Airfield Pavement Design Considerations and Material Specifications

ICAO ACR/PCR Workshop

Presented by: **Harold Muniz**
Airfield Pavement Engineer
FAA Headquarter, AAS-110

Overview

- **History of Design Procedures**
- **Aircraft Traffic Mix**
  - Aircraft weight
  - Tire pressure
- **Site Conditions Assessment**
- **Flexible Pavement Concept**
- **Rigid Pavement Concept**
- **Materials & Specifications**
  - Aggregate Layers
  - Stabilized Materials
  - Frost Consideration

Airfield Pavement History

- Most early runways (1910s-1930s) were sod or dirt
- First permanent, hard-surfaced runways in United States:
  - Dearborn, Michigan (1928)
  - Newark, New Jersey (1928)
- Hard-surfaced runways became common in U.S. during World War II
- Very little “design” of early airfields
- Some application of highway design procedures
- Most often considered only subgrade strength/bearing capacity
- Subgrade characterized in various ways (CBR, k-value, shear strength)

Airfield Pavement History (Cont'd)

- Significant increases in aircraft weights
- Military aircraft were much heavier (e.g, B-17)
- Military recognized need for airfield pavement design procedures
- Hastened need for rational procedure
- No time for new procedure development
- Needed proven procedure applicable to airfields worldwide
- Corps of Engineers assigned responsibility
  - Flexible pavement design procedure
  - Rigid pavement design procedure

Airfield Pavement History (Cont'd)

Engineers in the U S Army Corps of Engineers' airfield pavement development program:

H. M. Westergaard, Harvard Professor
Methodology to Design/ Evaluate Rigid (PCC) Pavements

P. C. Rutledge, Purdue Professor
Materials Testing, Shear Strength of Soils

A. Casagrande, Harvard Professor
Soil Mechanics, Developed USCS

T. A. Middlebrooks, American Society of Civil Engineers
Earth-Dams and Foundations

O. J. Porter, California Highway Dept
Developed CBR Methodology to Design and Evaluate Flexible (AC) Pavements

CONFERENCE AT STOCKTON TEST TRACK, CALIFORNIA. *Front row (left to right): Col. Henry C. Wolfe, Harold M. Westergaard, Philip C. Rutledge. Back row (left to right): Arthur Casagrande, Thomas A. Middlebrooks, James L. Land, O. James Porter.*

Pavement Design Procedure

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

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*.

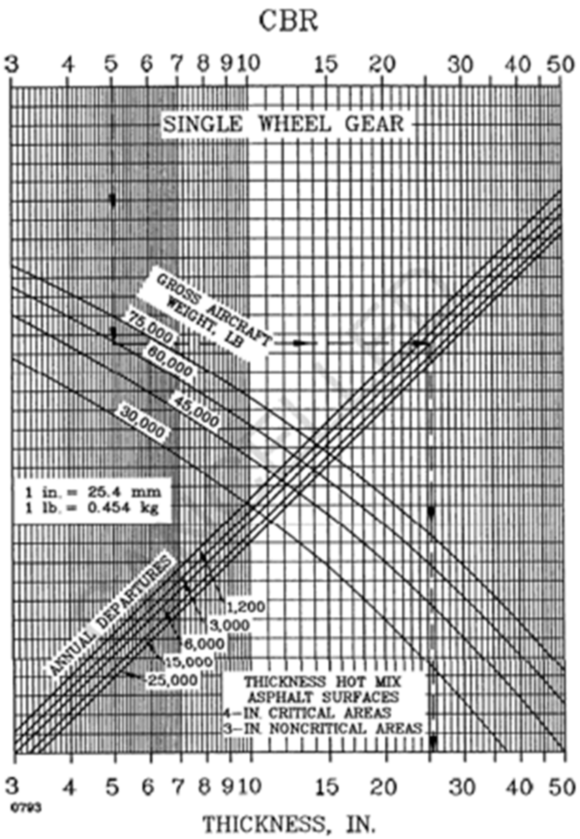
4 **Principal Changes.**
This AC contains the following principal changes:

1. Reformatted to comply with FAA Order 1320.46, *FAA Advisory Circular System*.

FAA Technical Center

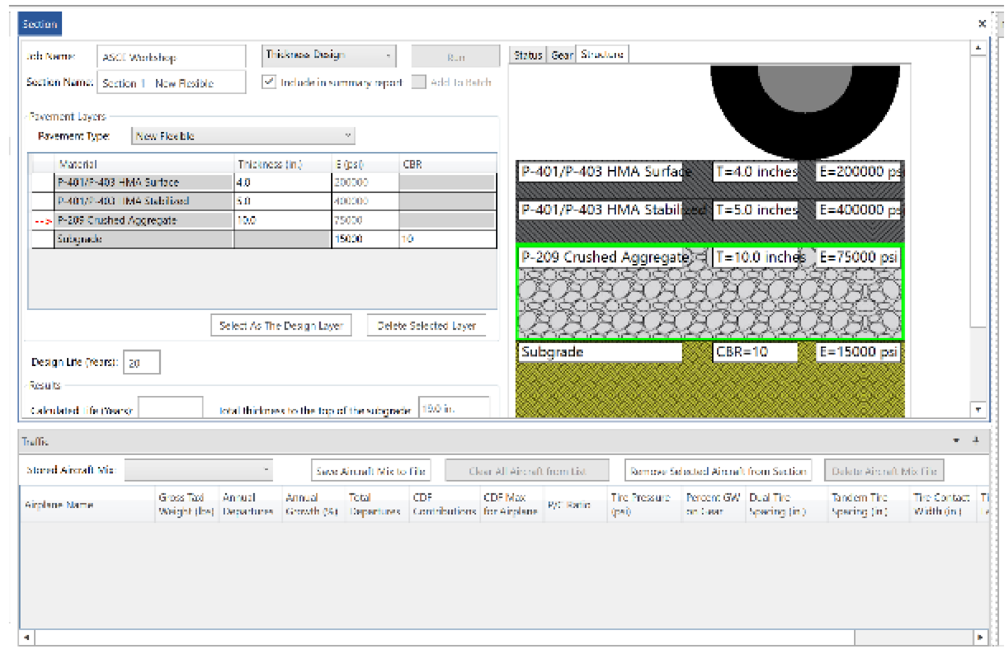
- National Airport Pavement Testing Facility (NAPTF)

Layer Thickness Design



Flexible Pavement

FAARFIELD 2.1



FAARFIELD: FAA Rigid and **F**lexible **I**terative **E**lastic **L**ayered **D**esign

Difference Between Highways and Airports

Highway Pavement

4,500 lb (2,000 kg) Wheel Loads

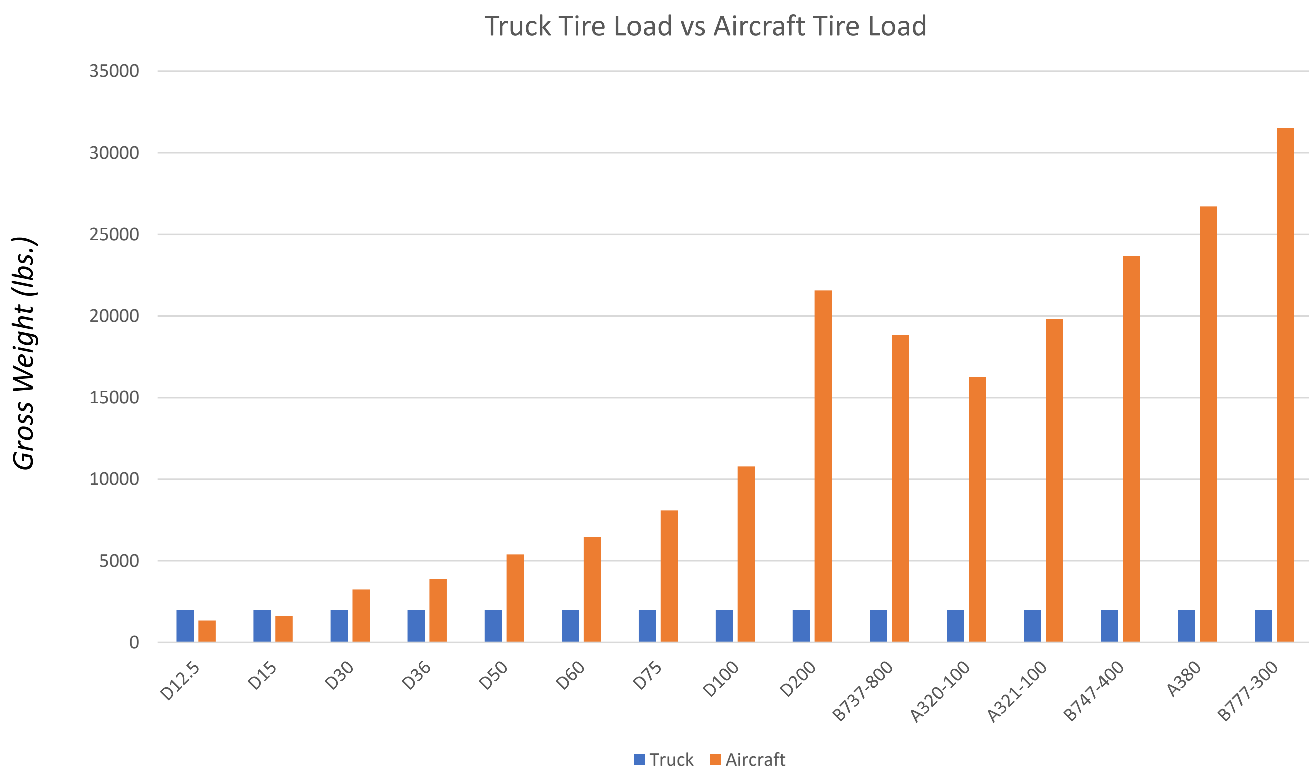
80-120 psi (0.5-.08 Mpa) Tire pressures

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



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)
- To be constructed properly using quality materials and workmanship
- To be maintained with regular and routine maintenance

Factors Affecting Pavement Responses and Performance

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

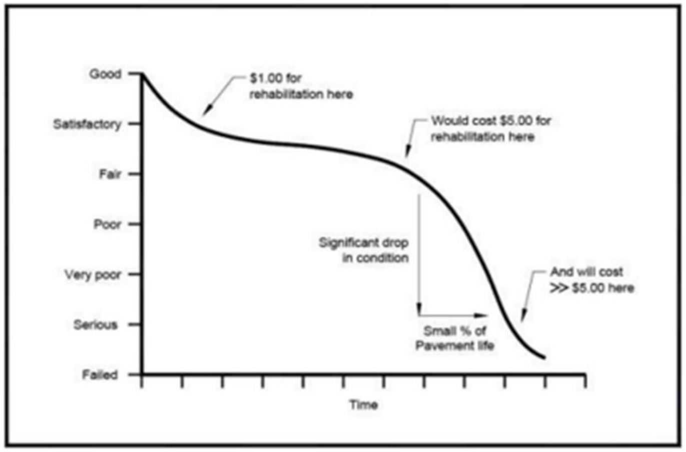
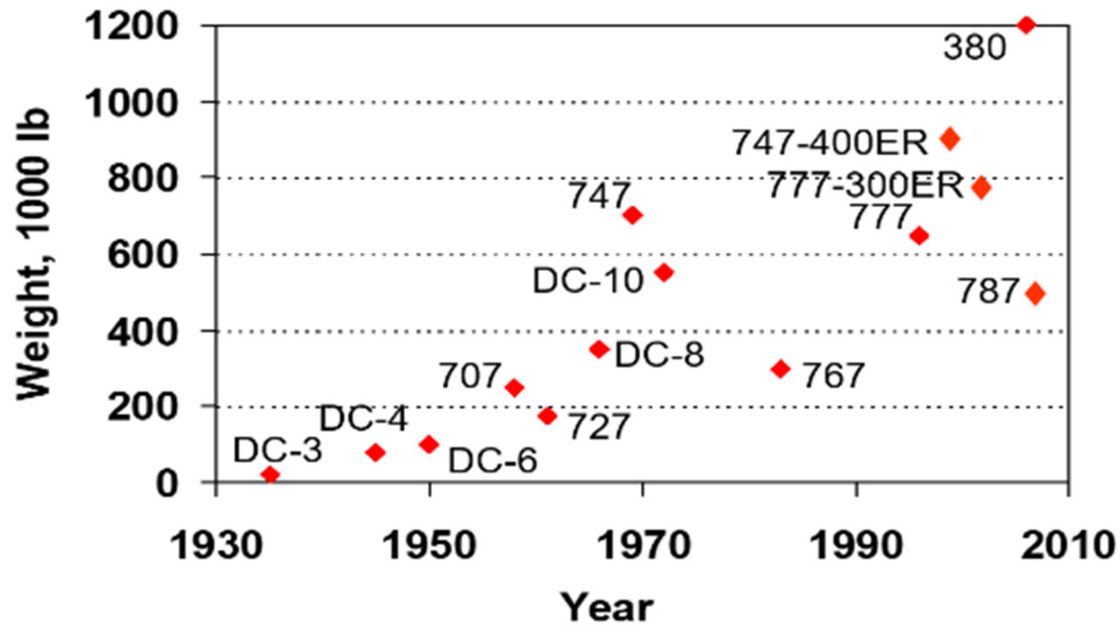


Figure 1. Typical Pavement Condition Life Cycle.

Traffic - Aircraft Weight

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

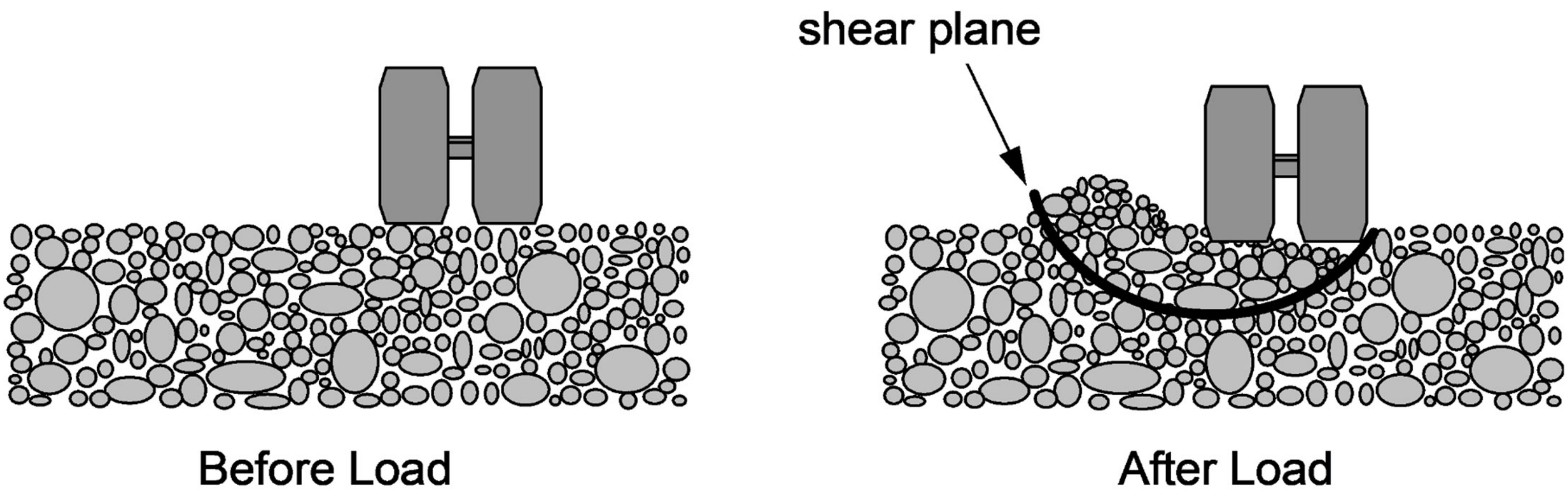


More than just weight....

- Tire pressure has a significant impact near surface.

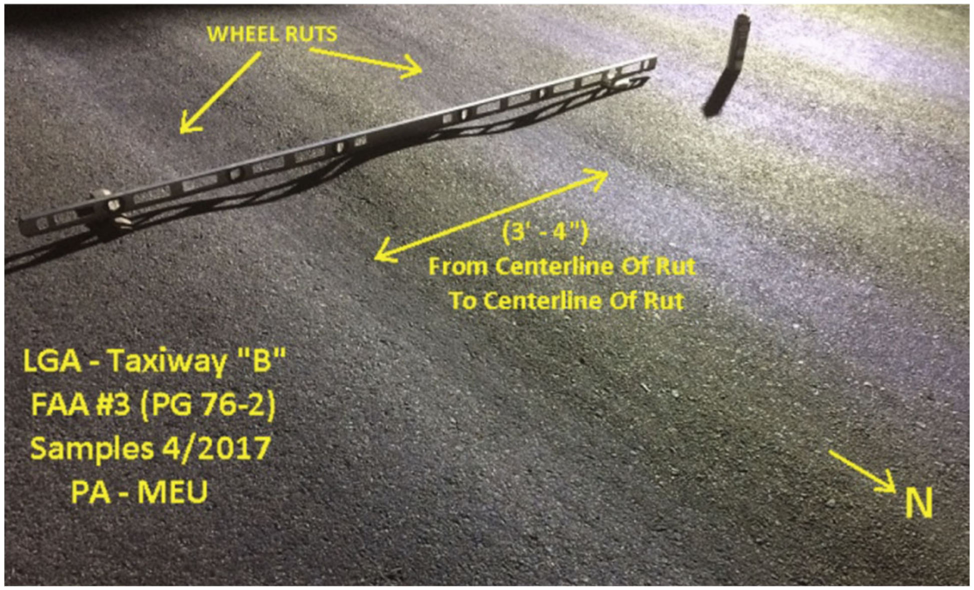
Aircraft	Gross Weight (kg)	Tire Pressure (Mpa)
Learjet 35/36	8100	1.18
Learjet 45/55	9675	1.38
Cessna Citation X	16200	1.30
Dassault Falcon 2000	15750	1.36
Dassault Falcon 50	17460	1.43
Gulfstream G-II	29700	1.10
Gulfstream G-V	40905	1.30
B737-900ER	84690	1.52
A321neo	96210	1.62

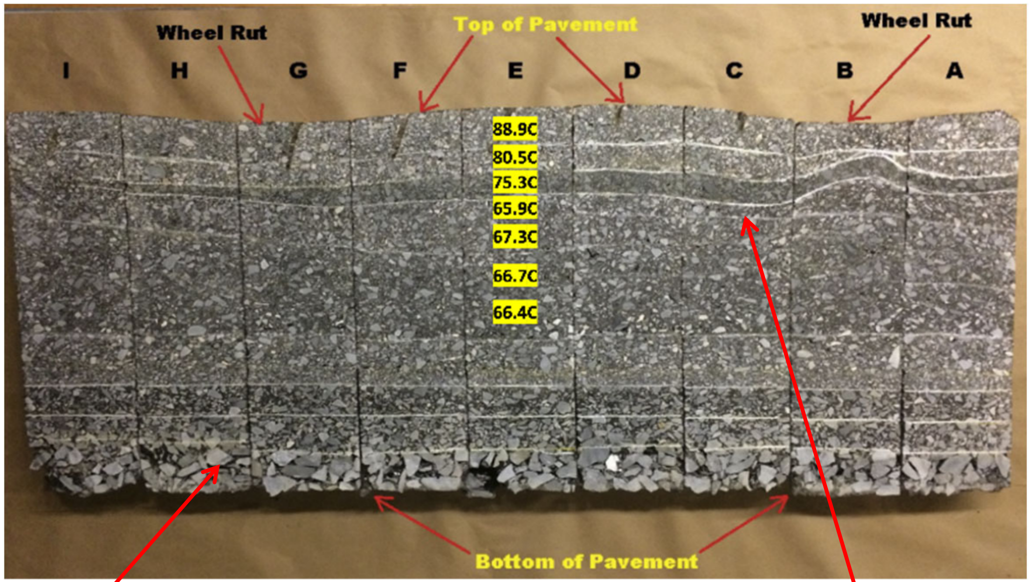
Does Tire Pressure Matter?



From Report
DOT/FAA/TC-22/25

Tire pressure impact near surface



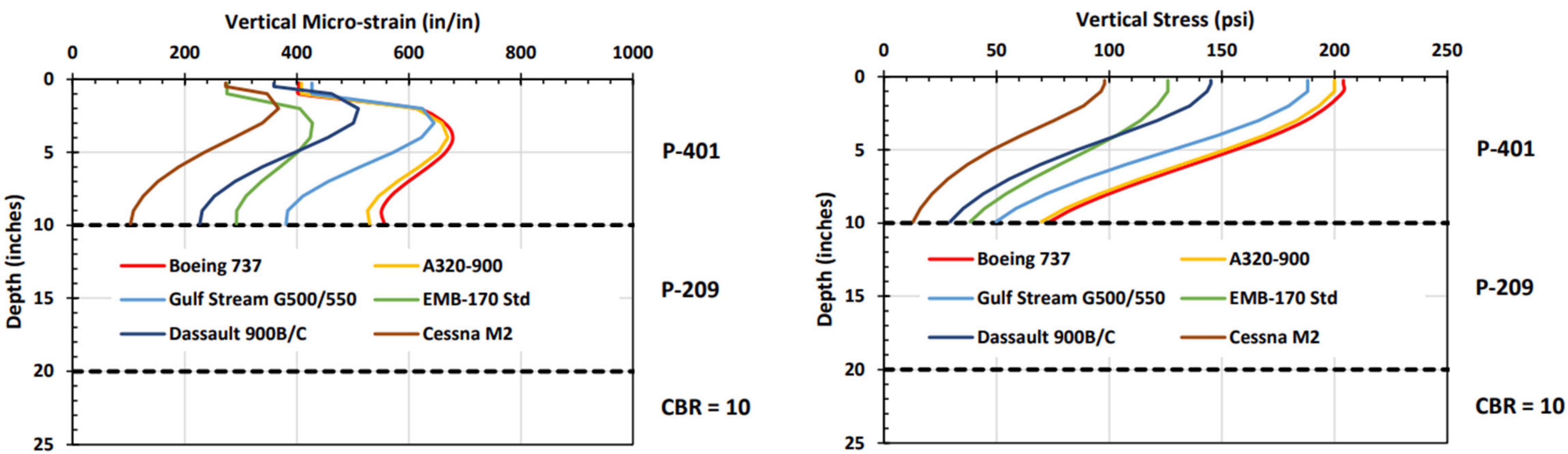


No rutting observed at the bottom

Rutting is in the upper lifts

From Report
DOT/FAA/TC-22/25

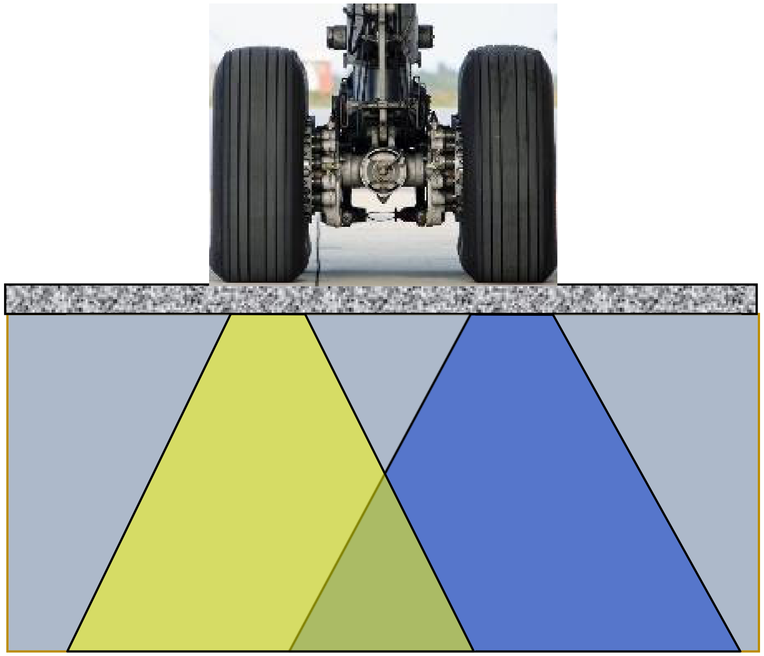
Tire pressure impact near surface



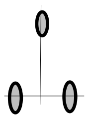
From Report
DOT/FAA/TC-22/25

Traffic-Stress

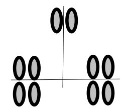
- Impact of multi-wheel landing gear
- Stresses from each tire can overlap
- Total combined stress is considered in design



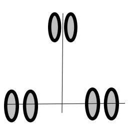
Traffic - Aircraft Gear Configuration



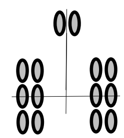
S
Single Wheel



2D
Dual Tandem



D
Dual Wheel



3D
Triple Dual Tandem

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

Traffic - Aircraft Gear Naming

Two-Part Name

Main Gear Designation | **Body/Belly Gear Designation**

 # X # / # X #

Main gear designation:

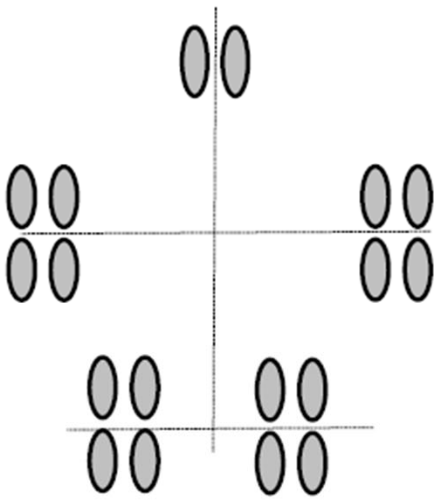
- **# of gear types in tandem**
  (A value of 1 is omitted for simplicity.)
- **Gear type, e.g. S, D, T, or Q**
- **# of main gears in line on one side of the aircraft**
  (Assumes gear is present on both sides. The value indicates number of gears on one side. A value of 1 is omitted for simplicity.)

Body/belly gear designation:

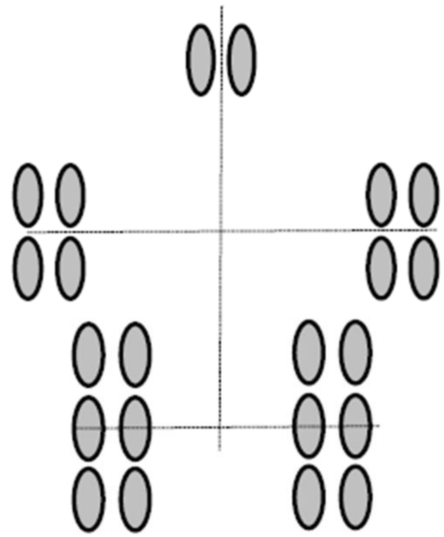
- **Total # of body/belly gears**
  (Because body/belly gear may not be symmetrical, the gear must identify the total number of gears present and a value of 1 is not omitted if only one gear exists.)
- **Gear type, e.g. S, D, T, or Q**
- **# of gear types in tandem**
  (A value of 1 is omitted for simplicity.)

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

Traffic - Aircraft Gear Examples



2D/2D2



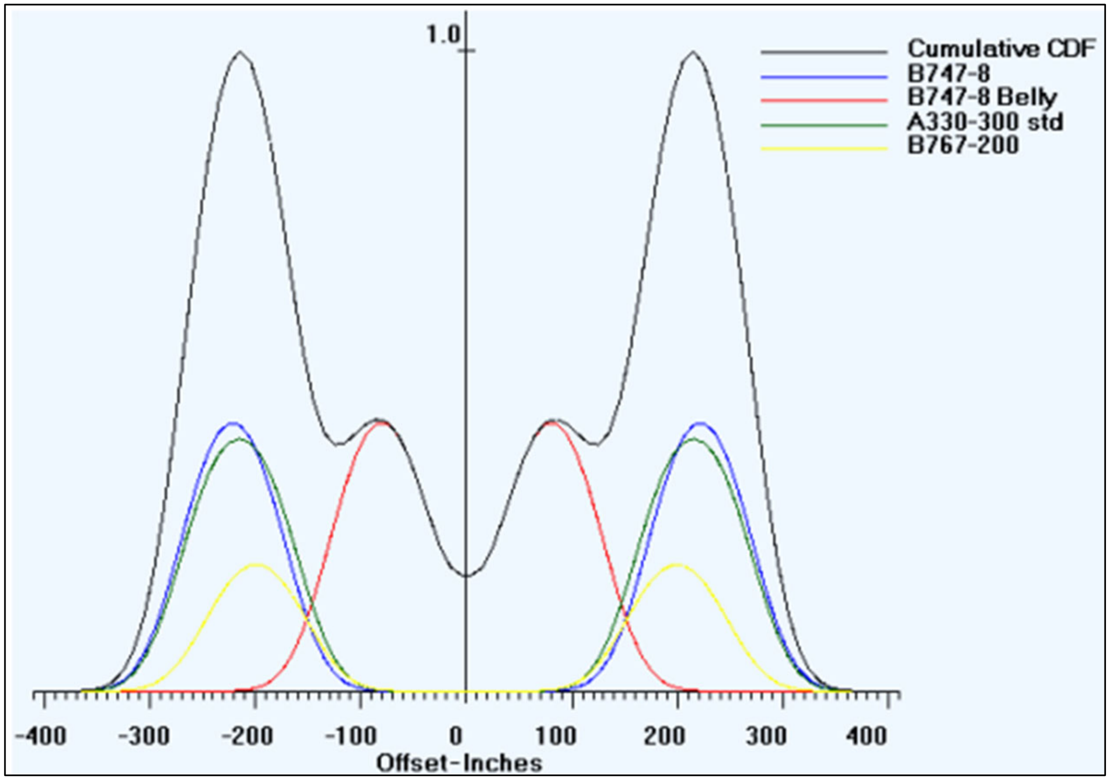
2D/3D2

Traffic - Fleet Mix Considerations

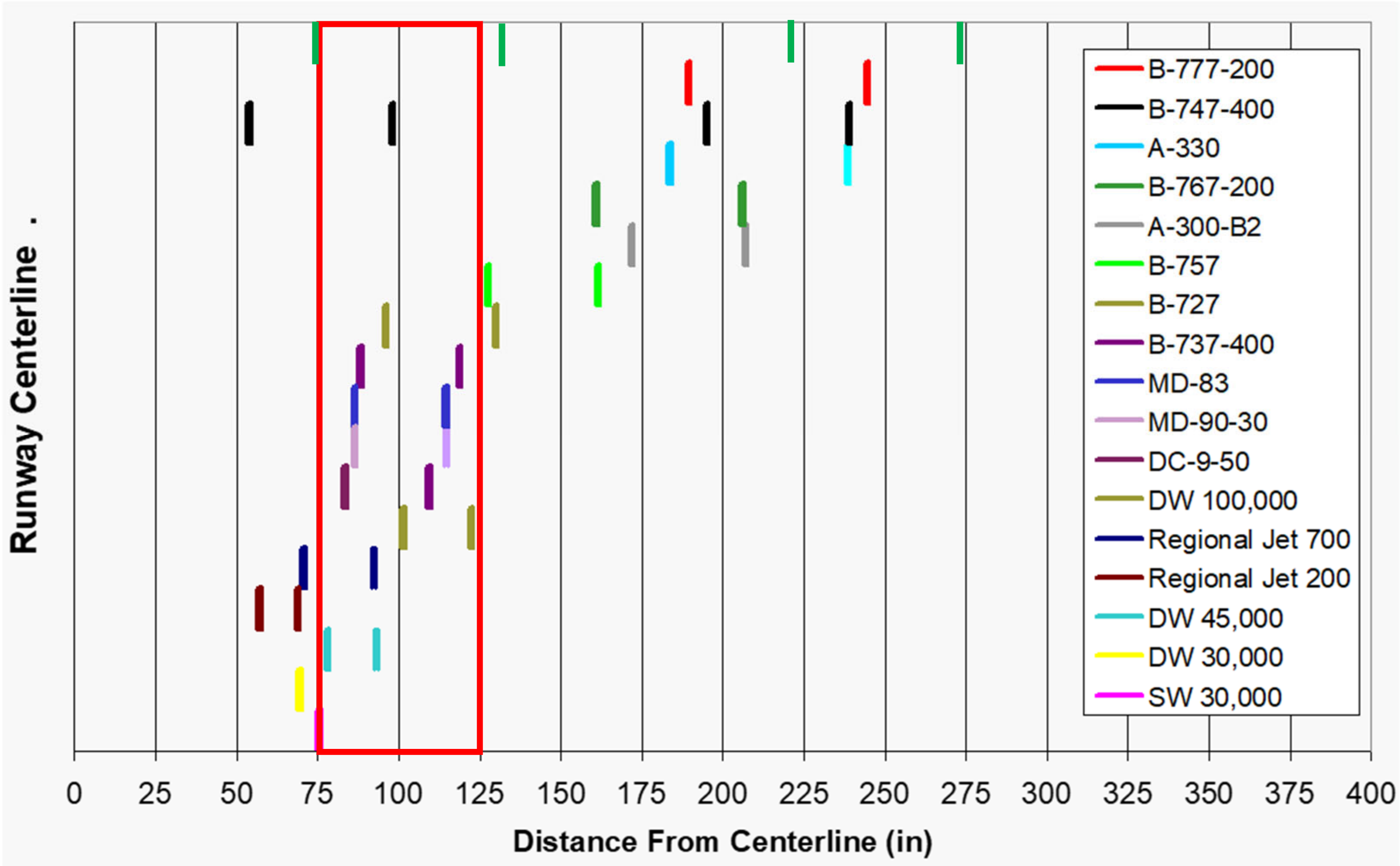
- **Fleet Mix should include all aircraft anticipated to operate on the pavement during its life**
  - For Federally Funded projects fleet mix must be FAA approved and typically based on planning documents such as master plan.
- **Determine type of aircraft (variant also) and expected operational load**
  - 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**

Traffic- Cumulative Damage Factor (CDF)

- Sums the damage contributed from each aircraft
- CDF = $\Sigma (n_i / N_i)$, 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



Mix Traffic - Aircraft Gear Locations



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

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**

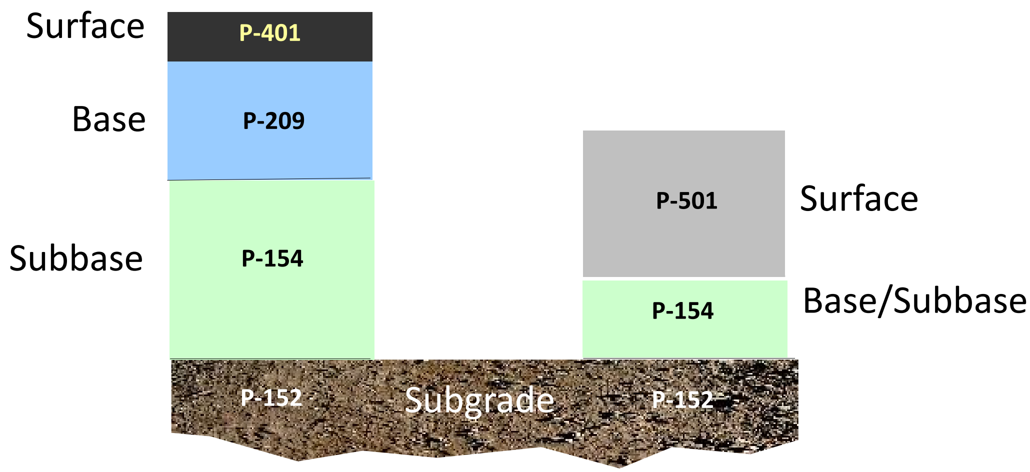
Site Conditions - Soil Investigation (New Const)

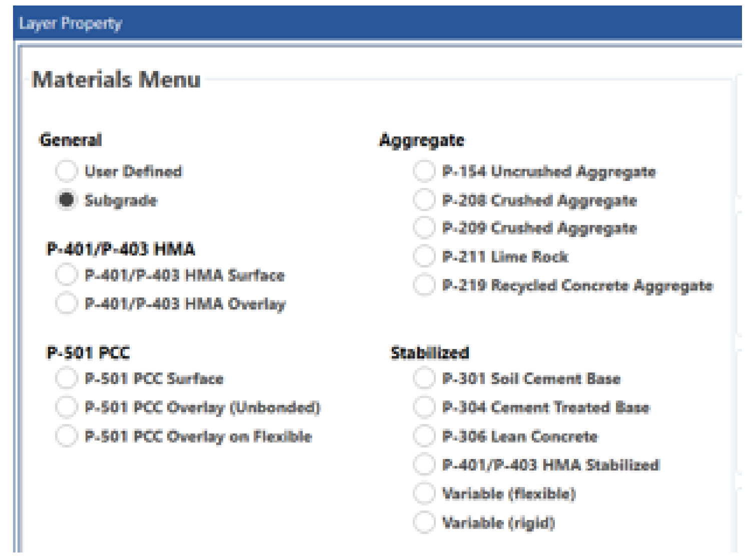
Area	Spacing	Depth
Runway/Taxiway	60m interval	3 m
Other areas	1 per 1,000 sq m	3 m
Borrow areas	Sufficient to define material	To depth of Borrow Excavation

Airport Pavement Design Guidance

Some Common Terminology Used in FAA Pavement Design

Flexible Pavement **Rigid Pavement**

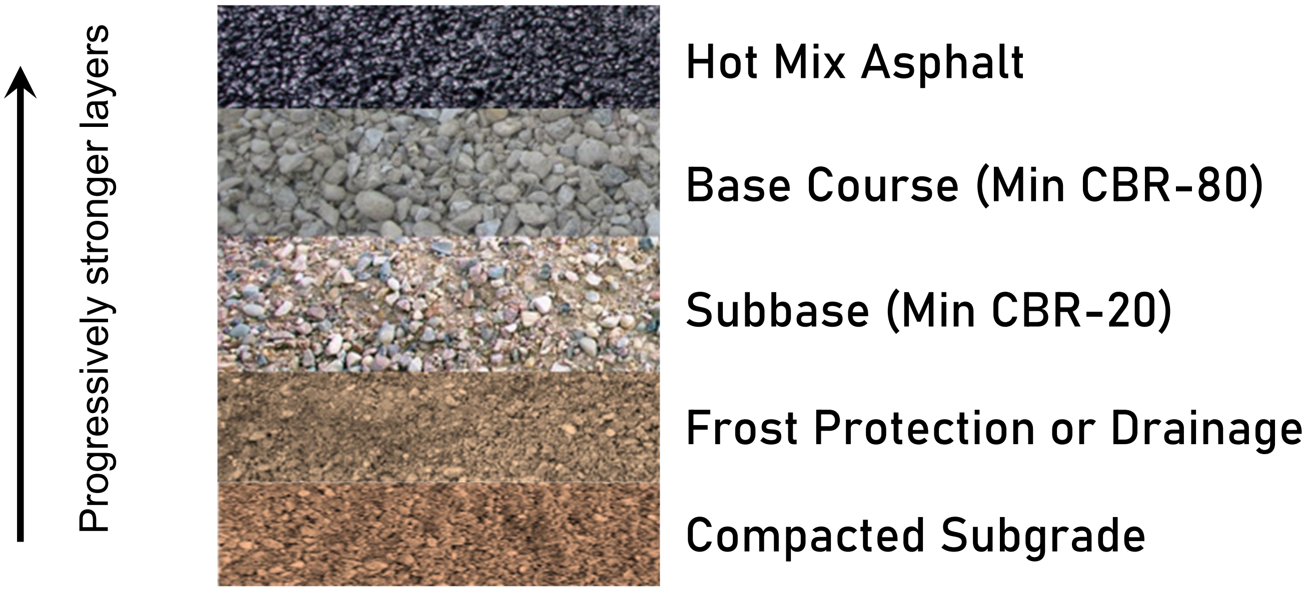


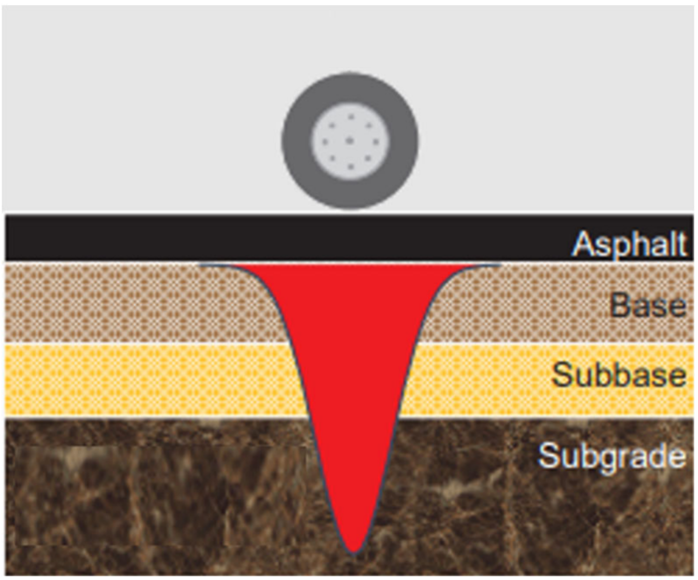


- Materials are outlined in AC 150/5320-6G (2021)
- Construction specifications in AC 150/5370-10H (2018)

Typical Pavement Structures

Flexible Pavement

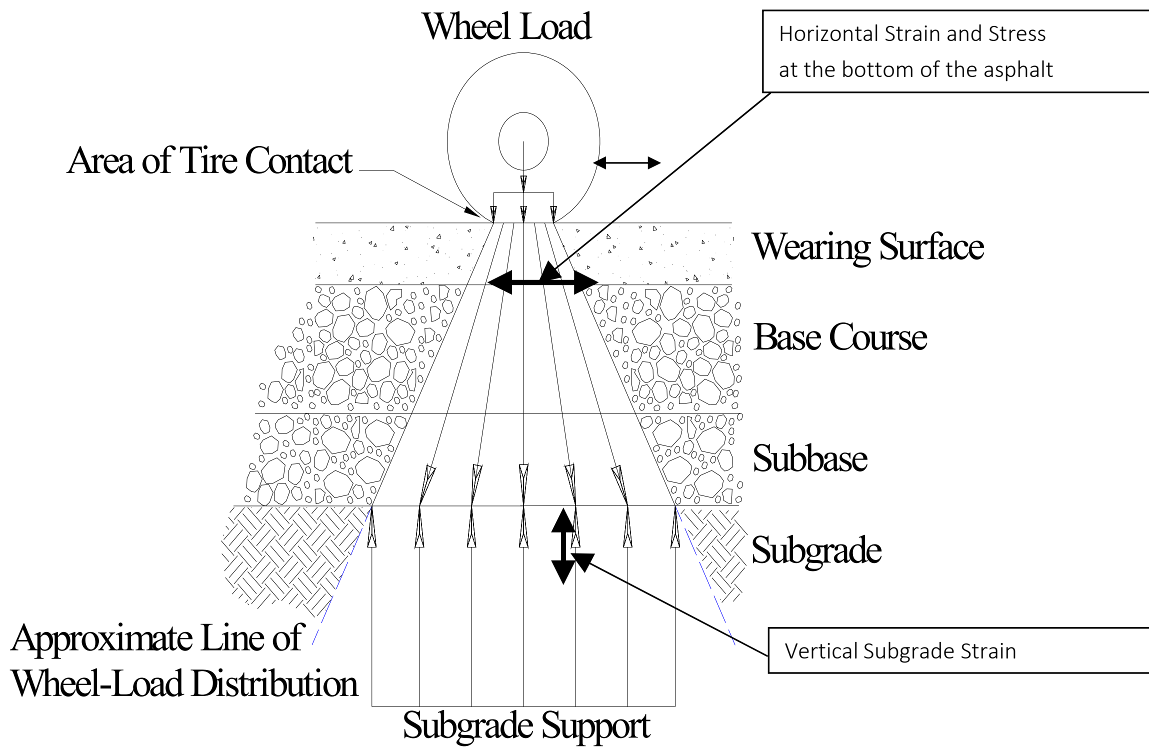




- Flexible pavement systems are designed with layers strong enough to withstand the stresses placed upon it and thick enough to distribute those stresses to the layer underneath it without causing deformation

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 Mix

- **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

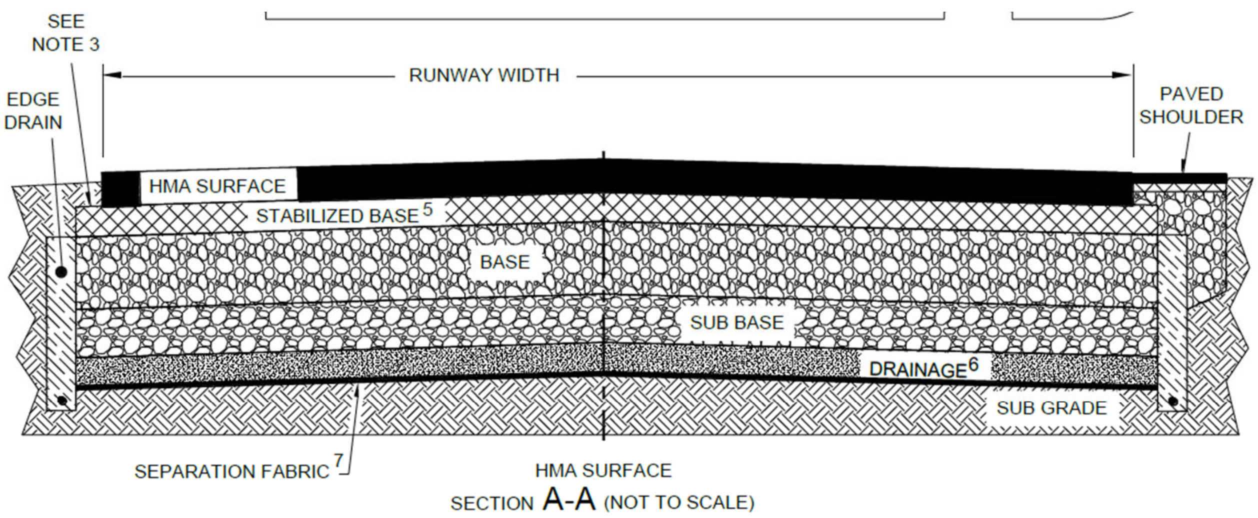


Figure 3-3 in AC 150/5320-6G

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 Pavement Structures

Rigid Pavement

PCC Surface

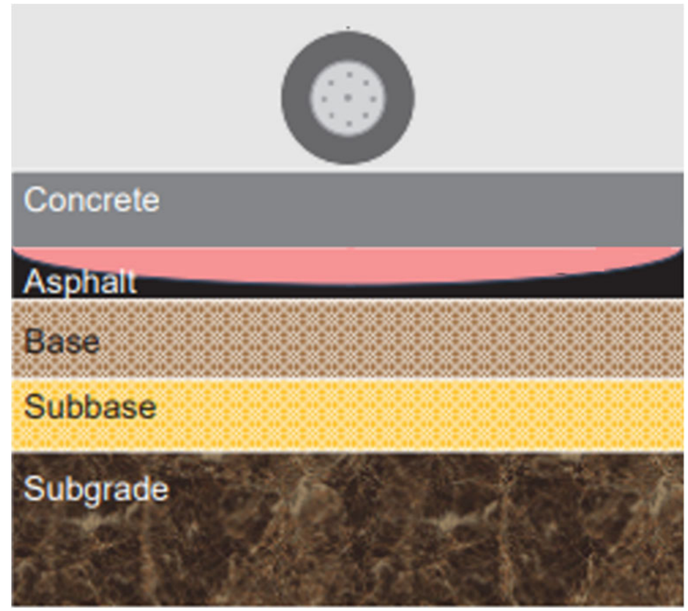
Base Course [1]

Subbase

Compacted Subgrade [2]

1- May require drainage layer above

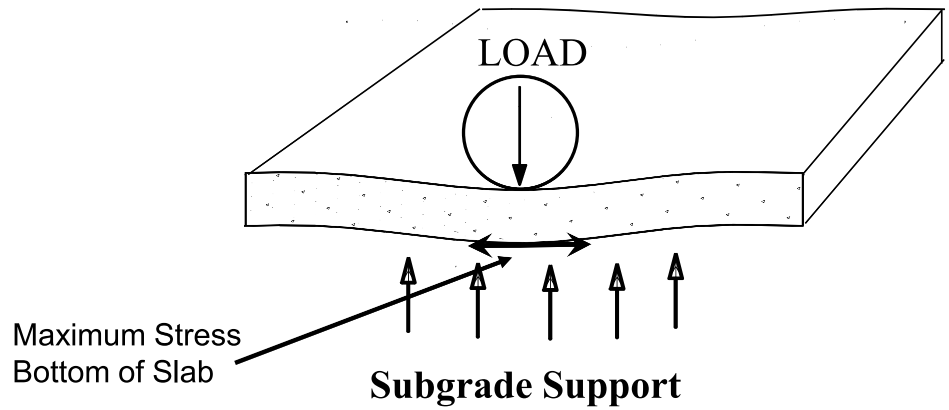
2- May require frost protection layer above



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

FAA Rigid Pavement Design

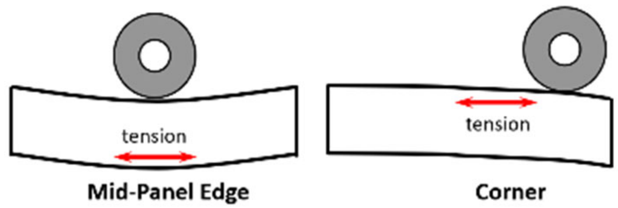
- Rigid pavement failure model is the same between FAARFIELD 1.42 and 2.1
- New 3-D finite element library (FAASR3D) used for calculation of slab stresses
- Design stress for new rigid pavement is the larger of:
  - 75% maximum free edge stress (computed by FAASR3D)
  - 95% of the layered elastic stress (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)



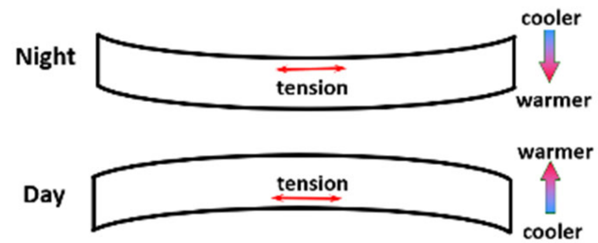
- Maximum stress at pavement edge
- 25% load transfer to adjacent slab

Rigid Pavement - Stresses

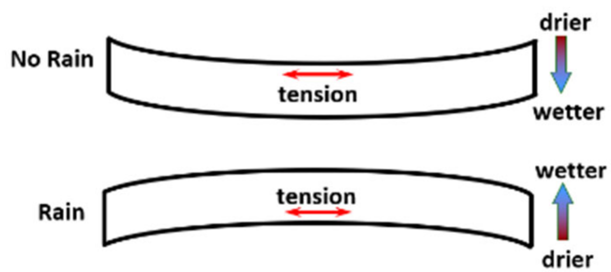
- Load-related stresses
- Cracking occurs when the tensile stress > flexural strength



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

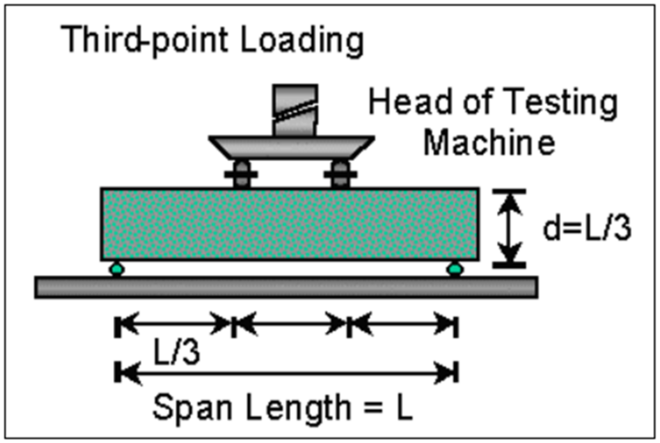


- Moisture-Gradient Stresses
- Variation in moisture between bottom and top of the slab



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.

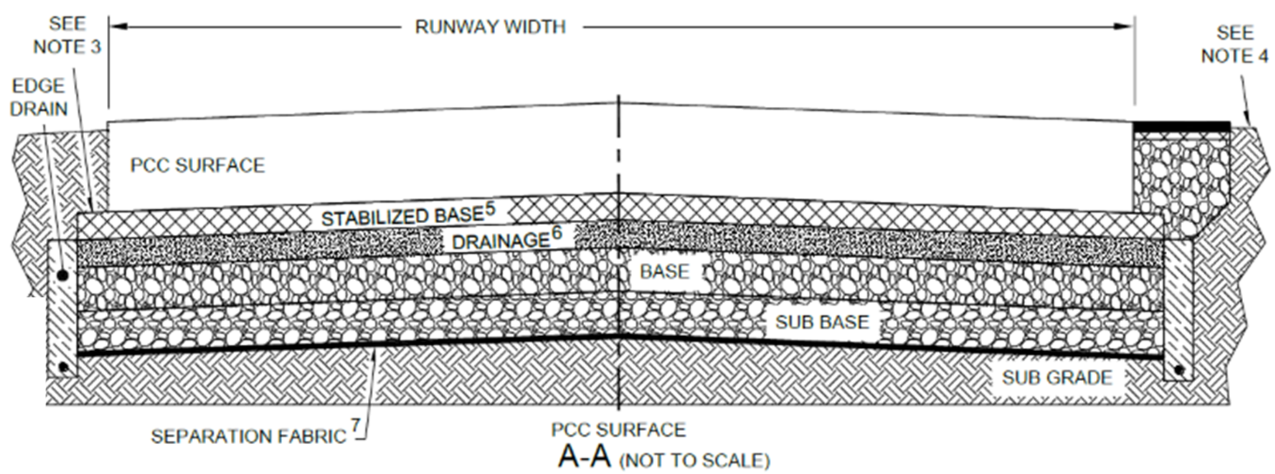


Figure 3-3 in AC 150/5320-6G

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 u
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 & FAA 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- Base Layer Requirements

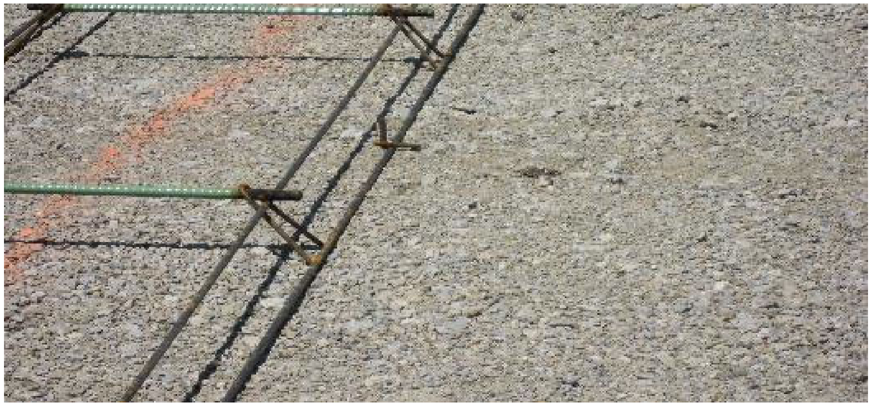
- **Requirements based on Gross Weight of Aircraft**
  - P-208 Aggregate Base Course
  - P-209 Crushed ABC*
- **Regional Usage**
  - P-210- Caliche BC
  - P-211- Lime Rock BC
  - P-212- Shell BC
  - P-213- Sand Clay BC Common in certain regions

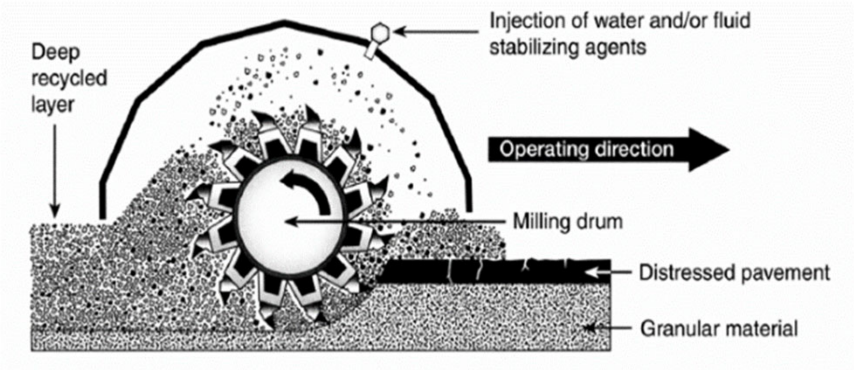
Minimum Base Layer Thickness					
Layer Type	**FAA Spec**	**Pavement Type**	**Maximum Aircraft Gross Weight Operating on Pavement (Kg)**		
			< 25,215	> 25,215 < 45,360	>45,360
Crushed Stone Base	**P-209 P-211**	*Flexible*	-	150 mm	150 mm
		Rigid	-	150 mm	150 mm
Unbound Aggregate Base	**P-207, P-208, P-210, P-212, P-213, P-219**	*Flexible*	150 mm	150 mm	-
		Rigid	-	150 mm	150 mm

* P-207, P-219 requires laboratory testing to establish if it will perform as a base or subbase. If CBR >80 may be used in place of P-209, CBR >60 in place of P-208. Both may be used as subbase under stabilized base

Design- Base Layer Requirements Cont

- **Difference between P-208 & P-209**
  - P- 208- 75% 1 fractured face / 60% 2 fractured faces
  - P- 209 -100% 1 fractured face / 90% 2 fractured faces
- **P-219 Recycled Concrete ABC**
  - Quality of recycled ABC is directly related to the quality of the source material and production.
- **P-207 In-depth Full Depth Reclamation**
  - Consist of pulverizing the full pavement section prior to overlaying with AC or PCC
  - Generally, stabilization agent is included
  - May be used as a base course under flexible and rigid pavements when pavement loads are 60,000 lbs or less, or when used as a base under stabilized bases





Design- Stabilized Base Layer

- **Aircraft > 100,000 lbs require stabilized base**
- **Research supports clear benefit to performance of pavements with stabilized base**
  - Extends pavement life after initial crack
- **Not as critical under rigid pavement as flexible**
- ***Caution: the stiffer the base, the higher likelihood for issues with cracking***
  - Increase in curling stress
  - Slab size becomes more critical

Design- Stabilized Base Layer

- **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**
- **PCC thickness design is not sensitive to thickness is not sensitive**

Minimum Stablized Layer Thickness					
Layer Type	**FAA Spec**	**Pavement Type**	**Maximum Aircraft Gross Weight Operating on Pavement (Kg)**		
			< 25,215	> 25,215 < 45,360	>45,360
Stabilized Base	**P-402, P-403, P-304, P-306**	*Flexible*	-	-	125 mm
		Rigid	-	-	125 mm

* See 150/5320-6G paragraph 5.5 Stabilized Base Course, for requirements and limitation. P-220 may be used under concrete with minimum thickness of 12" and when concrete thickness is

- **Bond breaker typically used between Rigid surface and stabilized base**
  - *Choke Stone***
  - Geosynthetic
  - Curing Compound (Double Application)

Design- Subbase Layers

- **Minimum material requirements**
  - P-154 Subbase Course (typical)
  - Any base material may also be used as a subbase

- **When aircraft loads over 60,000 lbs subbase is used for:**
  - Frost design (thickness based on frost depth)
  - Create a working platform for construction

Subbase Layer Thickness Requirements					
Layer Type	**FAA Spec**	**Pavement Type**	**Maximum Aircraft Gross Weight Operating on Pavement (Kg)**		
			< 25,215	> 25,215 < 45,360	>45,360
Subbase*	**P-154**	*Flexible*	150 mm	150 mm	150 mm
		Rigid	150 mm	*As Needed*	*As Needed*

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
- **Modeled as User Defined Layer with modulus values based on material type**

Minimum Drainage Layer Thickness

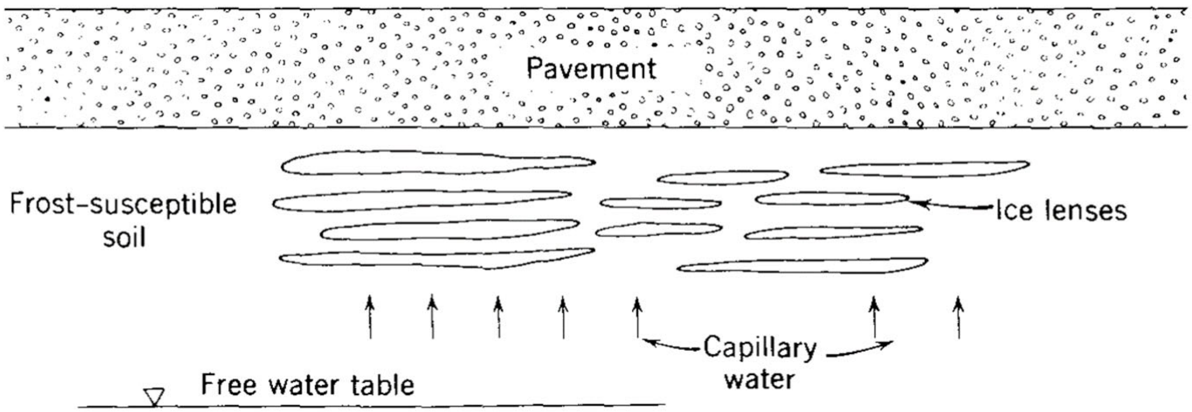
Layer Type	FAA Spec	Pavement Type	Maximum Aircraft Gross Weight Operating on Pavement (Kg)		
			< 25,215	> 25,215 < 45,360	>45,360
Drainage Layer	P-307 P-407*	*Flexible*	-	150 mm	150 mm
		Rigid	-	150 mm	150 mm

* See EB102, Aphalt Treated Permable Base Course

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



- Freezing can cause heaving at the surface

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
- **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

QUESTIONS?

Harold Muniz, Airfield Engineer
harold.muniz-ruiz@faa.gov
(202) 267-5190