
2” Hot Mix Asphalt Bond Breaker
8” Econocrete Base
8” Lime-Fly Ash Stabilized Subgrade

Table 1 – Chemical Composition of Cement and Slag

Chemical Composition	Percentages for Portland Cement	Percentages for Class "C" Fly Ash	Percentages for Ground Granulated Blast Furnace Slag, Grade 120 (GGBFS)
CaO	65	31	42
SiO_2	20	35	38
AL_2O_3	4	17	8
Fe_2O_3	3	6	Trace
MgO	3	5	7
SO_3	3	3.5	--
S	--		1
Na_2O+K_2O	1	1.5	0.4
MnO	--	--	1

When GGBFS is coupled with cement, a synergistic combination is formed. Each product hydrates on its own, forming strength bearing calcium silicate hydrate (CSH). The excess silica from GGBFS and the excess calcium from cement react to form additional strength bearing CSH in the pore spaces of the concrete. This makes a stronger, denser matrix with decreased permeability. The chemical reactions are as follows:

$$\text{Cement} + H_2O = CSH + Ca(OH)_2$$
$$\text{GGBFS} + H_2O = CSH + SiO_2$$
$$SiO_2 + Ca(OH)_2 + H_2O = CSH$$

Chemical Reactions in Fly Ash Concrete between Cement and Fly Ash

CaO

-Cementitious Materials

MgO

Al_2O_3
SiO_2 -Pozzolanic Materials
Fe_2O_3

$$CaO+MgO+H_2O+Al_2O_3/SiO_2/Fe_2O_3=\text{Cementitious Paste}+Ca(OH)_2$$

$$Ca(OH)_2+Al_2O_3/SiO_2/Fe_2O_3=\text{Cementitious Paste}$$

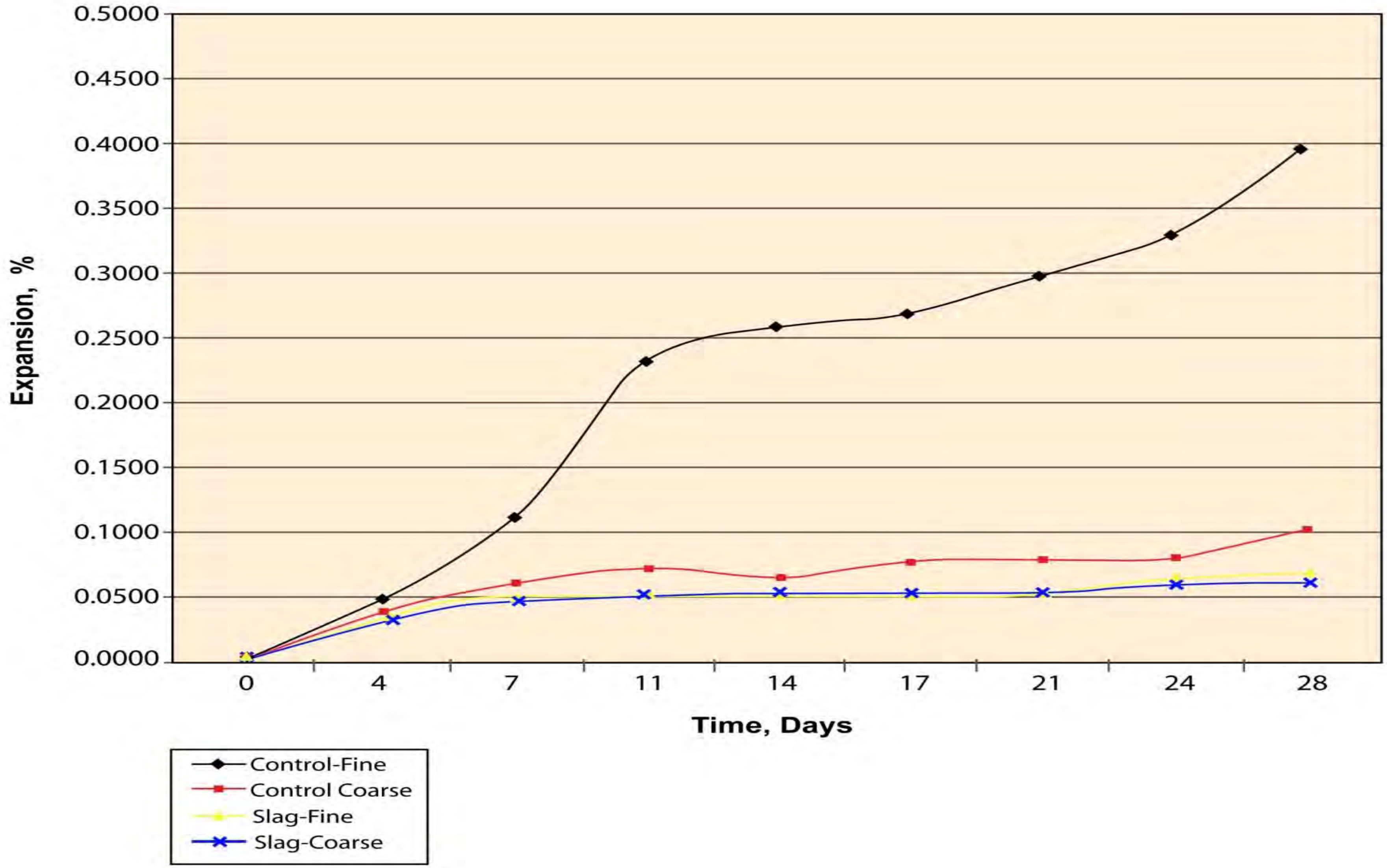
In concrete using only Portland cement, approximately 35% $Ca(OH)_2$ is formed, which lies dormant. By adding fly ash, the $Ca(OH)_2$ is utilized fully, because it reacts with the pozzolanic materials to form additional cementitious paste.

which are not susceptible to alkali silica reaction. Extensive quality assurance and testing requirements were introduced in the concrete pavement specifications to eliminate this hazard, which is becoming more prevalent nowadays.

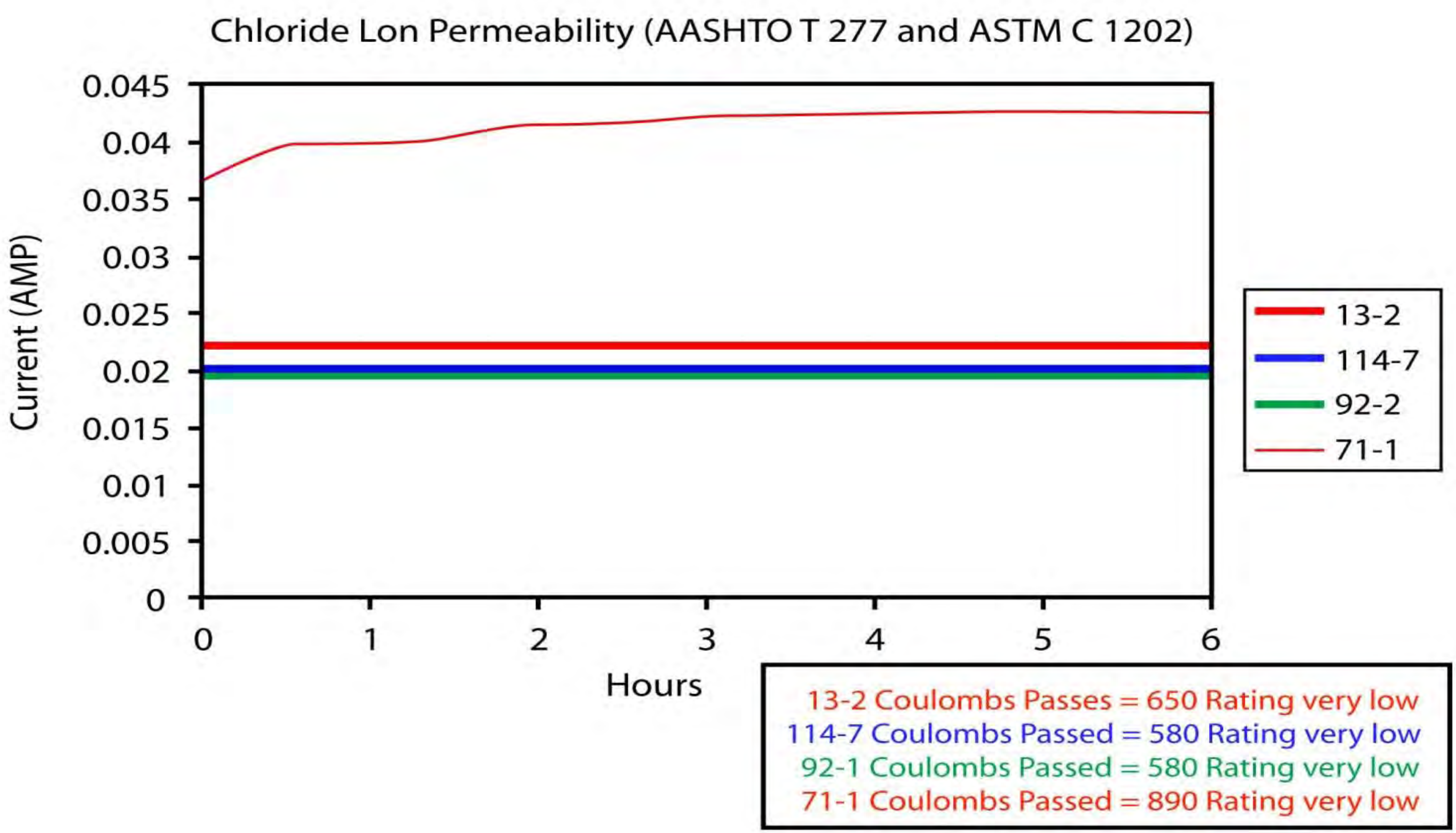
The concrete mix design was as follows:

Cement, Type I	270 lbs/C.Y.
Class "F" fly ash	135 lbs/C.Y.
Blast furnace slag, Grade 120	135 lbs/C.Y.
Total cementitious materials	540 lbs/C.Y.
Coarse aggregate (1:5" granite)	1,193 lbs/C.Y.
Fine aggregate (siliceous sand)	1,193 lbs/C.Y.
Water	209 lbs/C.Y.
Water – cementitious materials ratio	0.39
AEA	4.5 ozs/cwt
WRA	22.0 ozs/cwt

Here are the results of the petrographic analysis scanning election microscopic and other tests performed by the Texas Transportation Institute (Dr. Sarkar).



0.5000
0.4500
0.4000
0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
Expansion, %
0
4
7
11
14
17
21
24
28
Time, Days
Control-Fine
Control Coarse
Slag-Fine
Slag-Coarse



Chloride Lon Permeability (AASHTO T 277 and ASTM C 1202)
Current (AMP)
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
1
2
3
4
5
6
Hours
13-2
114-7
92-2
71-1
13-2 Coulombs Passes = 650 Rating very low
114-7 Coulombs Passed = 580 Rating very low
92-1 Coulombs Passed = 580 Rating very low
71-1 Coulombs Passed = 890 Rating very low

Concrete 90 Day Summary

Runway 8R-26L Reconstruction
Project 491B
Plant: W.W. Webber #2
Mix #2600: 294 lbs Type I Cement, 135 lbs Flyash, & 135 lbs Slag per cu. Yard
Mix #259: 423 lbs Type I Cement, 141 lbs Flyash, & 141 lbs Slag per cu. Yard
Specified Strength: 650 psi at 28 days

		Mix		Air	Flexural Strength, psi									Increase, 7-28 Day		Increase, 28-90 Day	
Lot #	Date	Number	Slump	Content	7 Day	7 Day	7 day Ave	28 Day	28 Day	28 day Ave	90 Day	90 Day	90 Day Ave	psi	%, 28 day	psi	%, 28 day
Lot 33-1	03/17/04	2600	2 1/2"	4.8%	480	520	500	760	780	770	715	705	710	270	35%	-60	-8%
Lot 33-3	03/17/04	2600	2"	5.0%	470	505	488	725	710	718	775	705	740	230	32%	22.5	3%
Lot 34-1	03/18/04	2600	1 1/2"	4.2%	555	530	543	700	760	730	765	830	798	187.5	26%	67.5	9%
Lot 34-3	03/18/04	2600	2"	4.5%	530	505	518	785	660	723	895	860	878	205	28%	155	21%
Lot 34-5	03/18/04	2600	1 1/2"	4.5%	525	510	518	730	705	718	865	800	833	200	28%	115	16%
Lot 35-1	03/19/04	2600	1 1/2"	4.5%	470	460	465	695	645	670	620	630	625	205	31%	-45	-7%
Lot 35-3	03/19/04	2600	2"	4.8%	520	515	518	750	660	705	825	790	808	187.5	27%	102.5	15%
Lot 36-1	03/19/04	2600	2"	4.3%	535	480	508	770	705	738	840	760	800	230	31%	62.5	8%
Lot 36-4	03/19/04	259	5"	6.5%	490	485	488	545	605	575	715	755	735	87.5	15%	160	28%
Lot 37-1	03/20/04	2600	2 1/2"	4.3%	500	490	495	690	705	698	830	785	808	202.5	29%	110	16%
Lot 37-3	03/20/04	2600	1 1/2"	4.5%	440	540	490	715	755	735	885	885	885	245	33%	150	20%
Lot 38-1	03/20/04	2600	1 1/2"	4.8%	530	540	535	700	750	725	860	840	850	190	26%	125	17%
Lot 38-3	03/20/04	2600	1 1/2"	4.3%	505	475	490	755	705	730	900	940	920	240	33%	190	26%
Lot 40-1	03/25/04	2600	1 1/2"	4.0%	480	450	465	645	615	630	820	820	820	165	26%	190	30%
Lot 40-2	03/25/04	2600	1 3/4"	4.2%	505	505	505	675	640	658	780	870	825	152.5	23%	167.5	25%
Lot 40-3	03/25/04	2600	1"	4.0%	560	530	545	635	630	633	885	870	878	87.5	14%	245	39%
Lot 40-4	03/25/04	2600	1 1/2"	4.0%	590	610	600	665	650	658	840	885	863	57.5	9%	205	31%
Lot 41-1	03/26/04	2600	1 1/4"	3.8%	435	385	410	690	765	728	700	800	750	317.5	44%	22.5	3%
Lot 41-3	03/26/04	2600	2"	3.4%	400	435	418	770	800	785	870	780	825	367.5	47%	40	5%

Concrete Statistics

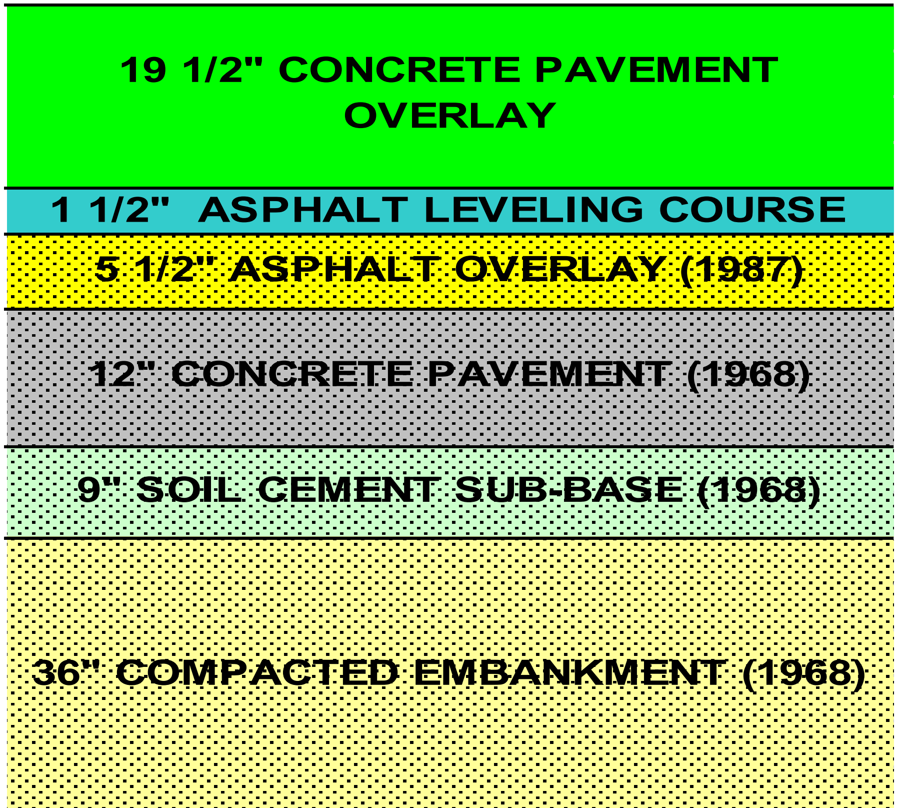
			7 Day	28 Day	90 Day
Average Slump:	1.9"	Average Flexural Strength:	500 psi	701 psi	808 psi
Average Air Content:	4.4%	S.D., Flexural Strength:	43 psi	52 psi	71 psi
		Minimum Beam Strength:	385 psi	545 psi	620 psi
		Maximum Beam Strength:	610 psi	800 psi	940 psi

Average Increase, 7 day to 28 dayi: 201 psi
Average Increase, 7 day to 28 day, % of 28 day: 28%
Average Increase, 28 day to 90 day: 107 psi

Fig. 6: Final Pavement Cross Section for Taxiway “WP”

George Bush Intercontinental Airport, Houston, Texas

Aerial View of Runway Rehabilitation



- **NORMAL STRESS = 20.70 psi**
- **SHEAR STRESS = 8.2 psi**
- **PRINCIPLE STRESS = 22 psi**
- **DISPLACEMENT (DEFLECTIVE)= 0.05”**
- **NORMAL STRAIN = 0.0000067**
- **SHEAR STRAIN = 0.0000049**
- **PRINCIPLE STRAIN = 0.0000072**

ELLINGTON FIELD AIRPORT - 90-110G - RESULTS OF 90-DAY BREAKS

Table 1: Compressive Strength Results

DRY DESCRIPTION	LL	PI	DENSITY (pcf)	q (kPa)	q (psi)
UNMODIFIED CLAY	55	38			
UNMODIFIED SANDY CLAY	45	29			
CLAY W/7% LIME		12			
CLAY W/ 4% LIME & 10% FLYASH		NP	97.8	3.50	50.83
		NP	97.6	4.20	60.56
CLAY W/ 4% LIME & 12% FLYASH		NP	95.1	12.18	174.40
		NP	94.2	12.39	177.22
SANDY CLAY W/ 4% LIME & 10% FLYASH		NP	100.4	19.32	276.11
		NP	100.6	16.38	234.44
SANDY CLAY W/ 4% LIME & 12% FLYASH		NP	103.2	20.02	286.39
		NP	101.0	28.21	403.61

Samples made on: September 29, 1990
Samples tested on: January 4,1991

The following Standards were used in performing the test:

1. Sample preparation — ASTM D *558* (Method A)
2. Compaction — ASTM D 559 (Method A)
3. Curing — ASTM D 1632
4. Compressive strength — ASTM D 1633 (Method A)

Table 4: Cement-Flyash Stabilized Subgrade Summary
Runway 8r-26l Reconstruction
For 4% Cement And 10% Flyash

Date	Report #	Moisture Content	Ave. Dens. pcf:	7 Day Cyl 1 psi	7 Day Cyl 2 psi	7 Day Average	7 Day Difference psi	7 Day Difference %	28 Day Cyl 1 psi	28 Day Cyl 2 psi	28 Day Average	28 Day Difference psi	28 Day Difference %	90 Day Cyl 1 psi	90 Day Cyl 2 psi	90 Day Average	90 Day Difference psi	90 Day Difference %
12/30/2003	38	23.3%	99.5	155	160	157.5	5	3.2%	190	195	192.5	5	2.6%	200	200	200	0	0.0%
12/30/2003	40	21.0%	101.1	50	50	50	0	0.0%	55	50	52.5	5	9.5%	40	30	35	10	28.6%
12/30/2004	42	16.0%	104.5	425	420	422.5	5	1.2%	565	570	567.5	5	0.9%	725	770	747.5	45	6.0%
1/10/2004	94	15.0%	110.5	395	400	397.5	5	1.3%	680	675	677.5	5	0.7%	1210	1215	1212.5	5	0.4%
1/102004	96	24.0%	95.5	425	440	432.5	15	3.5%	790	790	790	0	0.0%	1130	1235	1182.5	105	8.9%
1/14/2004	136	16.4%	109.9	55	55	55	0	0.0%	60	55	57.5	5	8.7%	65	65	65	0	0.0%
1/20/2004	166	14.8%	110.4	170	155	162.5	15	9.2%	315	325	320	10	3.1%	510	510	510	0	0.0%
1/20/2004	169	15.2%	110.2	180	170	175	10	5.7%	270	280	275	10	3.6%	365	385	375	20	5.3%
1/23/2004	190	16.7%	108.9	215	225	220	10	4.5%	390	390	390	0	0.0%	460	460	460	0	0.0%
1/23/2004	192	13.5%	113.6	410	410	410	0	0.0%	650	640	645	10	1.6%	885	780	832.5	105	12.6%
3/8/2004	587	19.7%	96.2	395	355	375	40	10.7%	595	580	587.5	15	2.6%	880	840	860	40	4.7%
3/8/2004	588	17.6%	105	115	110	112.5	5	4.4%	355	365	360	10	2.8%	725	700	712.5	25	3.5%
3/8/2004	589	15.1%	107.4	330	385	357.5	55	15.4%	680	695	687.5	15	2.2%	1000	885	942.5	115	12.2%
3/24/2004	756	14.8%	111.5	150	165	157.5	15	9.5%	165	170	167.5	5	3.0%	250	275	262.5	25	9.5%
3/24/2004	759	16.7%	109	105	105	105	0	0.0%	105	110	107.5	5	4.7%	125	115	120	10	8.3%
3/28/2004	803	19.4%	105.1	40	40	40	0	0.0%	35	35	35	0	0.0%	55	50	52.5	5	9.5%
3/28/2004	806	20.5%	103.7	45	45	45	0	0.0%	40	40	40	0	0.0%	65	75	70	10	14.3%
3/28/2004	809	13.4%	98.5	70	70	70	0	0.0%	80	90	85	10	11.8%	250	265	251.5	15	5.8%
3/30/2004	826	15.5%	112.3	445	460	452.5	15	3.3%	780	760	770	20	2.6%	1190	1165	1177.5	25	2.1%
3/31/2004	837	13.3%	102.2	240	250	245	10	4.1%	355	345	350	10	2.9%	475	495	485	20	4.1%
3/31/2004	840	12.8%	104.3	345	335	340	10	2.9%	435	445	440	10	2.3%	805	706	755.5	99	13.1%
3/31/2004	843	16.5%	106.8	175	170	172.5	5	2.9%	325	345	335	20	6.0%	645	730	687.5	85	12.4%
4/16/2004	968	18.9%	104.5	280	290	285	10	3.5%	430	445	437.5	15	3.4%	595	565	580	30	5.2%
4/16/2004	970	19.1%	104.4	345	350	347.5	5	1.4%	520	510	515	10	1.9%	735	710	722.5	25	3.5%
4/16/2004	973	20.5%	102.4	320	310	315	10	3.2%	380	360	370	20	5.4%	470	460	465	10	2.2%
4/19/2004	991	21.4%	100	160	155	157.5	5	3.2%	250	255	252.5	5	2.0%	335	330	332.5	5	1.5%
4/19/2004	993	14.1%	107.7	580	575	577.5	5	0.9%	660	690	675	30	4.4%	815	805	810	10	1.2%
4/19/2004	996	13.8%	112.1	360	375	367.5	15	4.1%	605	590	597.5	15	2.5%	725	735	730	10	1.4%
4/30/2004	1068	16.4%	105.1	760	755	757.5	5	0.7%	1475	1310	1392.5	165	11.8%	1860	1835	1847.5	25	1.4%
4/30/2004	1069	18.1%	104.7	480	515	497.5	35	7.0%	955	825	890	130	14.6%	1310	1440	1375	130	9.5%
4/30/2004	1070	18.2%	105	145	140	142.5	5	3.5%	275	245	260	30	11.5%	315	300	307.5	15	4.9%
5/3/2004	1082	21.4%	853	575	570	572.5	5	0.9%	720	750	735	30	4.1%	730	760	745	30	4.0%
5/3/2004	1084	15.1%	102.1	275	260	267.5	15	5.6%	400	400	400	0	0.0%	450	460	455	10	2.2%
5/3/2004	1085	23.3%	95.6	60	60	60	0	0.0%	85	80	82.5	5	6.1%	95	95	95	0	0.0%
5/5/2004	1099	14.2%	98.7	595	535	565	60	10.6%	1035	855	945	180	19.0%	1445	1565	1505	120	8.0%
5/5/2004	1100	14.9%	101.2	425	425	425	0	0.0%	580	565	572.5	15	2.6%	730	675	702.5	55	7.8%

Strength Statistics

	Moisture Content	Density pcf.
Average	17.2%	104.1
St. Dev.	3.1%	5.8
Minimum	12.8%	85
Maximum	24.0%	114

7 Day

Avg. Compressive Strength, psi:	286
S.D. Compressive Strength, psi	180.9
Minimum Strength, psi	40
Maximum Strength, psi	760
Average Within Set Variation, psi	11.0
Number of sets:	36

Average compressive strength, 2000 kPa

28 Day

Avg. Compressive Strength, psi	446
S.D. Compressive Strength, psi	303.4
Minimum Strength, psi	35
Maximum Strength, psi	1475
Average Within Set Variation, psi	22.9
Number of sets:	36

Average compressive strength, 3120 kPa

90 Day

Avg. Compressive Strength, psi	630
S.D. Compressive Strength, psi	437.0
Minimum Strength, psi	30
Maximum Strength, psi	1860
Average Within Set Variation, psi	34.4
Number of sets:	36

Average compressive strength, 4400 kPa

Questions & Answers

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