Airfield Pavement Design & Rehabilitation

ICAO Aerodome Pavement Workshop

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Overview

- **Airfield Pavement Concepts**
- **Airfield Pavement Design Considerations**
  - Traffic
  - Soil Investigation
  - Flexible Pavement Design
  - Rigid Pavement Design
- **Materials & Specifications**
  - Aggregate Layers
  - Stabilized Materials
  - Frost Consideration
- **Reconstruction Alternatives**
  - Overlays
  - Alternative Methods for Existing Pavements

What do we need pavements to do?

- Structural capacity to support the imposed loads
- A smooth, but skid-resistant surface
- Adequate drainage
- To be free of foreign object debris (FOD)
- Sufficient stability to withstand the abrasive action of traffic, adverse environmental conditions, and other deteriorating influences (durability)

Factors Affecting Pavement Responses and Performance

Airfield Pavement Concepts

Difference Between Highways and Airports

Highway Pavement

4,500 lb (2000 kg) Wheel Loads

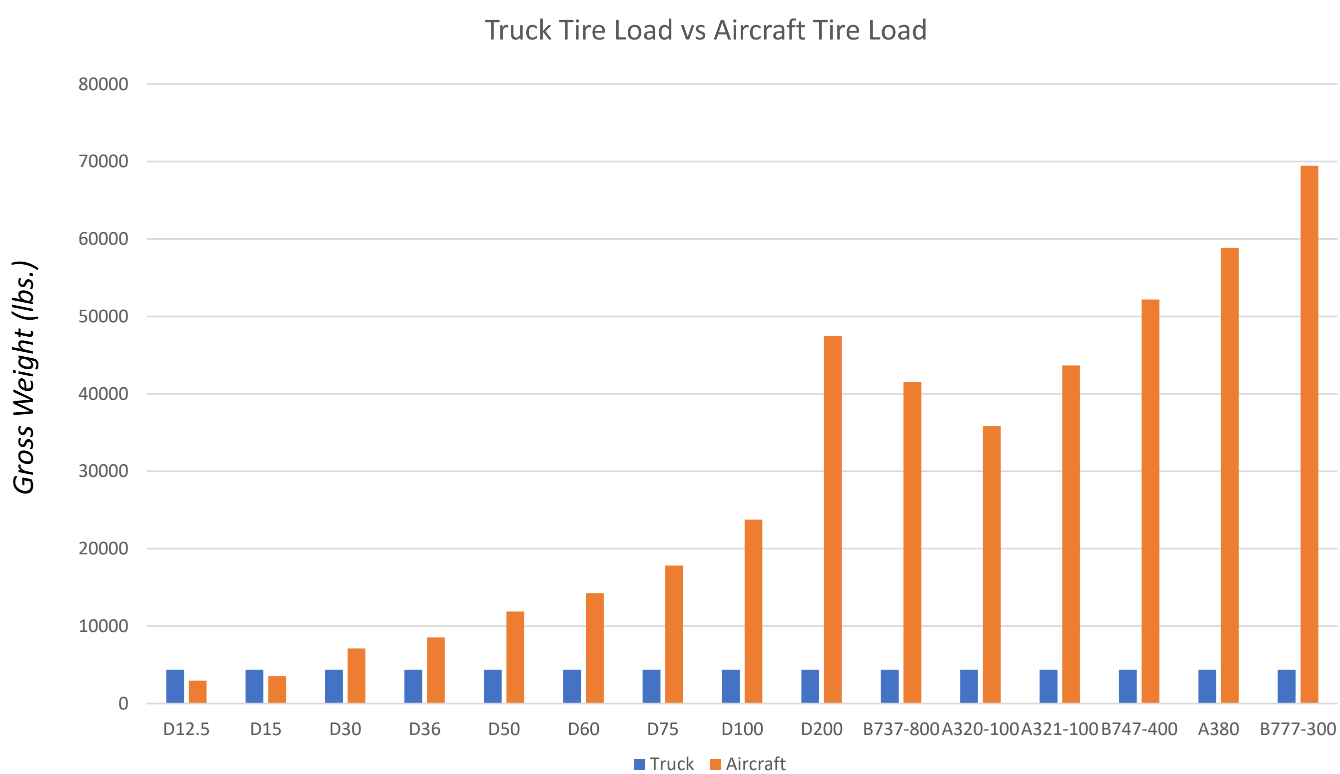
80-120 psi (0.5-.08 Mpa) Tire pressures

Airfield Pavement

>60,000 lb (29,000 kg) Wheel Loads

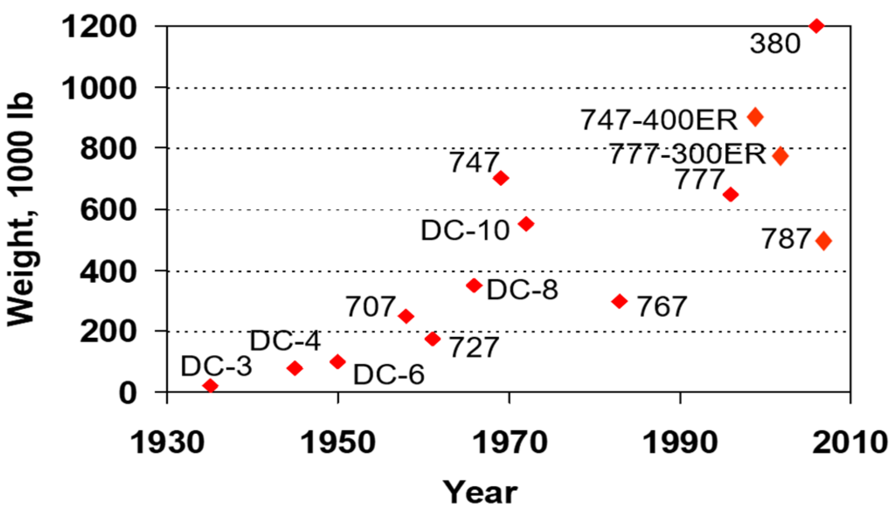
150-250 psi (1.0-1.7 Mpa) Tire pressures

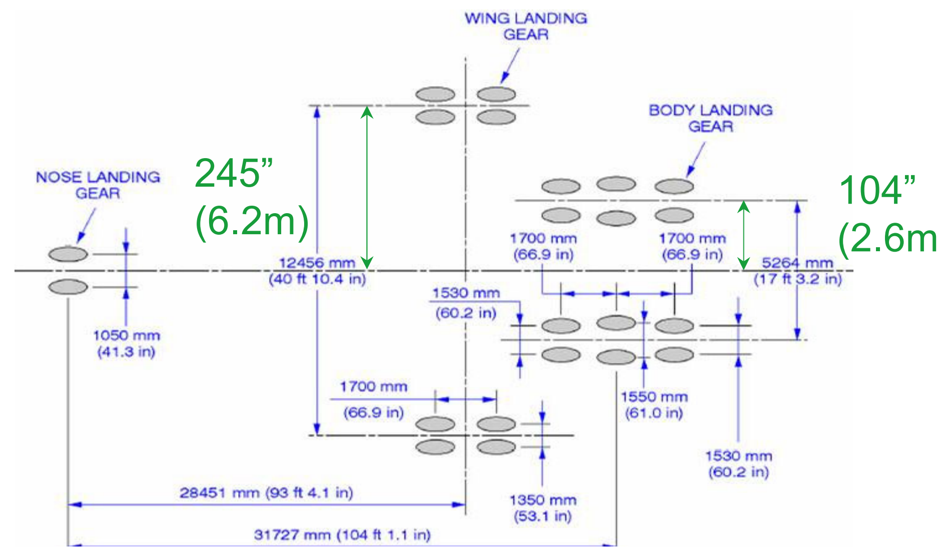
Difference Between Highways and Airports



Traffic - Aircraft Weight

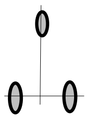
- Aircraft can impart heavy loads on pavement
- Weights are increasing tire pressures
- Increasingly complicated gear configurations



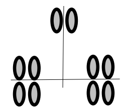


Airbus A-380

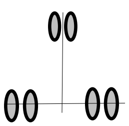
Traffic - Aircraft Gear Configuration



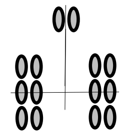
S
Single Wheel



2D
Dual Tandem



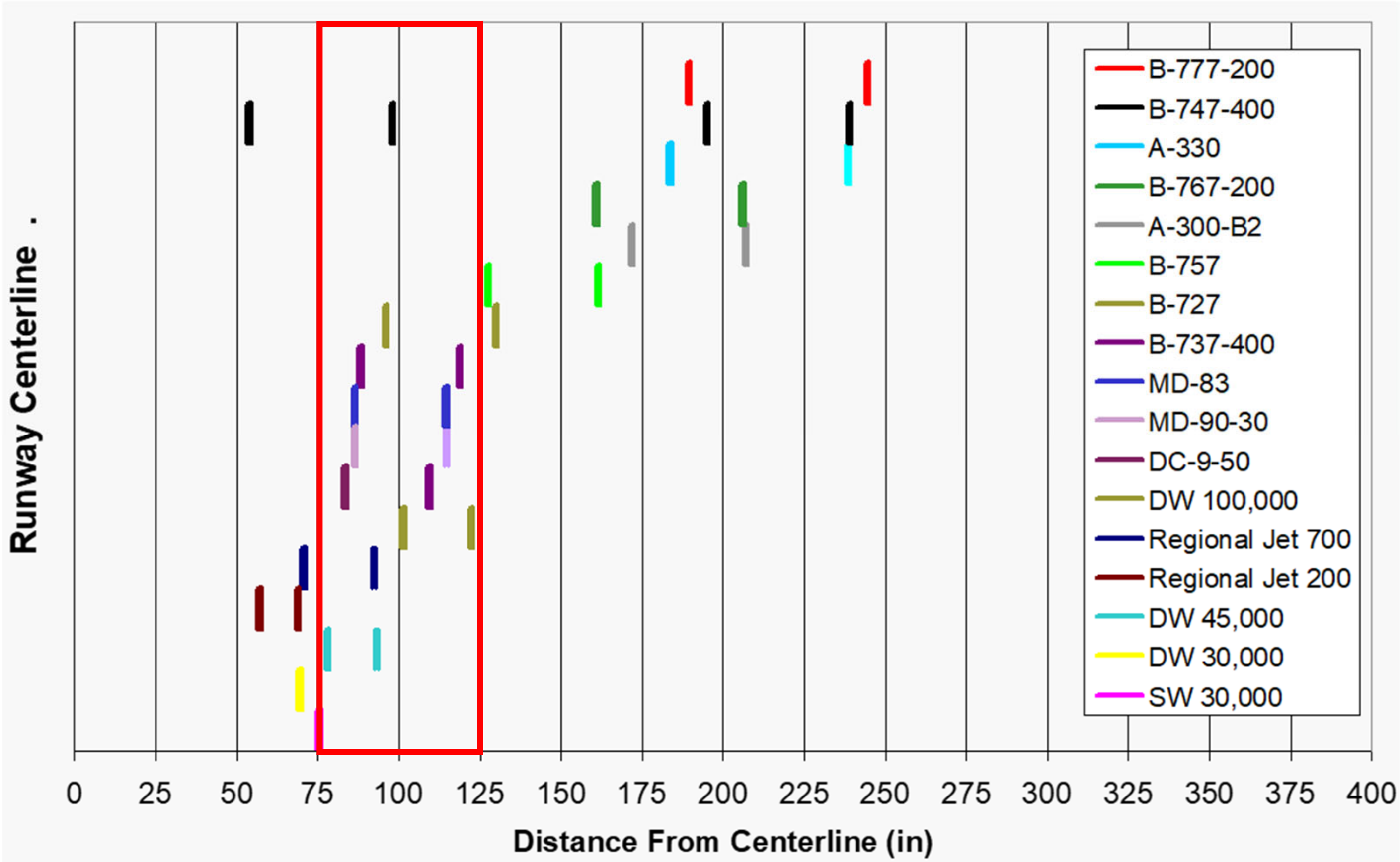
D
Dual Wheel



3D
Triple Dual Tandem

FAA Order 5300.7- *Standard Naming Convention for Aircraft Landing Gear Configurations*

Mix Traffic - Aircraft Gear Locations



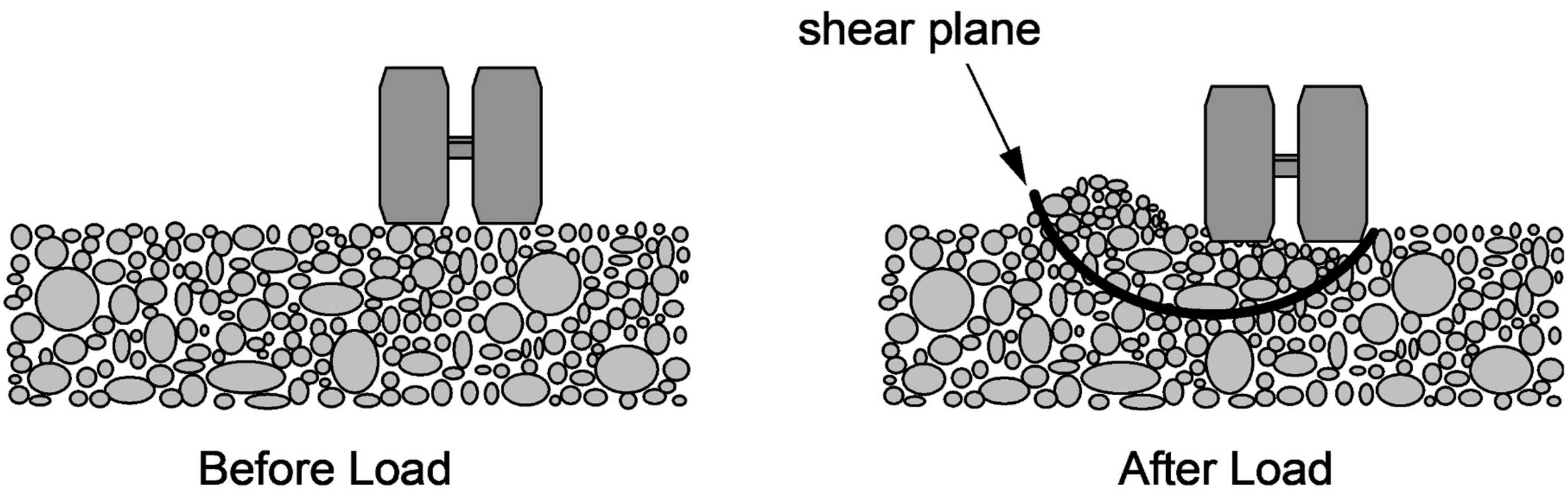
Federal Aviation Administration

More than just weight....

- Tire pressure has a significant impact near surface.

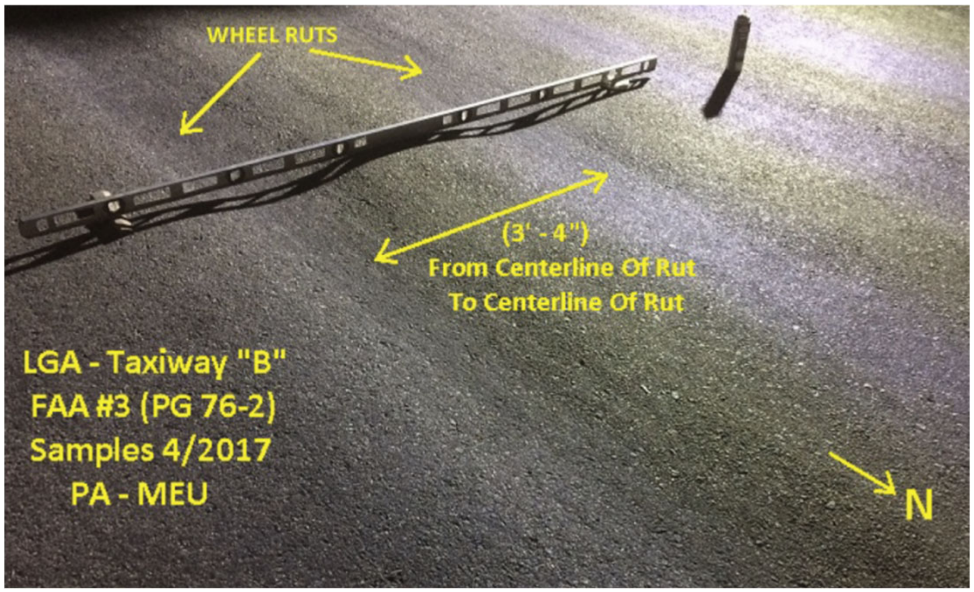
Aircraft	Gross Weight (lbs)	Tire Pressure (PSI)
Learjet 35/36	18,000	171
Learjet 45/55	21,500	201
Cessna Citation X	36,000	189
Dassault Falcon 2000	35,000	197
Dassault Falcon 50	38,800	208
Gulfstream G-II	66,000	160
Gulfstream G-V	90,900	188
B737-900ER	188,200	220
A321neo	213,800	235

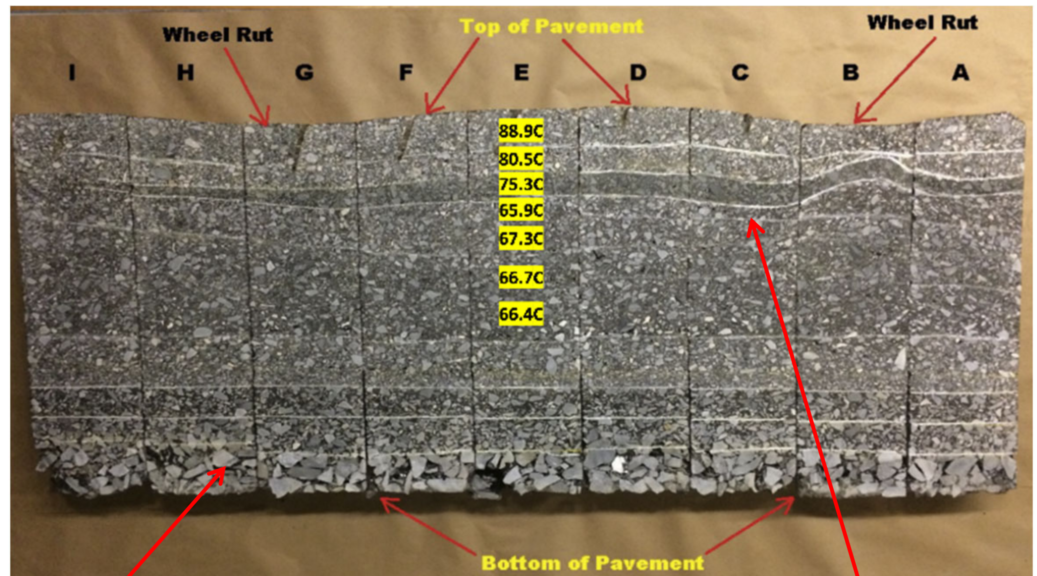
Why does Tire Pressure Matter?



From Report
DOT/FAA/TC-22/25

Why does Tire Pressure Matter?



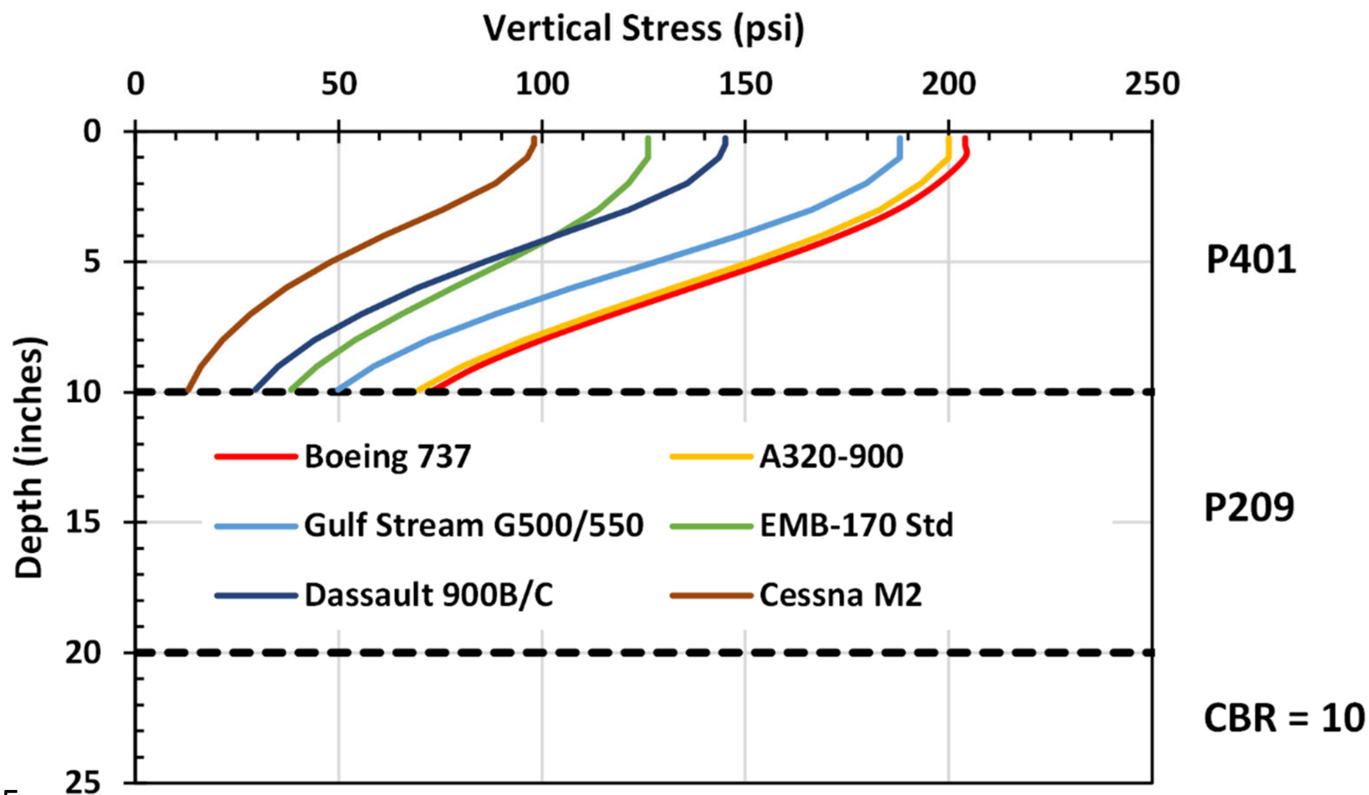


No rutting observed at the bottom

Rutting is in the upper lifts

From Report
DOT/FAA/TC-22/25

Why does Tire Pressure Matter?



From Report
DOT/FAA/TC-22/25

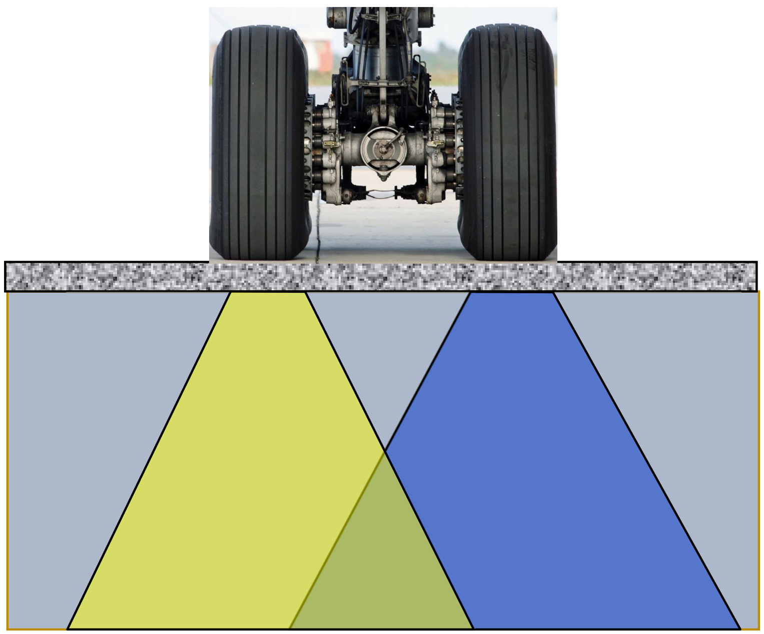
What is the Risk of Poor Quality Materials?

What are the Consequences?

What are the Consequences?

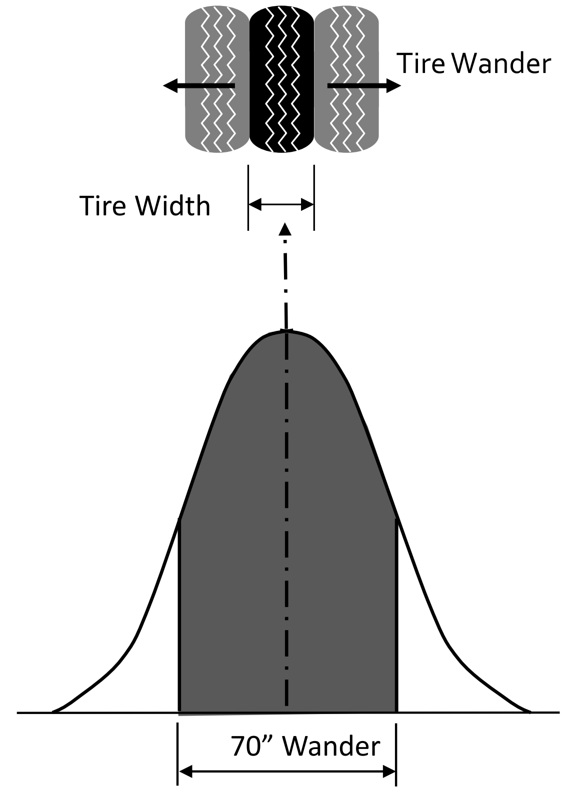
Traffic-Stress

- Impact of multi-wheel landing gear
- Stresses from each tire can overlap
- Total combined stress is considered in design



Traffic- Wander

- An aircraft movement across a section is known as a **pass**
- Aircraft seldom travel along a perfectly straight path or along the same path each time.
- This lateral movement is known as aircraft **wander**
- FAARFIELD assumes 75% of passes occur with 70” wander

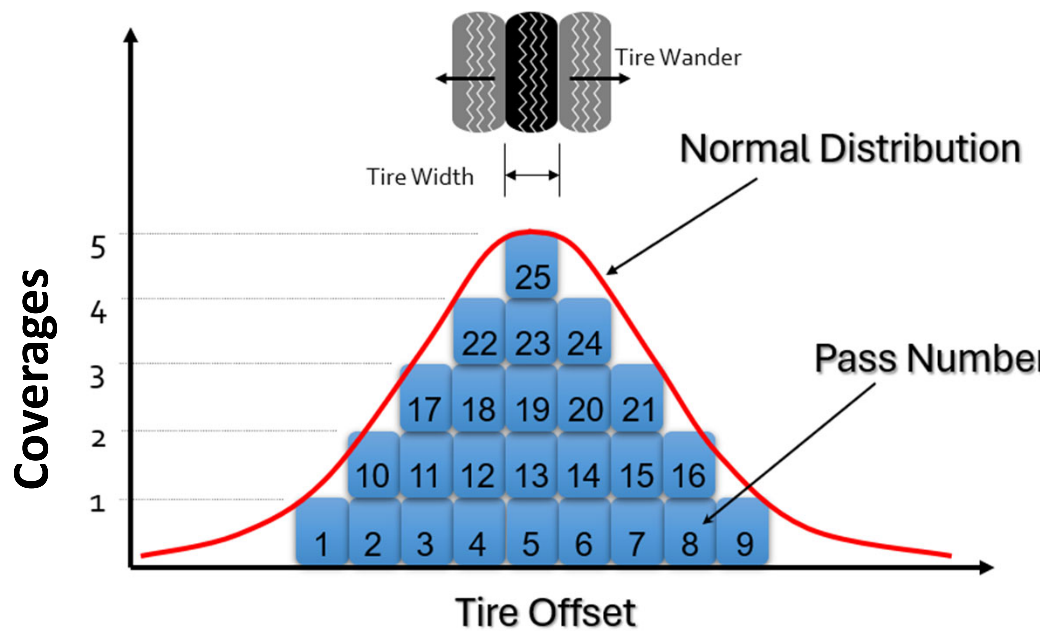


*The **wander width** is that width over which the centerline of the aircraft traffic is distributed 75% of the time.*

Original Slide by Richard B. Smith, USAF

Traffic- Coverages

- Several passes over a specific point is a known as **<u>coverage</u>**
- A **<u>coverage</u>** defines the number of maximum stress repetitions that occur in a pavement as a result of aircraft operations.
- A coverage is a function of <u>gear and tire width</u>
- The ratio of number of passes required to apply one coverage to a unit area of the pavement is expressed by the pass-to-coverage **(P/C) ratio.**



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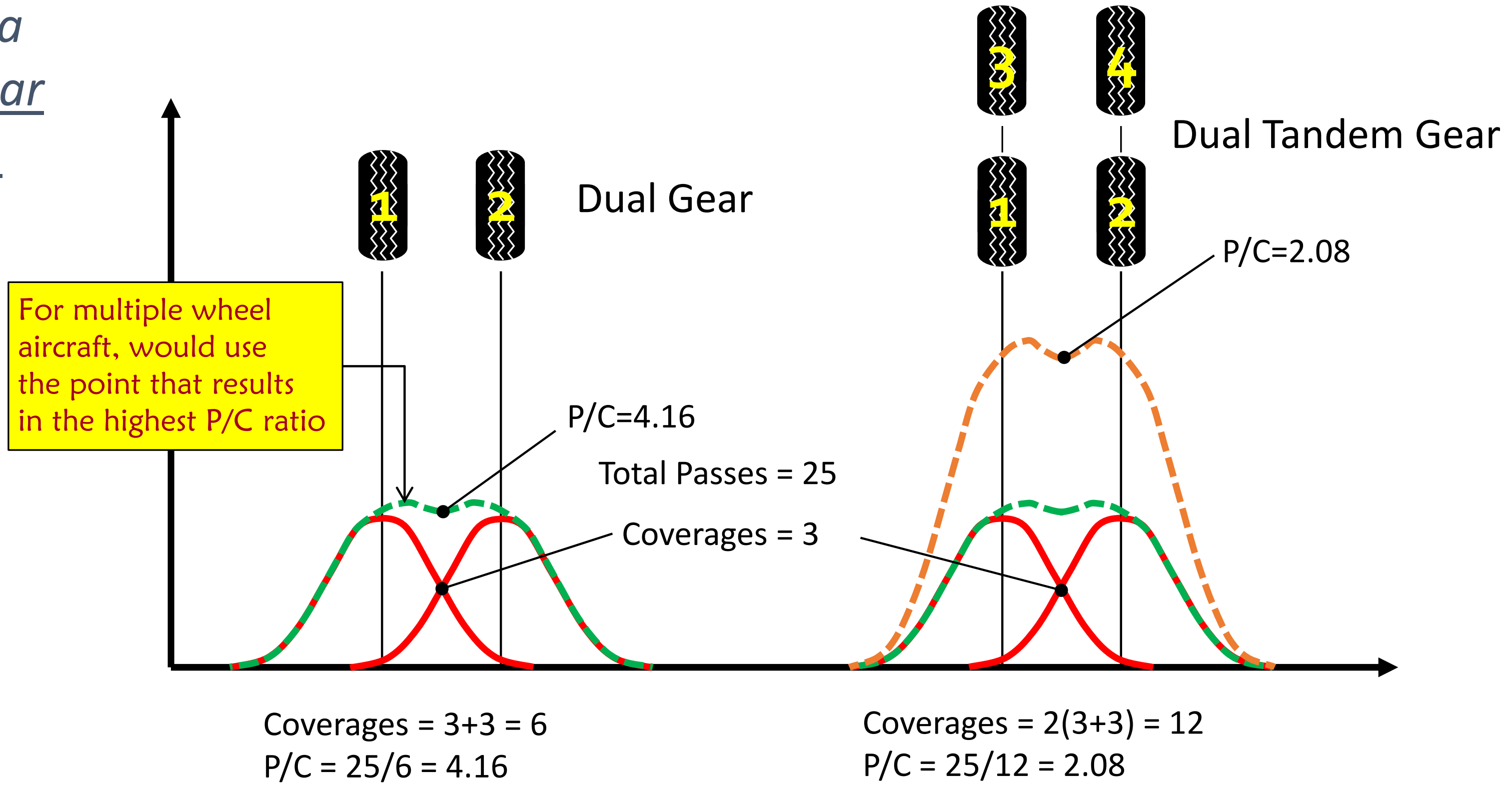
Traffic- Pass/Coverage

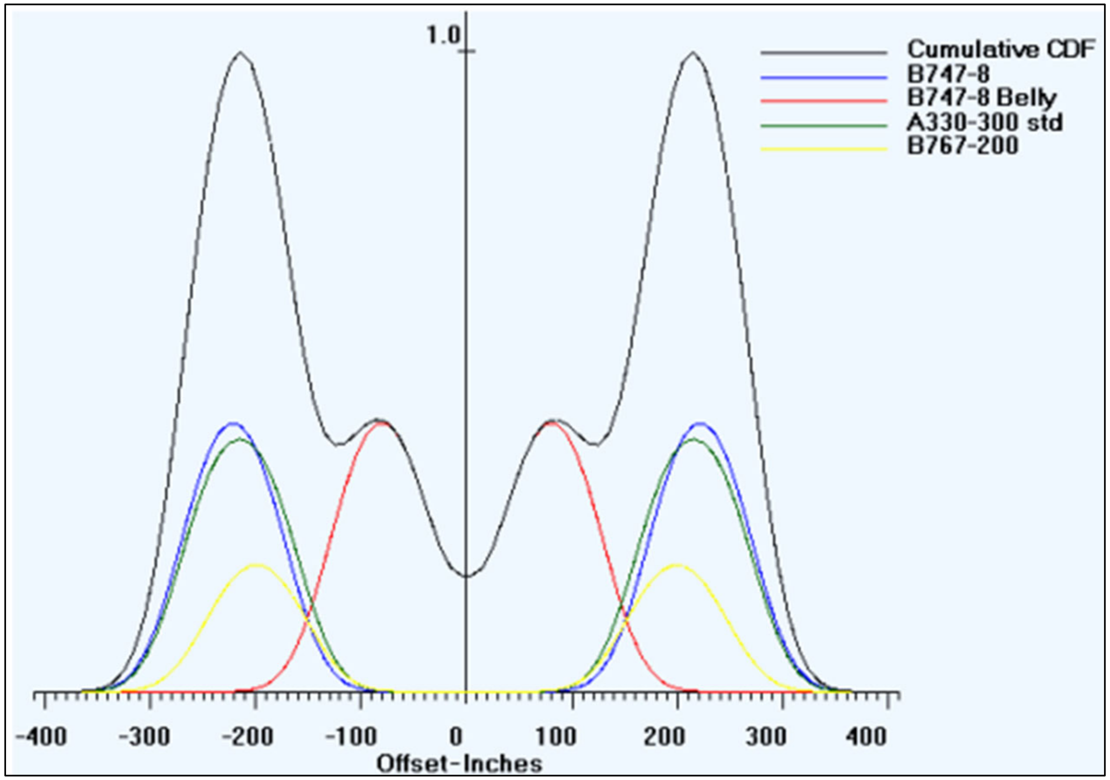
- *A coverage is a function of gear and tire width*



Original Slide by Richard B. Smith, USAF

Traffic- Cumulative Damage Factor (CDF)

- Sums the damage contributed from each aircraft
- CDF = Σ (n_i / N_i), where:
  - n_i = actual passes of individual aircraft *i*
  - N_i = allowable passes of individual aircraft *i*
- When CDF = 1, design life is exhausted.
- Miner's Rule (linear summation of damage)
- Accounts for cumulative damage of traffic mix



Airfield Pavement Design

Airport Pavement Design Considerations

AIRCRAFT TRAFFIC

- Weights
- Tire Pressure
- Aircraft Mix
- Annual Departures

SITE CONDITION

- Subgrade Conditions
- Drainage
- Existing Pavement
- Environment

DESIGN

- Pavement Use
- Design Life
- Economics
- Materials

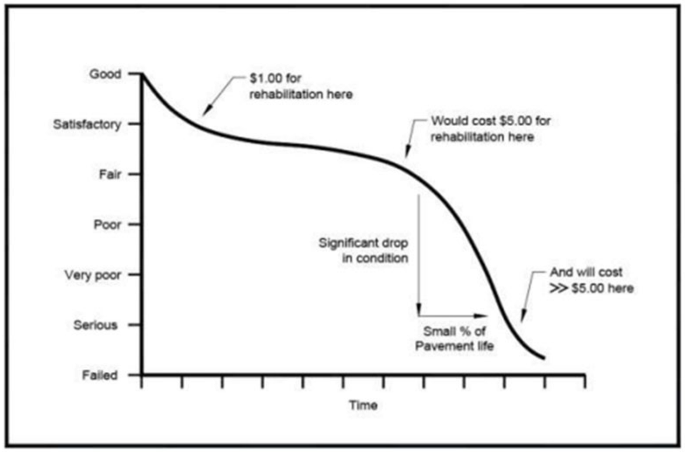


Figure 1. Typical Pavement Condition Life Cycle.

FAA Airfield Pavement Design Guidance

- Advisory Circular **150/5320-6G**, Airport Pavement Design and Evaluation, was published in June 2021.
- Contents
  - Chapter 1. Airport Pavements – Their Function and Purposes
  - Chapter 2. Soil Investigations and Evaluation
  - Chapter 3. Pavement Design
  - Chapter 4. Pavement Maintenance, Rehabilitation and Reconstruction
  - Chapter 5. Pavement Structural Evaluation
  - Chapter 6. Pavement Design for Shoulders
  - Appendices A-K

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Airport Pavement Design and Evaluation	Date: 6/7/2021 Initiated By: AAS-100	AC No: 150/5320-6G Change:

1 **Purpose.**
This advisory circular (AC) provides guidance to the public on the design and evaluation of pavements used by aircraft at civil airports. For reporting of pavement strength, see AC 150/5335-5D, *Standardized Method of Reporting Airport Pavement Strength – PCR*.

2 **Cancellation.**
This AC cancels AC 150/5320-6F, *Airport Pavement Design and Evaluation*, dated November 10, 2016.

3 **Applicability.**
This AC does not constitute a regulation, and is not legally binding in its own right. It will not be relied upon as a separate basis by the FAA for affirmative enforcement action or other administrative penalty. Conformity with this AC is voluntary, and nonconformity will not affect rights and obligations under existing statutes and regulations, except for the projects described in subparagraphs 2 and 3 below:

1. The standards and processes contained in this AC are specifications the FAA considers essential for the reporting of pavement strength.
2. Use of these standards and guidelines is mandatory for projects funded under Federal grant assistance programs, including the Airport Improvement Program (AIP). See Grant Assurance #34.
3. This AC is mandatory, as required by regulation, for projects funded by the Passenger Facility Charge program. See PFC Assurance #9.

Note: This AC provides one, but not the only, acceptable means of meeting the requirements of 14 CFR Part 139, *Certification of Airports*.

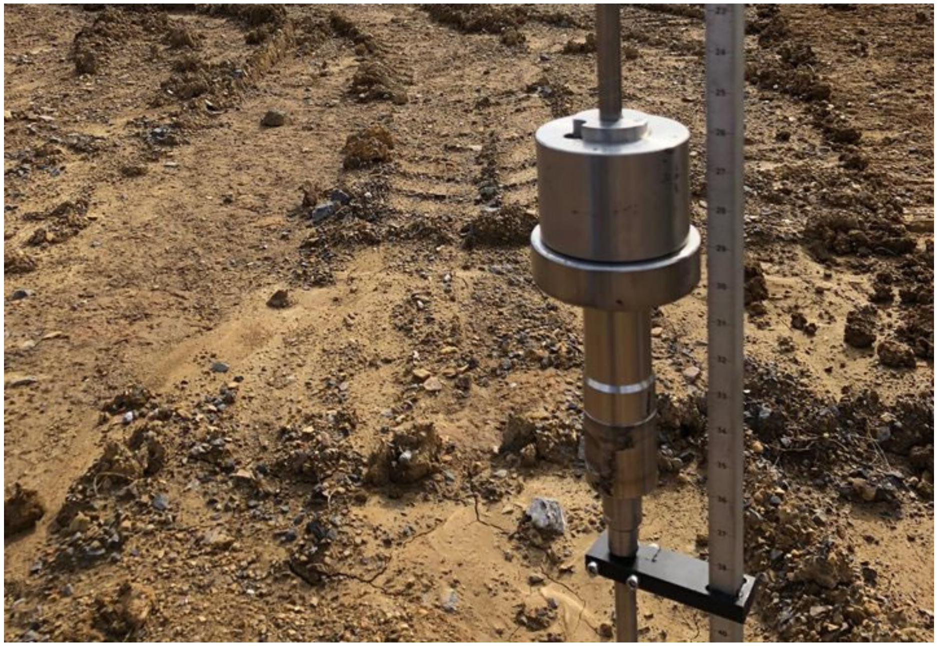
4 **Principal Changes.**
This AC contains the following principal changes:
1. Reformatted to comply with FAA Order 1320.46, *FAA Advisory Circular System*.

Traffic - Fleet Mix Considerations

- Fleet Mix should include all aircraft anticipated to operate on the pavement during its life
  - For Federally Funded projects fleet mix must be FAA approved and typically based on planning documents such as master plan.
- Determine type of aircraft (variant also) and expected operational load
  - If in doubt use FAARFIELD default load. But think about if an aircraft can operate at that load.
- Estimate annual departures of each aircraft
  - May need to consider taxi operations and arrivals
  - Think about aircraft distribution (i.e. multiple runways)
- Estimate Annual Growth

Site Conditions

- Subgrade soil layer forms the foundation of a pavement system
  - Characterization of existing soil conditions
- Assessment of drainage conditions
- Elevation of the water table
- Existing pavement



Site Conditions - Soil Investigation

- Conduct 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.
- Obtain representative samples of the different soil layers encountered and perform laboratory tests to determine their physical and engineering properties.
- Standards:
  - ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
  - ASTM D420, Standard Guide to Site Characterization
  - ASTM D2488, Standard Practice for Description and Identification of Soils
  - Soil Maps, Aerial Photography
    - https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

Site Conditions - Soil Investigation

- Laboratory test
  - Particle size analysis
  - Atterburg Properties:
    - Liquid Limit
    - Plastic Limit
    - Plasticity Index
  - Moisture-density relations of soil
    - Organic materials
    - Expansive Soils
  - Strength and other tests: CBR, Permeability etc.
- Field test – CBR, DCP etc.
- Borings – split-spoon, Standard Penetration Test
- NDT data back calculation

Site Conditions - Soil Investigation (New Const)

Area	Spacing	Depth
Runway/Taxiway	200 ft interval	10 ft
Other areas	1 per 10,000 sq ft	10 ft
Borrow areas	Sufficient to define material	To depth of Borrow Excavation

Pavement Design Procedure Background

FAA Flexible Pavement Design Procedure

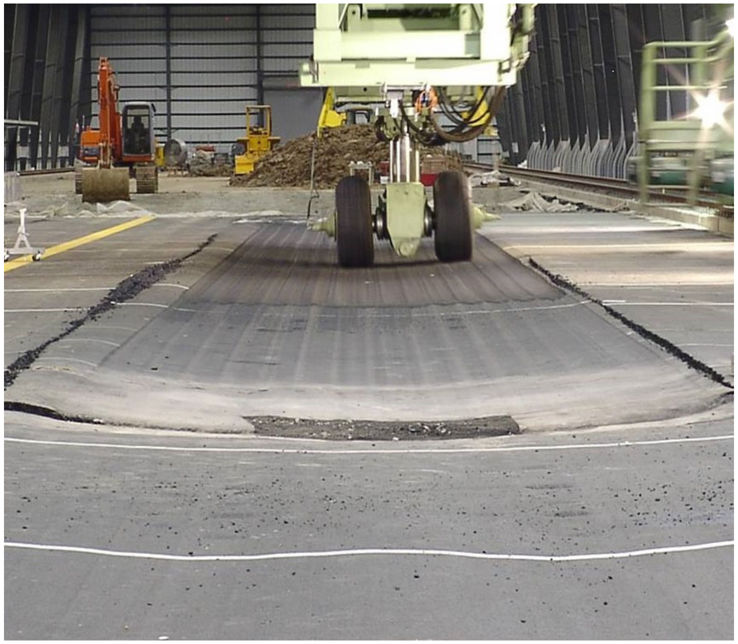
- Early procedure based on subgrade soil classifications and aircraft weights (Civilian Aeronautics Administration)
- FAA later adopted COE CBR procedure
- Previous procedure up to AC 150/5320-6D (1995; change 4 is June 2006 included Layered Elastic Analysis [LEA])
- Procedure in AC 150/5320-6E (Sept 2009) first to include LEA

FAA Rigid Pavement Design Procedure

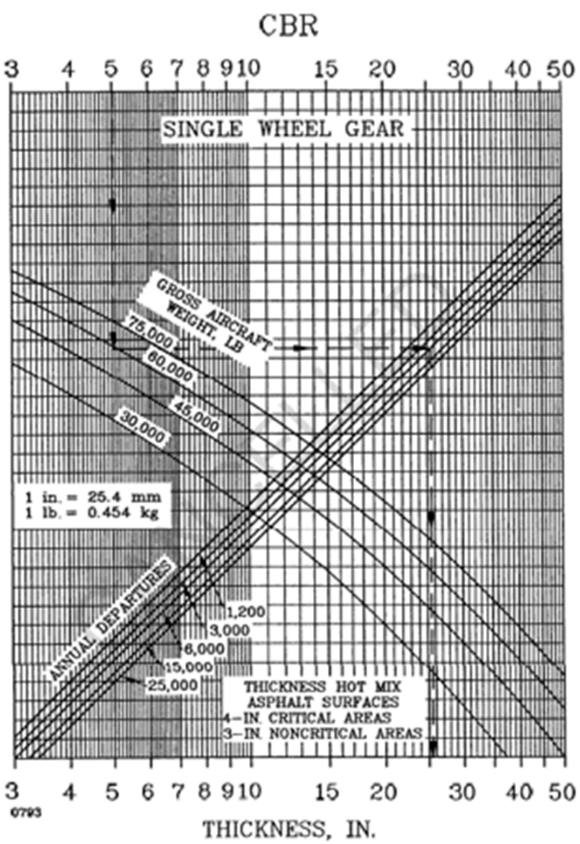
- Early procedure based on subgrade soil classifications and aircraft weights (Civilian Aeronautics Administration)
- FAA later adopted COE Westergaard-based procedure
- Previous procedure documented in AC 150/5320-6D
- Procedure in AC 150/5320-6E (Sept 2009) introduced Finite Element Modeling (FEM) design

Pavement Design Life

- National Airport Pavement Testing Facility (NAPTF)

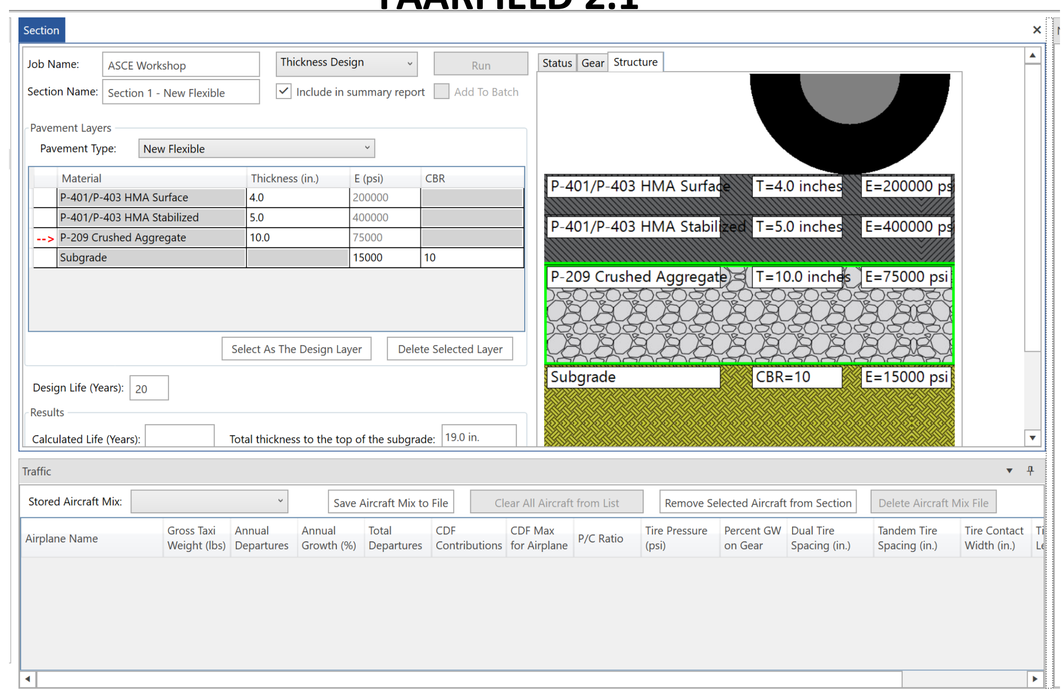


Layer Thickness Design



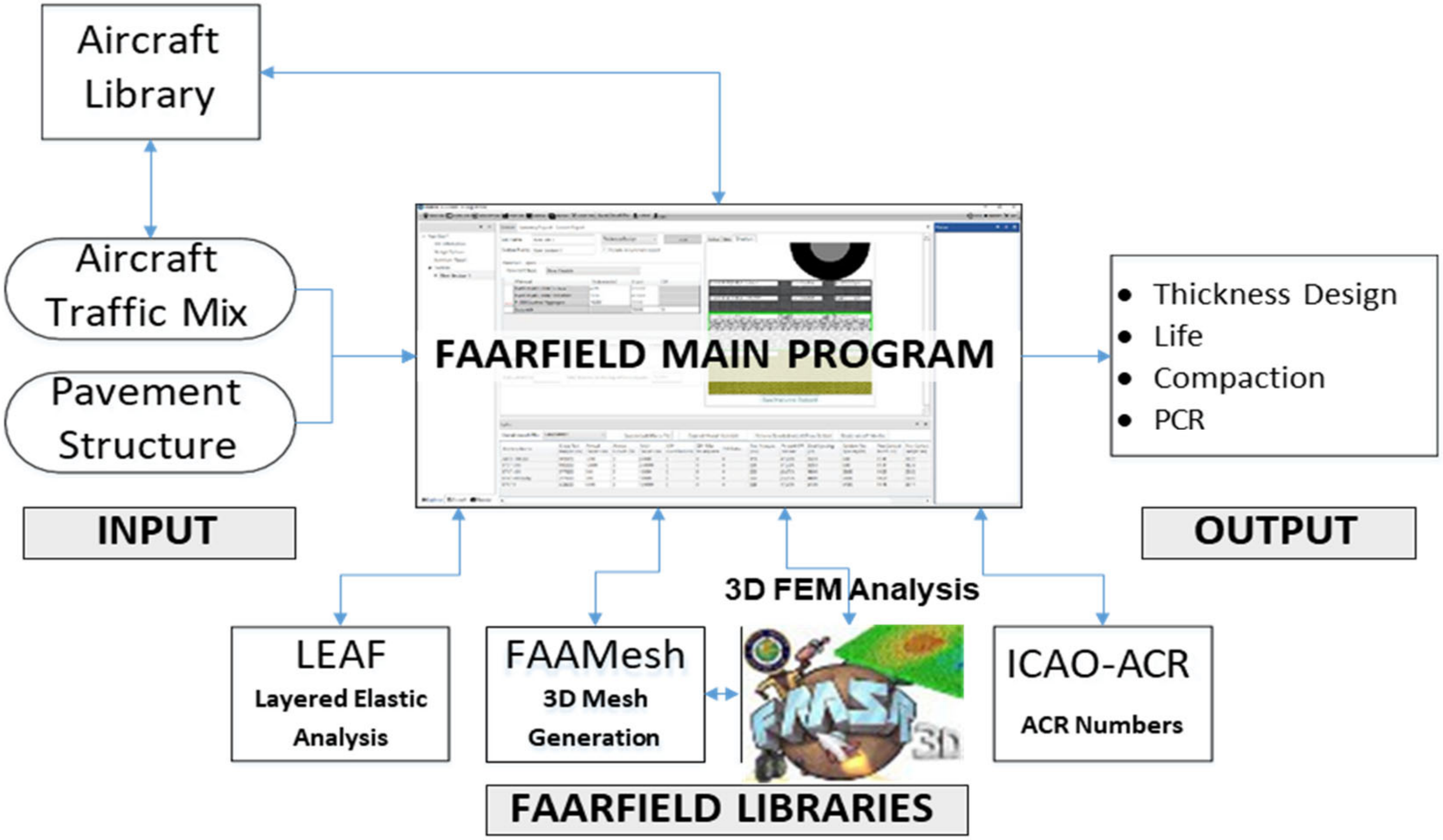
Flexible Pavement

FAARFIELD 2.1

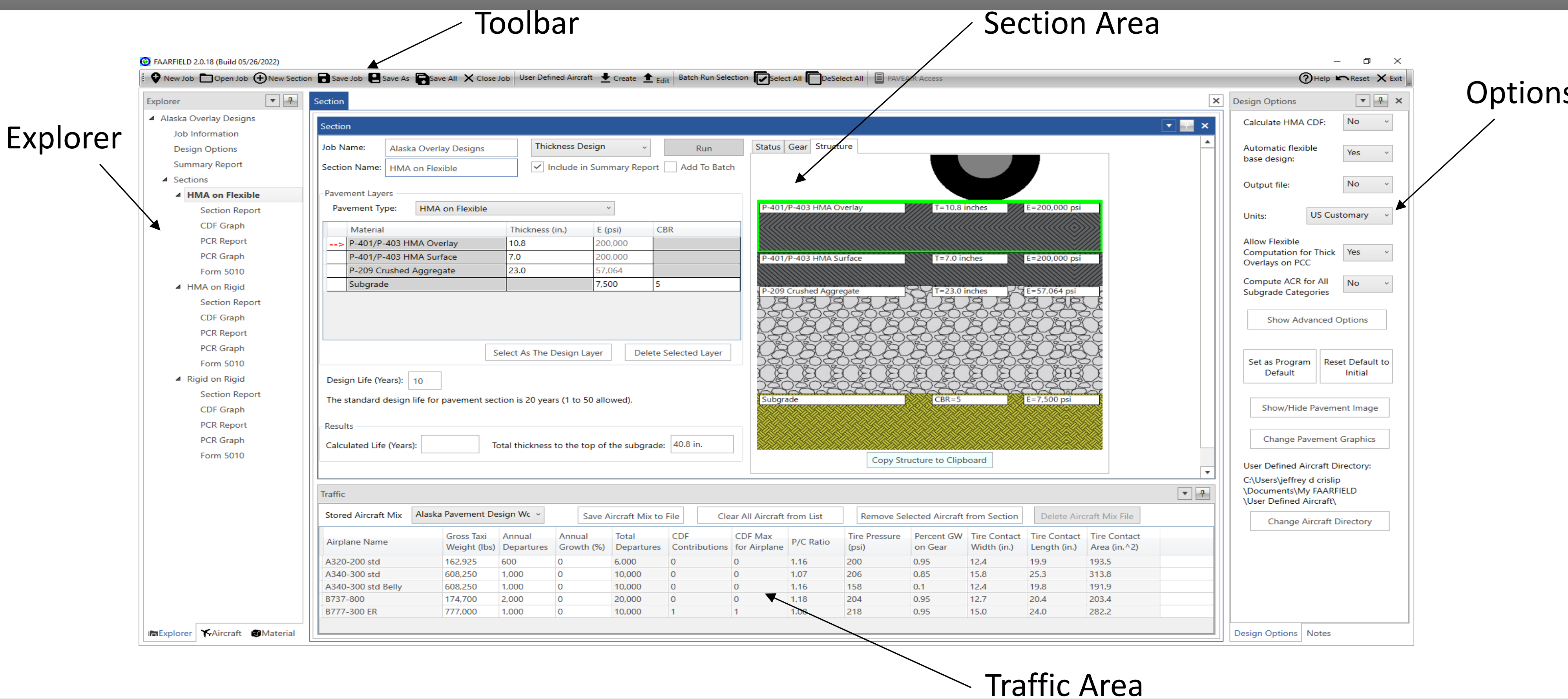


FAARFIELD: FAA Rigid and Flexible Iterative Elastic Layered Design

Introduction to FAARFIELD 2.1



FAARFIELD 2.1



Pavement Design Life

- **Structural Life:** Total number of load cycles a pavement structure will carry before it fails structurally.

  -**Design Life** in FAARFIELD refers to structural life
- **Functional Life:** the period of time that the pavement is able to provide an acceptable level of service as measured by performance indicators such as FOD, skid resistance, or roughness. Also known as useful life.

  -Pavements may have significant remaining functional life, even after they have failed structurally.
- **Actual life of pavement should be based on functional performance, not structural performance**
  - A pavement can still be safe and serviceable even after reaching structural failure
- **Proper design, quality materials and construction techniques are required for pavements to perform as desired**
- **Adequately maintained pavements will have longer functional life**

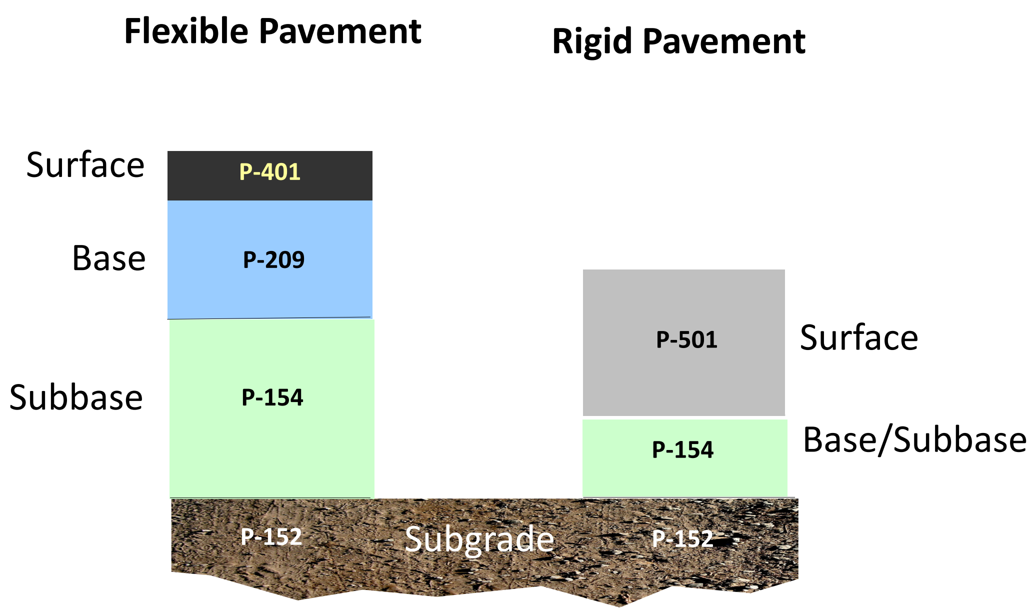
Pavement Design Life

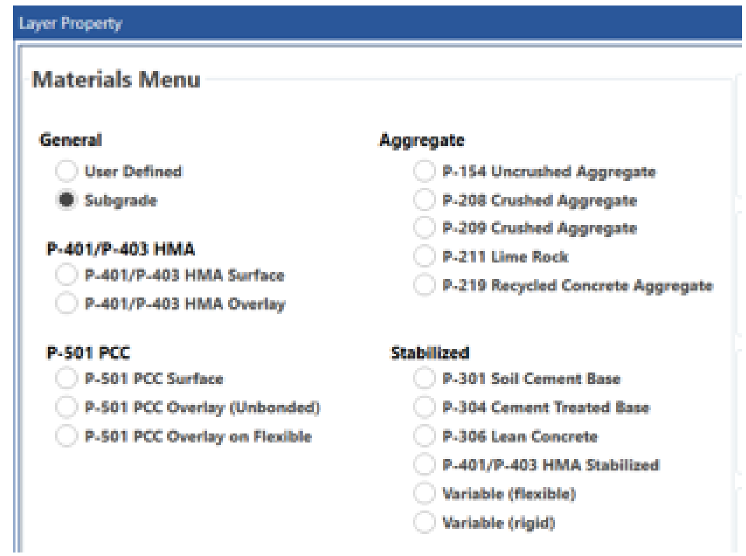
- **Design of new pavements on federally funded FAA projects for a minimum of a <u>20-years design life</u>**
- **Rehabilitation projects should be designed for a minimum <u>10-year design life</u>**
- **FAA requires the engineer to provide justification of design life in engineer's report**

- **To achieve intended design life requires consideration of several factors;**
  - Actual aircraft traffic mix vs traffic considered during the design
  - Initial quality of the material and construction
  - Timely application of routine and preventative maintenance

Airport Pavement Design Guidance

Some Common Terminology Used in FAA Pavement Design





- Materials are outlined in AC 150/5320-6G (2021)
- Construction specifications in AC 150/5370-10H (2018)

Typical Flexible Pavement Structure

- Flexible pavement systems are designed with layers strong enough to withstand the stresses placed upon it and thick enough to distribute those stresses to the layer underneath it without causing deformation

Flexible Pavement

Progressively stronger layers

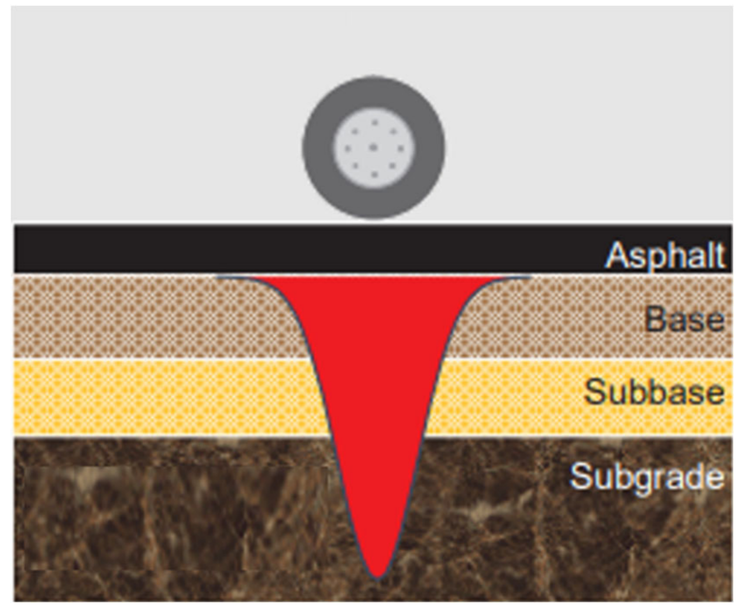
Hot Mix Asphalt

Base Course (Min CBR-80)*

Subbase (Min CBR-20)

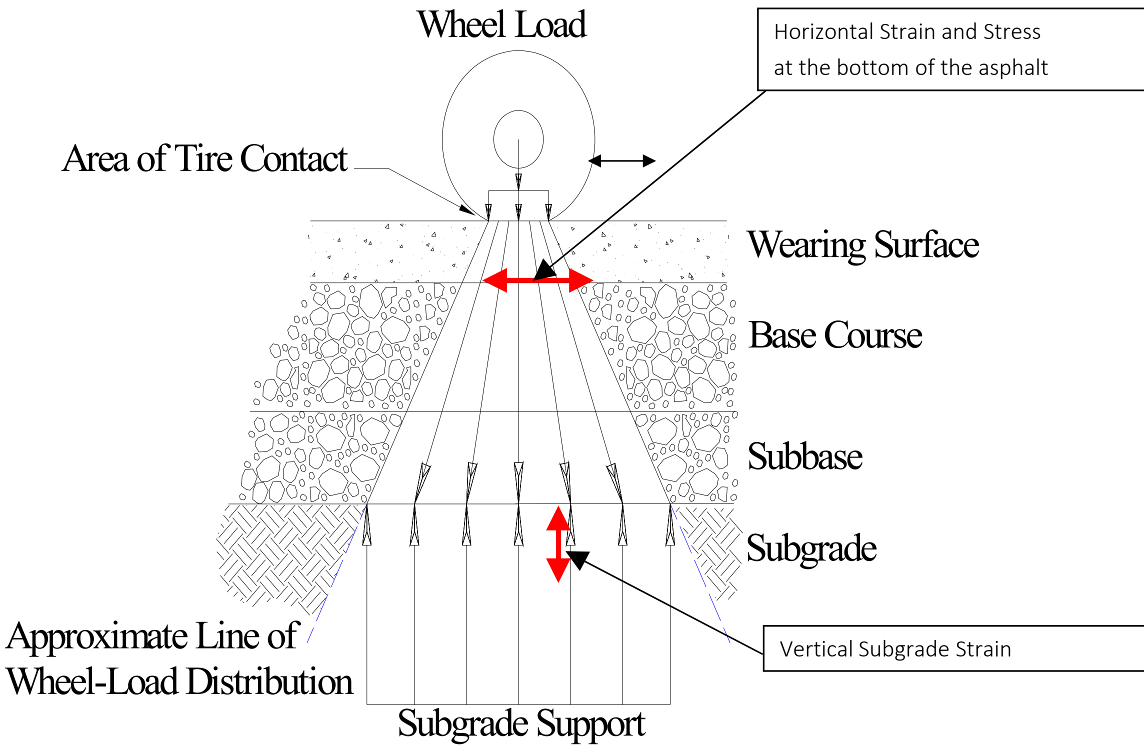
Frost Protection or Drainage*

Compacted Subgrade



FAA Flexible Pavement Design Concept

- For flexible design, layered elastic (LEAF) is used in FAARFIELD
- Maximum vertical strain at the top of subgrade
  - Typically, the controlling failure mode for flexible pavements
- Maximum horizontal strain at bottom of asphalt surface layer
  - FAARFIELD does not design by default
  - Need to select in Options if you want to analyze
  - It is good practice to always check this

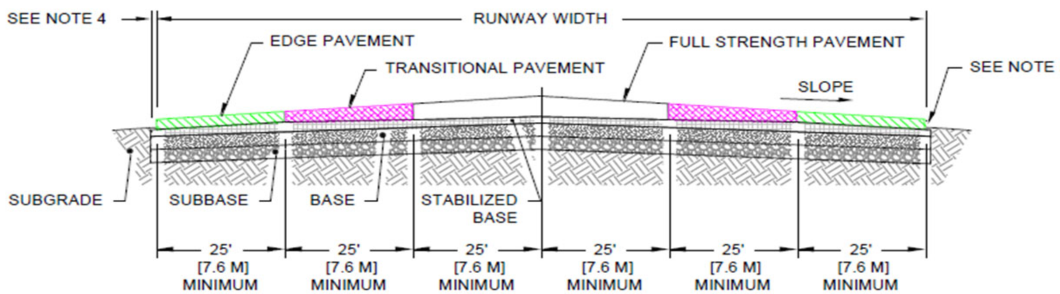


Asphalt Surface Layer

- **Minimum Material Requirements**
  - P-401 – Heavy Load Airfield Pavement
  - P-403 – Light Load Airfield Pavement
  - P-404 – Fuel Resistance (surface lift only)
- **Minimum Thickness (varies by aircraft weight)**
  - Can adjust thickness, but FAA minimum is typically what FAA will fund
- **Modulus fixed at 200,000 psi in FAARFIELD**
  - Corresponds to pavement surface temperature of 90 °F
- **Warm-Mix Asphalt (Specification coming with 10J)**

Typical Asphalt Pavement Sections

- Airport pavements are generally constructed in uniform, full-width sections
- Variable sections are permitted on runway pavements
  - AC 150/5320-6G Appendix I provides guidance on variable sections



- Designer should consider
  - **Practical feasibility: Complex construction operations can be a challenge**
  - **Economic feasibility: Complex construction is going to increase project costs**
- Minimum pavement section may not always be most economical
  - Life-cycle analysis may be used to analyze the benefits of different pavement sections

Typical Asphalt Pavement Sections

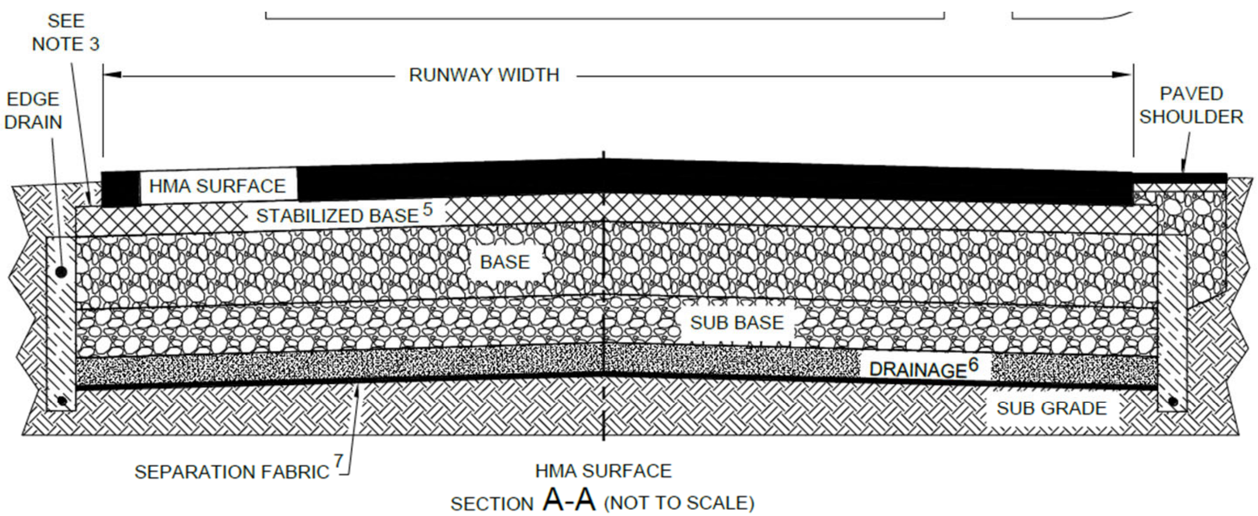


Figure 3-3 in AC 150/5320-6G

NOTES:

1. RUNWAY, TAXIWAY AND SHOULDER WIDTHS; TRANSVERSE SLOPES, ETC. PER AC 150/ 5300-13, AIRPORT DESIGN
2. SURFACE, BASE, PCC, ETC. THICKNESS PER AC 150/5320-6.
3. STABILIZED BASE, BASE AND SUBBASE MINIMUM 12 INCHES [30CM] UP TO 36 INCHES [90 CM] BEYOND FULL STRENGTH PAVEMENT.
4. CONSTRUCT A 1.5 INCH [4 CM] DROP BETWEEN PAVED AND UNPAVED SURFACES.
5. WHEN REQUIRED, SEE PARAGRAPH 3.5.
6. LOCATION AND NEED FOR DRAINAGE LAYER AS RECOMMENCED BY GEOTECHNICAL AND PAVEMENT ENGINEER.
7. WHEN RECOMMENDED BY GEOTECHNICAL AND PAVEMENT ENGINEER.

Flexible Pavement- Minimum Thickness

Table 3-3. Minimum Layer Thickness for Flexible Pavement Structures[1]

Layer Type	FAA Specification Item	Maximum Aircraft Gross Weight Operating on Pavement, lbs (kg)		
		<60,000 (27,215)	< 100,000 (45,360)	≥100,000 (45,360)
Asphalt Surface[2]	P-401/P-403	3 in (75 mm)	4 in (100 mm)	4 in (100 mm)
Stabilized Base[3]	P-401 or P-403; P-304; P-306[3]	Not Required	Not Required	5 in (125 mm)
Crushed Aggregate Base[5,6]	P-209, P-211	Not Required	6 in (150 mm)	6 in (150 mm)
Aggregate Base[5,6]	P-207, P-208, P-210, P-212, P-213, P-219	6 in (75 mm)	n/a	n/a
Drainable Base (When Used)	P-307, P-407[7]	Not Required	6 in (150 mm) when used	6 in (150 mm) when used
Subbase[6,8]	P-154	6 in (150 mm) (if required)	6 in (150 mm) (If required)	6 in (150 mm) (if required)

Required Inputs for Design

- Subgrade support condition
  - -CBR or Modulus (**E = 1500 X CBR**)
- Material properties of each layer
  - Modulus
  - Thickness for most layers
  - Poisson's Ratio (fixed in FAARFIELD)
- Traffic Mix
  - Frequency of loading
  - Airplane Characteristics (load, gear configuration, tire pressure

Table 3-2. Allowable Modulus Values and Poisson's Ratios Used in FAARFIELD

Layer Type	FAA Specified Layer	Rigid Pavement psi (MPa)	Flexible Pavement psi (MPa)	Poisson's Ratio
Surface	P-501 Cement Concrete	4,000,000 (30,000)	NA	0.15
	P-401/P-403[1]/P-404 Asphalt Mixture	NA	200,000 (1,380)[2]	0.35
Stabilized Base and Subbase	P-401/P-403Asphalt Mixture	400,000 (3,000)		0.35
	P-306 Lean Concrete	700,000 (5,000)		0.20
	P-304 cement treated aggregate base	500,000 (3,500)		0.20
	P-220 Cement treated soil base	250,000 (1,700)		0.20
	Variable stabilized rigid	250,000 to 700,000 (1,700 to 5,000)	NA	0.20
	Variable stabilized flexible	NA	150,000 to 400,000 (1,000 to 3,000)	0.35
Granular Base and Subbase	P-209 crushed aggregate	Internal calculation by FAARFIELD[4]		0.35
	P-208, aggregate	Internal calculation by FAARFIELD[4]		0.35
	P-219, Recycled concrete aggregate	Internal calculation by FAARFIELD[4]		0.35
	P-211, Lime rock	Internal calculation by FAARFIELD[4]		0.35
	P-207 Recycled Asphalt aggregate base[3]	25,000-500,000		0.35
	P-154 uncrushed aggregate	Internal calculation by FAARFIELD[4]		0.35
Subgrade[5]	Subgrade	1,000 to 50,000 (7 to 350)		0.35
User-defined	User-defined layer	1,000 to 4,000,000 (7 to 30,000)		0.35

AC 150/5320-6G

Typical Rigid Pavement Structures

Rigid pavements are stiffer and have a ”beam action” or flexural capability that spreads or distributes the load more widely assuming it is uniformly supported

Rigid Pavement

Progressively stronger layers

Portland Cement Concrete (PCC) Surface

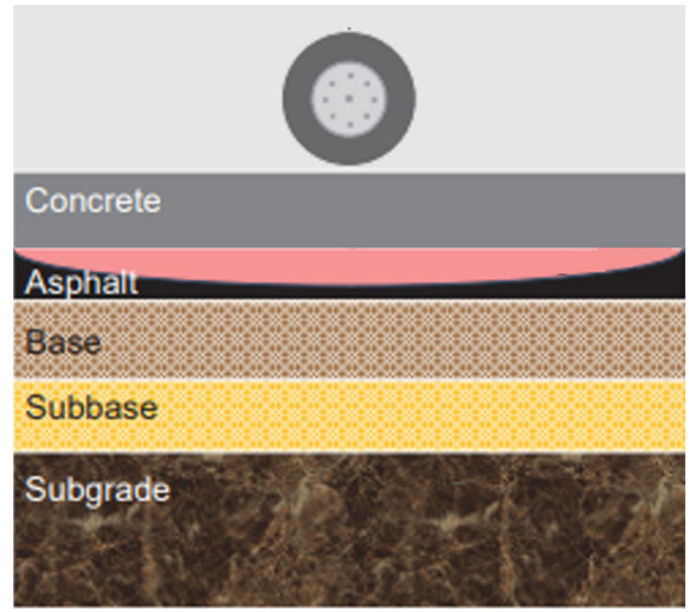
Base Course [1]

Subbase

Compacted Subgrade [2]

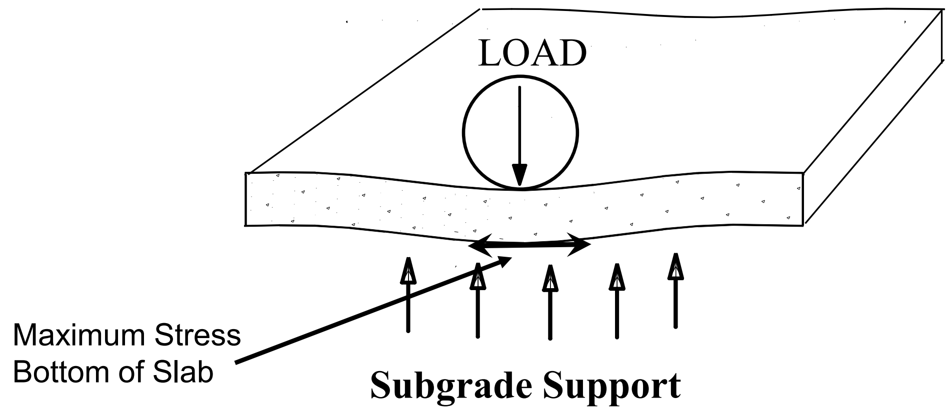
1- May require drainage layer above

2- May require frost protection layer above



FAA Rigid Pavement Design

- Rigid pavement failure model is the same between FAARFIELD 1.42 and 2.1
- New 3-D finite element library (FAASR3D) used for calculation of slab stresses
- Design stress for new rigid pavement is the larger of:
  - 75% maximum free edge stress (computed by FAASR3D)
  - 95% of the layered elastic stress (computed by LEAF)
- Predictor of pavement life
  - Maximum stress at pavement edge
  - Interior stress (if traffic is dominated by 6-wheel and certain 4-wheel gear configurations)



- Maximum stress at pavement edge
- 25% load transfer to adjacent slab

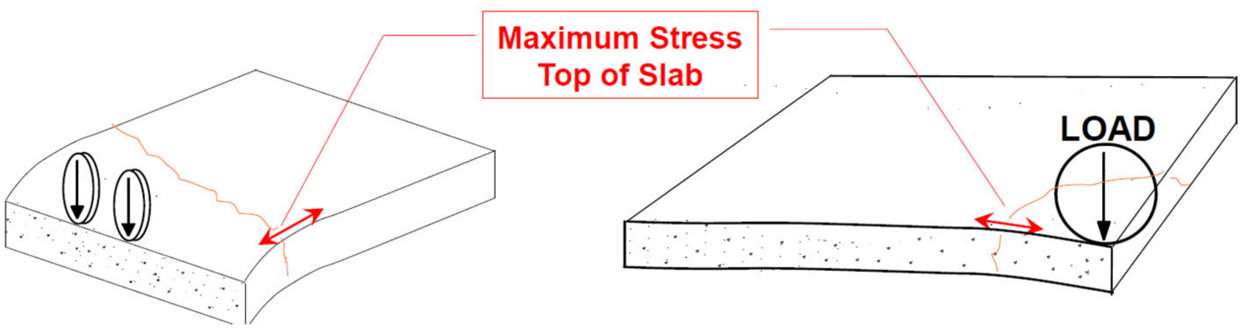
FAA Rigid Pavement Top-Down Cracking

- **Top-down cracking due to edge or corner loading NOT included in design**

- Maximum stress due to corner or edge loading condition

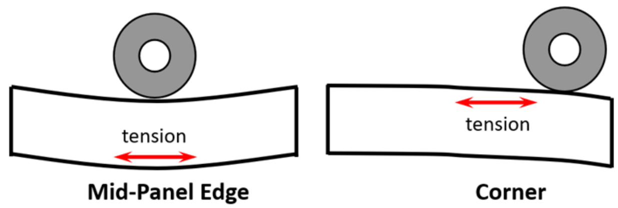
- Risk increases with large multi-wheel gear configurations

- These conditions may need to be addressed in future procedures

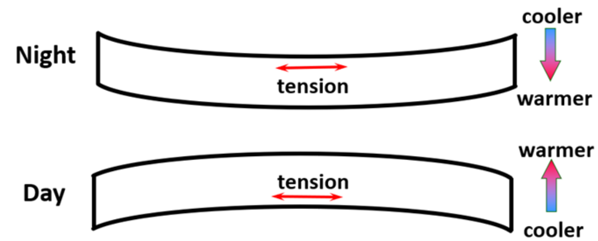


Rigid Pavement - Stresses

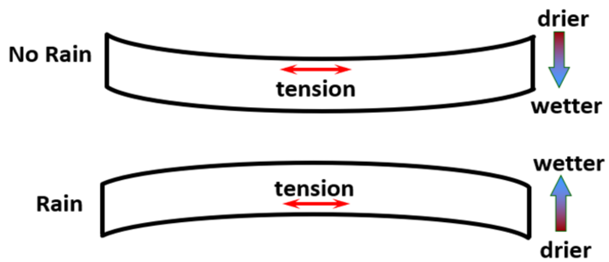
- Load-related stresses
- Cracking occurs when the tensile stress > flexural strength



- Thermal-Gradient Stresses
- Differential temp between top and bottom of the slab

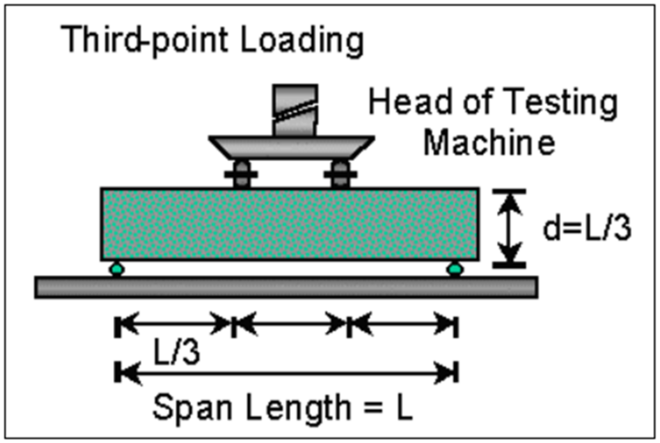


- Moisture-Gradient Stresses
- Variation in moisture between bottom and top of the slab



PCC Layer Characteristics

- **Minimum Material Requirements**
  - P-501 – Heavy Load Airfield Pavement
- **Flexural strength as design variable**
  - FAARFIELD allows 500-800 psi
  - FAA recommends 600-750 psi for design
  - ASTM C78, Flexural Strength of Concrete
    - Simple Beam with Third-Point Loading
- **Modulus fixed at 4,000,000 psi in FAARFIELD**
  - Corresponds to pavement surface temperature of 90 °F
- **6-inch minimum thickness requirement**
  - Rounded to nearest ½ inch



PCC Design Flexural Strength Consideration

- **Capability of industry in the area to produce desired**
- **Flexural strength vs. cement content data from prior projects at the airport**
- **Need to avoid high cement content**
  - Can affect concrete durability
- **P-501 typically uses 28-day strength for acceptance**
  - Can expect long-term strength to increase 5%

PCC Design – Subgrade Characteristics

- Subgrade assumed to be infinite in thickness
- FAARFIELD accepts Resilient Modulus (E_{sg}) or k-value
  - Only one is needed

Convert k-value to modulus

$$E_{SG} = 20.15 \times k^{1.284}$$

E_{SG} = Elastic modulus (E-modulus) of the subgrade, psi
k = Modulus of Subgrade Reaction of the subgrade, pci

Convert CBR to k-value

$$k = 28.6926 \times \text{CBR}^{0.7788}, \text{(k, pci)}$$

Convert CBR to modulus

$$E = 1500 \times \text{CBR} \; (E \text{ in psi})$$

Typical Rigid Pavement Sections

NOTES:

1. RUNWAY, TAXIWAY AND SHOULDER WIDTHS; TRANSVE
   SLOPES, ETC. PER AC 150/ 5300-13, AIRPORT DESIGN
2. SURFACE, BASE, PCC, ETC. THICKNESS PER AC 150/53
3. STABILIZED BASE, BASE AND SUBBASE MINIMUM 12 INCHES [30CM] UP TO 36 INCHES [90 CM] BEYOND FULL STRENGTH PAVEMENT.
4. CONSTRUCT A 1.5 INCH [4 CM] DROP BETWEEN PAVED AND UNPAVED SURFACES.
5. WHEN REQUIRED, SEE PARAGRAPH 3.5.
6. LOCATION AND NEED FOR DRAINAGE LAYER AS RECOMMENCED BY GEOTECHNICAL AND PAVEMENT ENGINEER.
7. WHEN RECOMMENDED BY GEOTECHNICAL AND PAVEMENT ENGINEER.

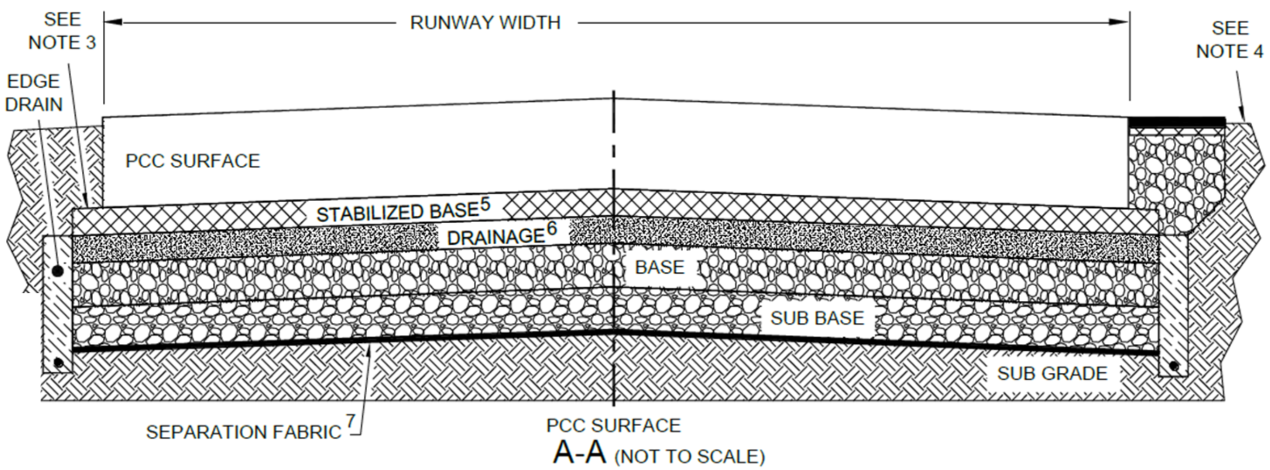


Figure 3-3 in AC 150/5320-6G

Minimum Thickness- Rigid Pavement

Table 3-4. Minimum Layer Thickness for Rigid Pavement Structures[1]

Layer Type	FAA Specification Item	Maximum Aircraft Gross Weight Operating on Pavement, lbs (kg)		
		<60,000 (27,215)	< 100,000 (45,360)	≥ 100,000 (45,360)
Rigid Surface[2]	P-501, Cement Concrete Pavement	6 in (150 mm)[2]	6 in (150 mm)[2]	6 in (150
Drainable Base (When Used)	P-407[5], P-307		6 in (150 mm) when used	6 in (150 When us
Stabilized Base[3]	P-401 or P-403; P-304; P-306	Not Required	Not Required	5 in (125 mm)
Base[4]	P-209, P-207, P-208, P-210, P-211, P-212, P-213, P-219, P-220	Not Required	6 in (150 mm)	6 in (150 mm)
Subbase[5]	P-154	6 in (100 mm)	As needed for frost or to create working platform	As needed for frost or to create working platform

Types of PCC Pavements

- Jointed plain concrete pavement (JPCP)
- Jointed reinforced concrete pavement (JRCP)
- Continuously reinforced concrete pavement (CRCP)
- Composite – HMA over PCC
  - HMA thickness << PCC thickness

AC 150/5320-6G no longer provides guidance for JRCP and CRCP

Materials & Specifications

Specification AC 150/5370-10H

AC 150/5370-10H - Standard Specifications for Construction of Airports

Airport Engineering Briefs

EB 106	Guidance for the Implementation of Changes in Industry Cement Standard Specifications	Feb. 7, 2023
EB102	Asphalt Treated Permeable Base Course	March 25, 2021

Table of Contents

Design - Base Layers

- **Base layers generally placed directly beneath the pavement**
  - Uniform support
  - Distributes stresses
  - Strength
  - Durability
- **Two Main Categories**
  - Unbound aggregate
  - Stabilized aggregate

Design - Aggregate Base Layers

- **Aggregate material requirements**
  - P-208, P-209: Typical aggregate bases used
  - P-219: Recycled Concrete
  - P-210, 211, 212, 213: Common in certain regions
- **Design assumes min strength – CBR >80**
- **Base Course thickness of 6 inches (150mm) when aircraft gross loads > 60,000 lbs (~27,200 kg)**
  - *Reference AC 150/5320-6G, Table 3-3 for min thickness requirements*
- **Base Course is not required in pavement supporting gross loads < 60,000 lbs (~27,200)**
  - P-154 is substituted for base course in light load pavement

Design - Stabilized Base Layer

- **Generally Required for airplane gross weight > 100,000 lbs (~45,300 kg)**
- **Material requirements**
  - P-304 Cement-Treated Aggregate Base Course (CTB)
  - P-306 Lean Concrete Base Course
  - P-403 Asphalt Pavement Base/Leveling/Surface Course*
- **Modulus fixed in FAARFIELD depending on material type**
- **Minimum thickness of 5 inches (125 mm) when required**
  - Typically, you don't change thickness of stabilized base
- **Bond breaker typically used between Rigid surface and stabilized base**
  - Choke Stone
  - Double coat of curing compound
  - Geotextile fabric

Design - Subbase Layers

- **Minimum material requirements**
  - P-154 Subbase Course (typical)
  - Any base material may also be used as a subbase
- **Minimum 6 in required for light load pavement (< 60,000 lbs)**
- **When aircraft loads over 60,000 lbs (~27,000 kg) subbase is used for:**
  - Frost design (thickness based on frost depth)
  - Create a working platform for construction

Design - Subgrade Layer

- In-situ soil serves as foundation a pavement system
- Flexible pavement design largely based on protecting this layer from deformation
  - Asphalt thickness is sensitive to subgrade CBR
- Soil characteristics & stabilization discuss in geotechnical report
- May require soil stabilization

Design - Subgrade Stabilization

- **Consider for the following conditions:**
  - Weak soils
  - Poor drainage
  - Adverse surface drainage
  - Frost (beware that long-term stabilization of soils susceptible to frost may not be possible; stabilization may trap water so be sure to include subsurface drainage in frost areas)
  - Need working platform

Design - Subgrade Stabilization

- **Chemical**
  - Lime
  - Fly Ash
  - Portland cement

- **Mechanical**
  - Bridging
  - Geotextiles/geogrids
  - Ongoing research evaluating performance under aircraft loads

Design - Subgrade Stabilization

- **FAA Material Requirements**
  - P-153 Controlled Low-Strength Material
  - P-155 Lime-Treated Subgrade
  - P-156 Cement Treated Subgrade
  - P-157 Cement/Lime Kiln Dust Treated Subgrade
  - P-158 Fly Ash Treated Base

- **Model as “User Defined” in FAARFIELD**

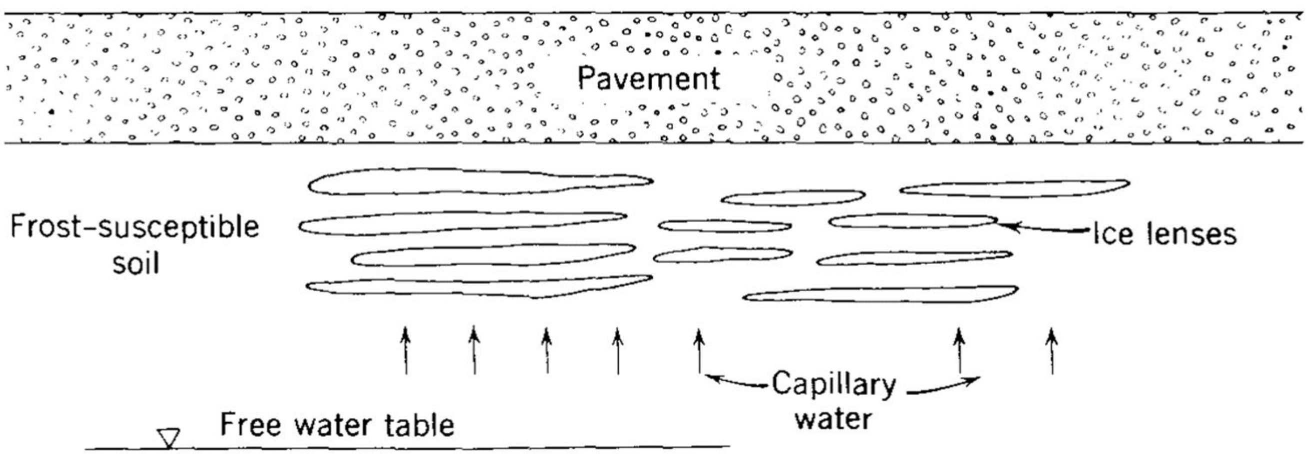
Design - Drainage Layers

- **Recommended for pavement serving aircraft greater than 60,000 lbs when:**
  - Constructed in areas with excessive subsurface moisture and subgrade have low permeability
  - Frost areas when pavement is constructed on frost susceptible subgrade soil
  - For rigid pavement place directly below P-501 in place of stabilized base
  - For flexible pavement generally placed directly above the subgrade
- **Recommended thickness is 6 inches**
- **Modeled as User Defined Layer with following modulus values:**
  - P-307 Cement Treated Permeable Base: E = 250,000 psi
  - P-407 Asphalt Treated Permeable Base (EB-102): E = 150,000 psi
  - Aggregate Drainage Layer (unstabilized): E = 15,000 – 30,000 psi

Design - Seasonal Frost

For detrimental frost, three conditions are required

1. Frost susceptible soil
2. Freezing temperatures must penetrate into frost susceptible soil
3. Free moisture must be available in sufficient quantity to form ice lenses



Design - Alternative Frost Protection

- **Complete Frost Protection**
  - Remove frost susceptible materials to below frost depth
- **Limited Subgrade Frost Penetration** ← most common
  - Remove frost-susceptible material to a minimum of 65% of frost depth
  - Limits frost heave to acceptable level, typically less than 1 inch (25 mm)
- **Reduced Subgrade Strength**
  - Reduce subgrade support value, typically about 50% of design strength
  - Design adequate load carrying capacity for weakened condition
  - Not allowed for FG-4 soils

Frost Group	Kind of Soil	Percentage Finer than 0.02 mm by Weight[3]	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 15	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

Reconstruction Alternatives

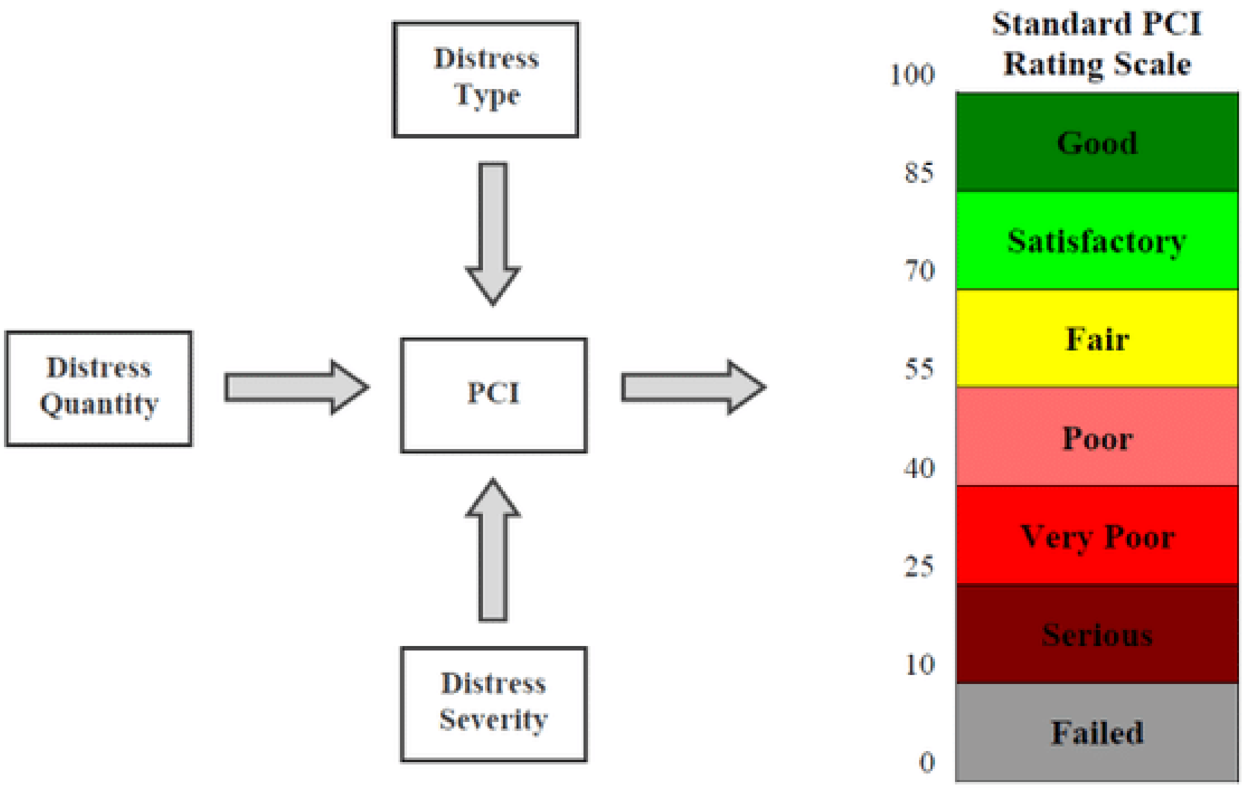
Overlays

- Structural Overlays
  - Flexible Overlay of Flexible
  - Flexible Overlay of Rigid
  - Rigid Overlay of Rigid
    - Bonded (requires FAA Approval)
    - Unbonded
  - Rigid Overlay of Flexible
- Functional Overlays
- Alternate Reconstruction of Existing Pavement
  - PCC Rubblization
  - Full Depth Reclamation

Required Inputs for Overlay Design

- **Existing Pavement Structure**
  - Layer Types and Thicknesses
  - Modulus for all layers (may require user defined layers)
  - Flexural strength of concrete
  - Subgrade strength
  - Existing Pavement Condition
    - Rigid Pavement requires Structural Condition Index (SCI)
    - Flexible requires engineering judgement
- **Traffic**
  - Airplane Type and Characteristics
  - Annual Departures
  - Annual Growth

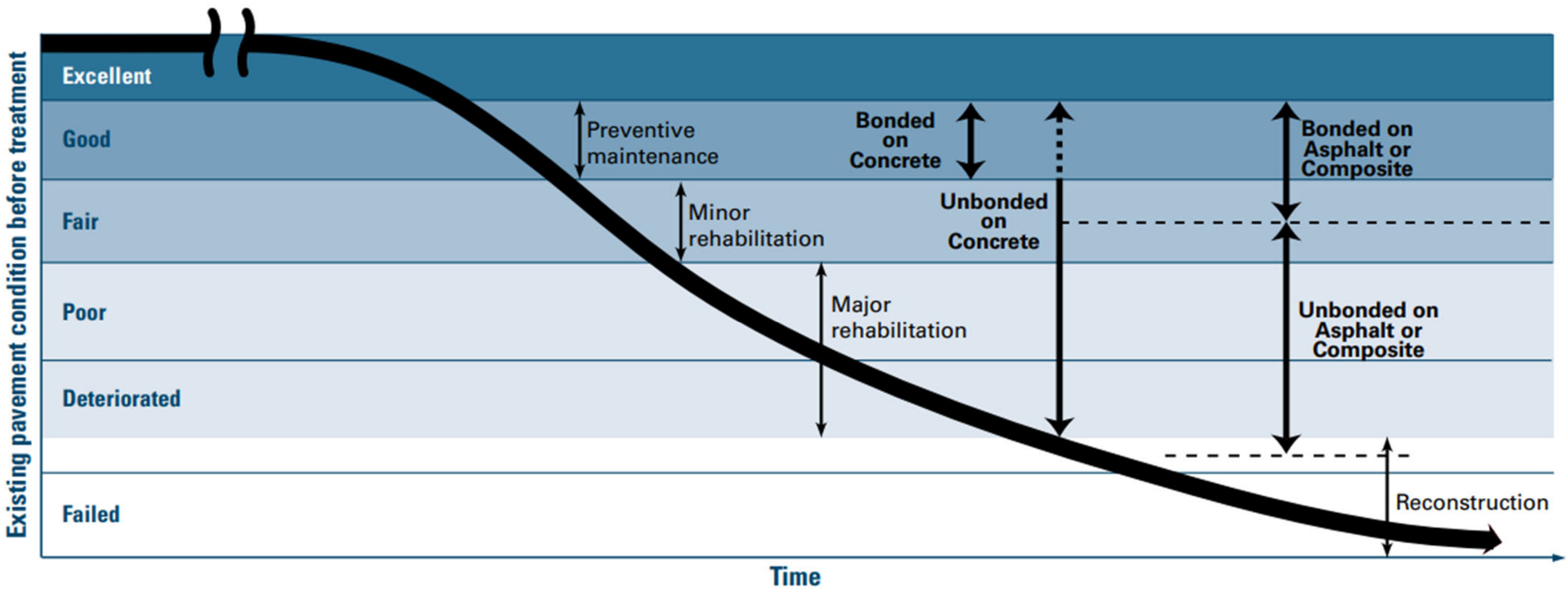
Pavement Condition Assessment



Pavement Condition Assessment

- **Structural Condition Index (SCI)-** Used to express structural condition of existing rigid pavement.
- **Computed using only structural distresses**
  - 6 of 15 distresses used
- **SCI will always be greater than or equal to PCI**
- **SCI = 80 is the FAA definition of structural failure**
  - 50% of panels in traffic area have a structural crack
- **Pavement with SCI = 80 and few durability issues can appear to be in surprisingly good condition**
  - This is why we care about functional life
- **Pavement with SCI > 80 but with durability issues can look severely failed**

Overlay - Existing Pavement Condition



CP Tech Center

Overlay Design Life (AC 150/5320-6G)

- **Design overlays for a 20-year structural life from time of overlay**
- **A design life less than 20 years (minimum of 10 years) may be considered if:**
  - The original pavement is more than 15 years old at the time of overlay, and;
  - The primary purpose of the overlay is functional rehabilitation of the pavement surface (i.e.) where the underlying pavement retains considerable structural integrity.
- **Document and support the design life used in the engineer's report**

HMA Overlay HMA

- **Nonstructural Asphalt Overlays -** correct functional problems such as restoring the crown, correcting longitudinal profile, and/or improving skid resistance.
  - Improve surface characteristics
  - Minimum overlay thickness is dependent on gradation (no calculation required)
  - Consider minimum construction thicknesses for the P401/P403 150/5370-10H
  - Leaving less than 2 in (50 mm) of AC pavement can be problematic
- **Structural Overlay Asphalt Overlay -** consider when additional capacity and is needed. Can also correct functional problems.
  - Consider impacts of increased thickness
  - 3 in (75 mm) minimum overlay thickness
- An interlayer placed between the existing pavement and the overlay to improve overlay performance

HMA Overlay Over PCC

- Generally used to slow rate of deterioration of the rigid layer with signs of some structural distress.
- Good candidates have an SCI <100 and >80
- Can be used to strength pavement to accept heavier aircraft.
- FAA requires a minimum 3-inch (75-mm) HMA overlay on PCC
  - Thin overlays have a tendency to delaminate as they deteriorate
  - Need to consider minimum P-401 lift thickness guidance

- FAARFIELD is trying to protect PCC from falling below SCI of 40 on aggregate base, 57 on stabilized base
  - FAARFIELD does not consider reflective cracking, delamination, or other deterioration in computed structural life
  - Often overlay functional life is significantly less than 20 years, especially when it is thin
  - Bond is the #1 concern; crack maintenance is the 2nd concern that airports must consider when selecting an HMA overlay of PCC

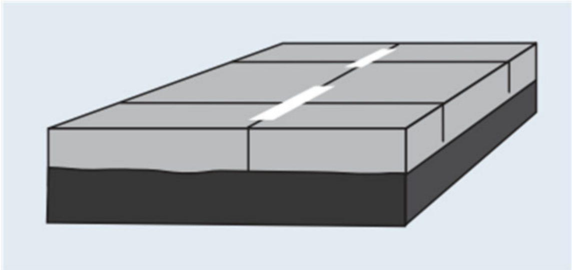
Rigid Overlay

- **Bonded Overlay -** considered when there is a need to increase capacity of existing pavement to support additional aircraft.
  - Layers are assumed to act as one monolithic layer
  - Underlying pavement should be in <u>good condition</u>
  - Not very common
  - Require FAA approval
- **Unbonded Overlays -** major rehabilitation effort restores/increases a pavements structural and functional life
  - New PCC acts independent from base layer
  - No extensive pre-overlay repairs generally required
  - Bond-breaker may be asphalt, geosythentic, or choke stone
  - FAARFIELD iterates overlay thickness until it finds a design thickness that produces SCI = 80 for the overlay at the end of the 20-year design life

Rigid Pavement Over Asphalt

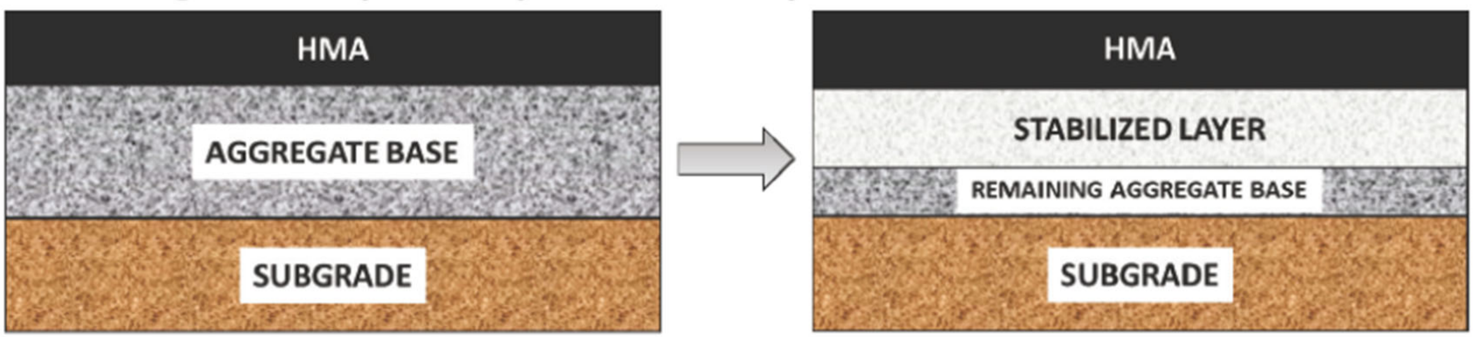
- **Uses same basic design methods as new Rigid Design**
  - Allows HMA surface modulus value to be used under PCC instead of stabilized base modulus
- **Overlay will design until a CDF of 1.0 is reached, or minimum thickness is reached**
  - For overlays minimum thickness of 5 inches (125 mm) is allowed
- **Poor drainage can cause stripping**

Unbonded Rigid over Asphalt



Full Depth Reclamation of In-place HMA

- **Existing HMA, base, subbase layers pulverized and mixed to create a homogeneous base material**
  - May include stabilization to create construction platform, or improve modulus
    - Fly ash, Portland cement, emulsified or foamed asphalt
  - May include blending of virgin aggregate to control gradation
  - Lab testing should be completed to assess material strength



Full Depth Reclamation of In-place HMA

- **Must Determine;**
  - Existing pavement profile
  - Depth of pulverization and mixing
  - Quality and gradation of base material
  - Extent of stabilization (if required)
- **Design in FAARFIELD as User Defined Layer**
  - Modulus can range from 25,000 psi to 500,000 psi (170 Mpa – 3400 Mpa)depending on geotechnical results
  - For airports serving aircraft less than 30,000 lbs (13,600 kg) can usually place new surface directly on FDR
  - For airports serving aircraft over 30,000 lbs (13,600 kg) a base material may be required
  - FAA approval is required for use at airports serving aircraft over 60,000 lbs (13,600 kg)
- **FDR is specified using P-207 (AC 150/5370-10H)**

Full Depth Reclamation of In-place HMA

- Porter County Regional Airport
- Completed in 2, 8-week phases
- FDR accomplished on Rwy & Twy
- Approx. 10” in depth
- Cement Stabilization

PCC Rubblization or Crack and Seat

- Both methods remove the structural capacity of the PCC to prevent reflecting cracking.
  - Rubblization is the most common method, Crack and Seat has faded in popularity
- Design in FAARFIELD as a User Defined Layer
  - Modulus is defined based on PCC thickness
    - 6-8 inches: E = 100,000 – 135,000 psi
    - 8-14 inches: E = 135,000 – 235,000 psi
    - Over 14 inches E = 235,000 – 400,000 psi
  - Other moduli can be select with proper analysis in engineer’s report
- If performing Rubblization or Crack and Seat refer to EB-66
  - **P-215** is included in **EB-66** as a standard specification

HMA Overlays of FDR or Rubblized PCC

- **Design process is similar to HMA overlay of Flexible Pavement**
  - FDR or Rubblized layer modeled as User Defined Layer
  - Modulus set based on engineer's analysis
  - Thickness set based on existing pavement thicknesses
    - Remember in FDR your final thickness may be different depending on compaction or introduction of virgin aggregates
- **FAARFIELD will design overlay thickness**
  - With FDR you may be able to balance modulus with overlay thickness if you ensure the material can achieve the modulus you design for
- **Don't forget that neither FDR or Rubblization can replace stabilized base if required (without FAA approval)**

PCC Overlay of FDR or Rubblized PCC

- **Model in FAARFIELD as a New PCC Pavement**
- **FDR or Rubblized PCC modeled as User Defined layer using thickness and modulus determined from geotechnical investigation**
- **For PCC pavement it is easier to justify Rubblization or FDR in place of stabilized base**
  - Can Rubblized concrete achieve similar strengths to CBR 100 material?
  - Can FDR be stabilized enough to achieve modulus similar to stabilized base?
- **If you are going to propose rubblization or FDR make sure you have done your homework:**
  - Discuss the option during development of design scope and fee. Don’t wait until preliminary design to start, you will not have the scope or budget to do it right!!!!

Review

- **Airfield Pavement Concepts**
- **Airfield Pavement Design Considerations**
  - Traffic
  - Soil Investigation
  - Flexible Pavement Design
  - Rigid Pavement Design
- **Materials & Specifications**
  - Aggregate Layers
  - Stabilized Materials
  - Frost Consideration
- **Reconstruction Alternatives**
  - Overlays
  - Alternative Methods for Existing Pavements

References

- AC 150/5320-6G - Airport Pavement Design and Evaluation
- AC 150/5370-10H - Standard Specifications for Construction of Airports
- Airport Design Software | Federal Aviation Administration (FAARFIELD)

QUESTIONS?

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