FAA Rigid Pavement Design Philosophy and Tools

Federal Aviation Administration

Presentation to: Northwest Region Airports Conference

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FAA Pavement Design Guidance

AC 150/5320-6D

- *Chapter 3 & 4*
  - Rigid Design based on Westergaard analysis (edge load with 25% load transfer)
  - Flexible Design based on CBR Design Method (S-77-1 US Corp of Engineers procedure)
- Chapter 7
  - Layered Elastic Design (LEDFAA v1.3) Interim rigid design procedure

Airfield Rigid Pavement Design

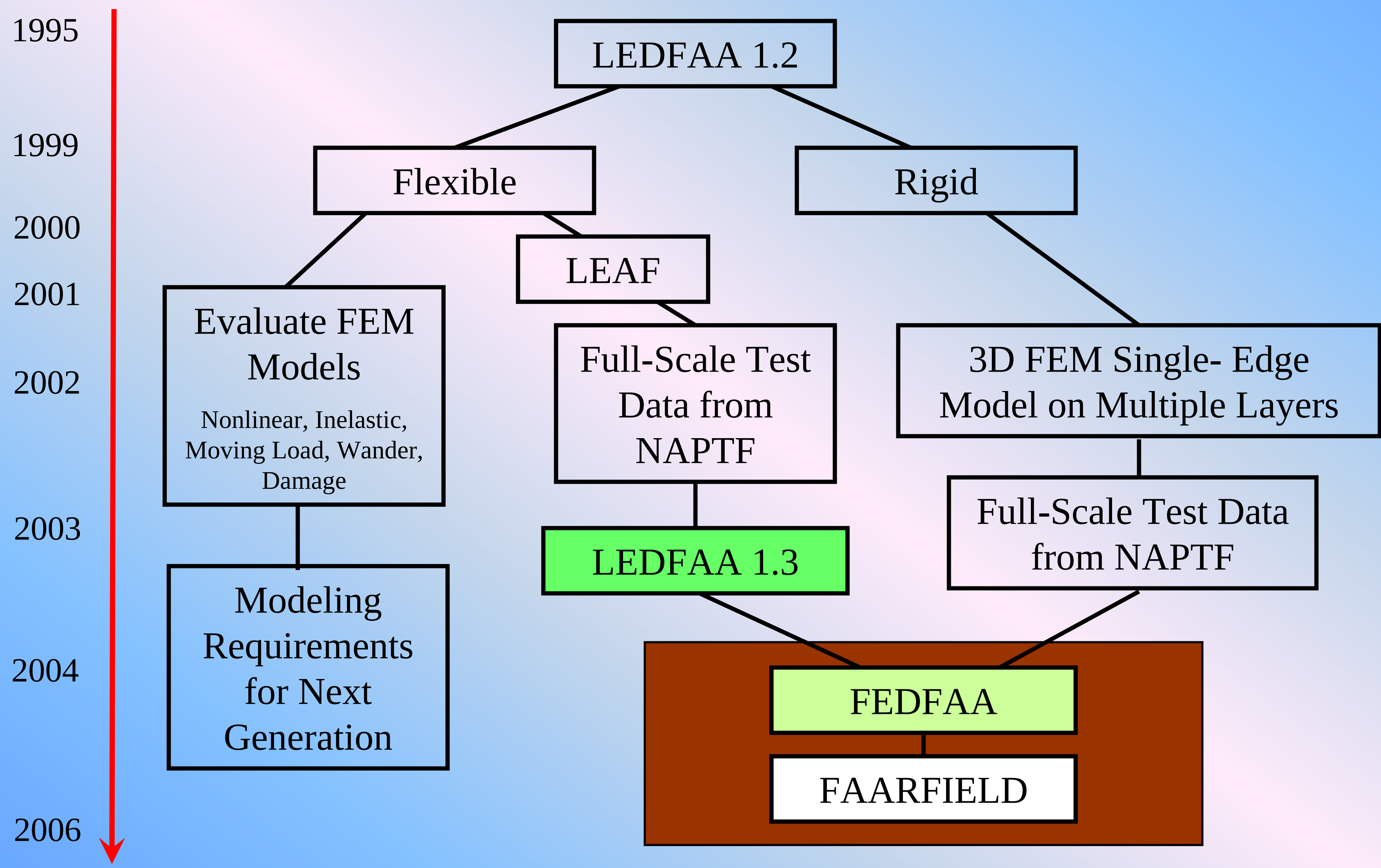
R805FAA.xls

Computer program for rigid airfield pavement design in accordance with AC 150/5320-6D Chapters 3 and 4

FAAFED (eventually named FAARFIELD)

Computer program for rigid airfield pavement design using finite element procedures.

Development of FAA Standards for Airport Pavement Thickness Design



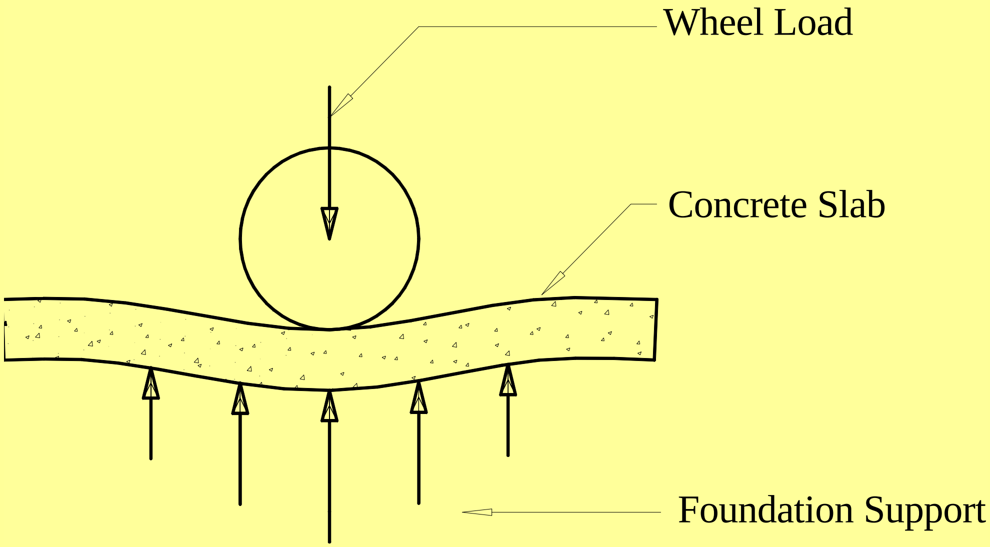
FAA Rigid Pavement Design

Chapter 3 – AC 150/5320-6D

FAA Rigid Pavement Design

Chapter 3 – AC 150/5320-6D

- ❖ Based on Westergaard Edge Load Analysis
- ❖ Assumes 25% Edge Load Transfer
- ❖ Additional adjustments for Traffic level
- ❖ Foundation assumed as a "dense liquid"



FAA Rigid Pavement Design

Westergaard Edge Load Analysis

- Westergaard analysis used to determine stress in the rigid panel

For single wheel analysis

$$\sigma_e = \frac{0.572P}{h^2}\left[4\log\left(\frac{l}{b}\right) + 0.359\right]$$

σ_e = Interior Load Stress
h = Pavement Thickness
l = Radius of Relative Stiffness
b = $\sqrt{1.6a^2 + h^2} - 0.675h$
a = Radius of Loaded Area

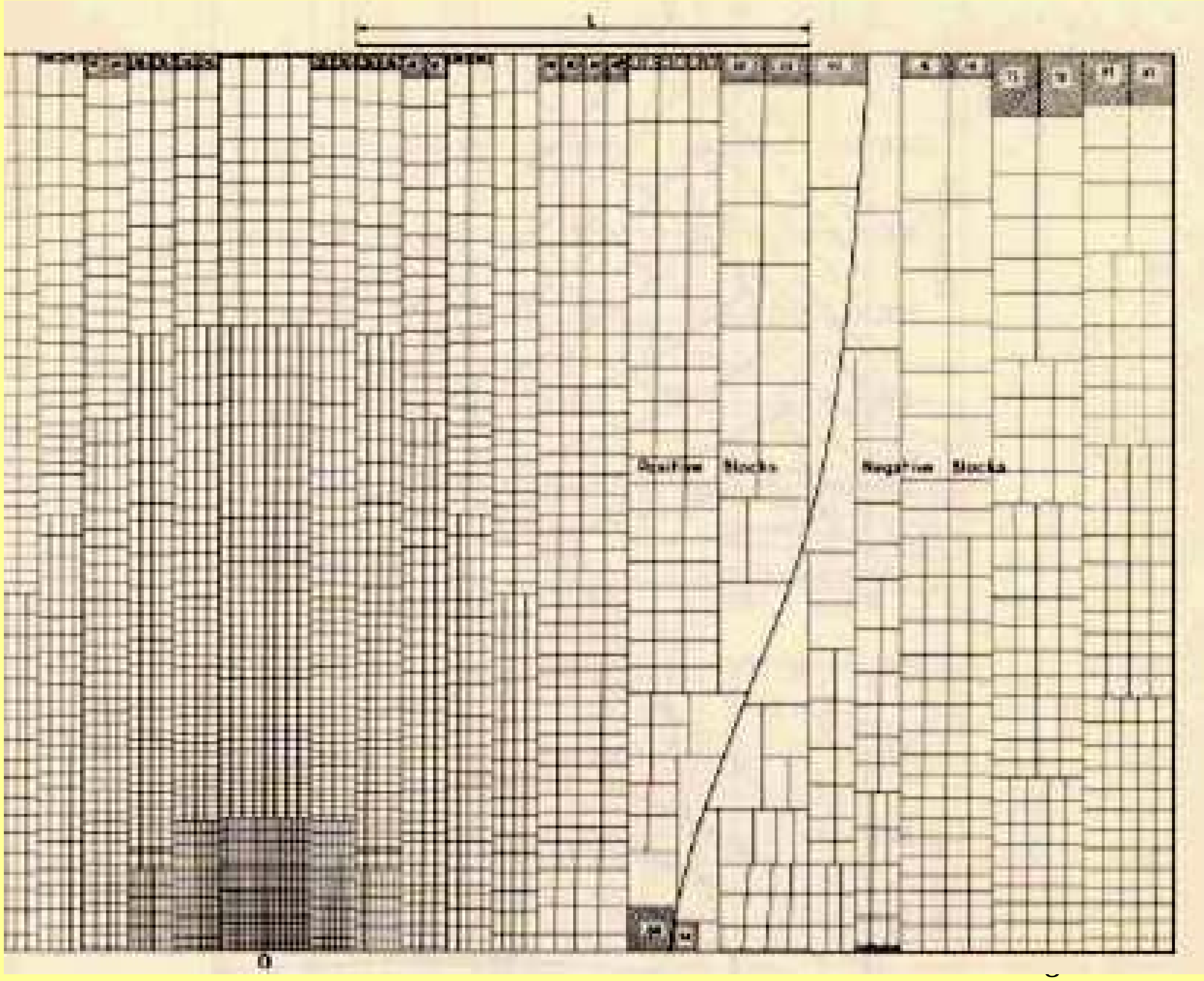
FAA Rigid Pavement Design

Westergaard Edge Load Analysis

- Westergaard analysis used to determine stress in the rigid panel

For multi-wheel analysis
Pickett and Ray Influence Chart

These have be automated.



FAA Rigid Pavement Design
Westergaard Edge Load Analysis

- Miner's Hypothesis
  - Damage accumulates linearly with number of loadings

$$FD = \sum_{i=1}^{k} \frac{n_i}{N_i}$$

FD = Accumulated fatigue damage over design period
n = Number of individual load applications at stress level *i*
N*i* = Maximum allowable number of load applications at stress level *i*

FAA Rigid Pavement Design

Westergaard Edge Load Analysis

- Fatigue Model to define maximum allowable number of load applications till "failure"

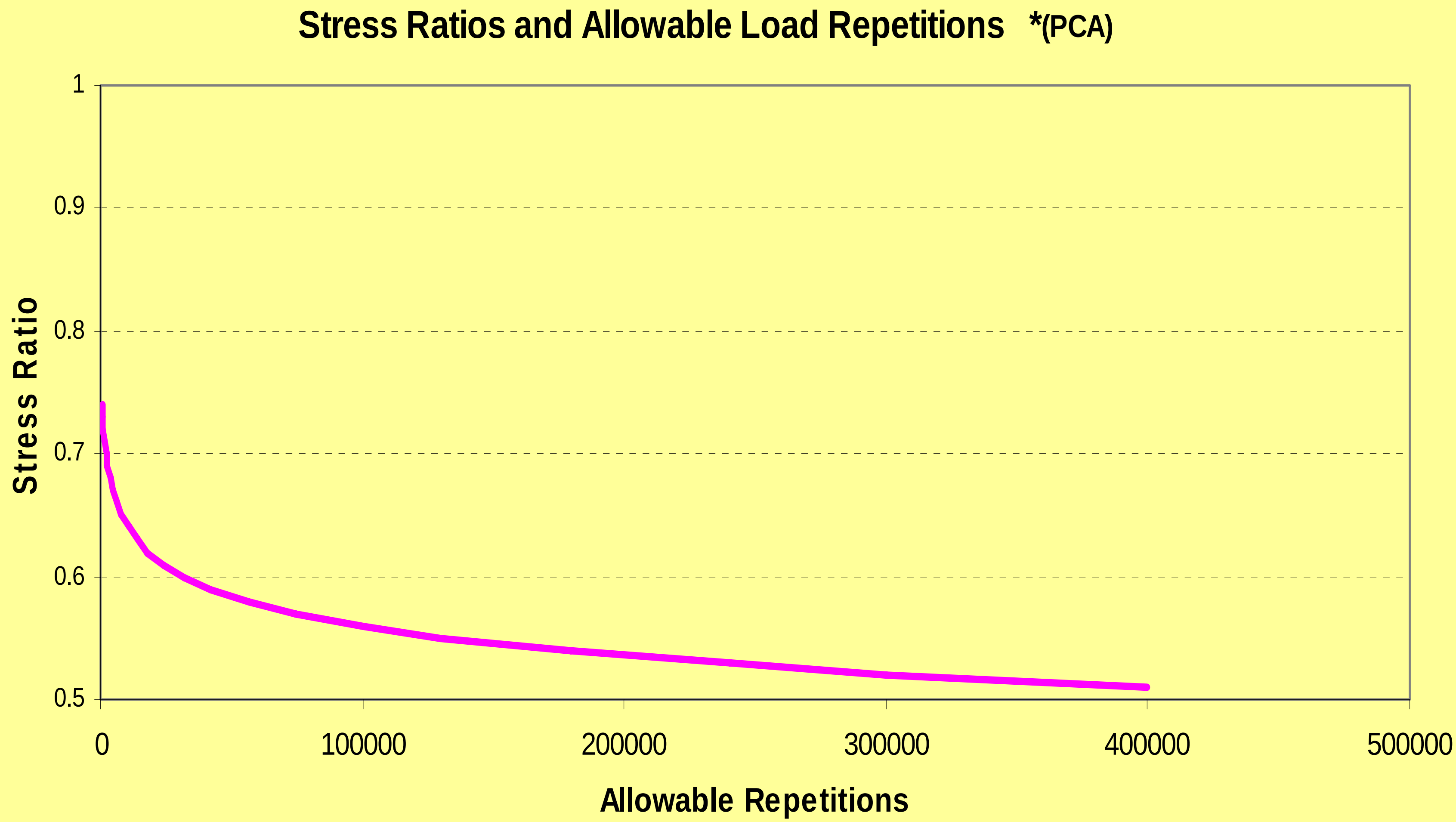
$$SR = \frac{\sigma}{Rc}$$

SR = Stress Ratio

σ = Critical bending stress

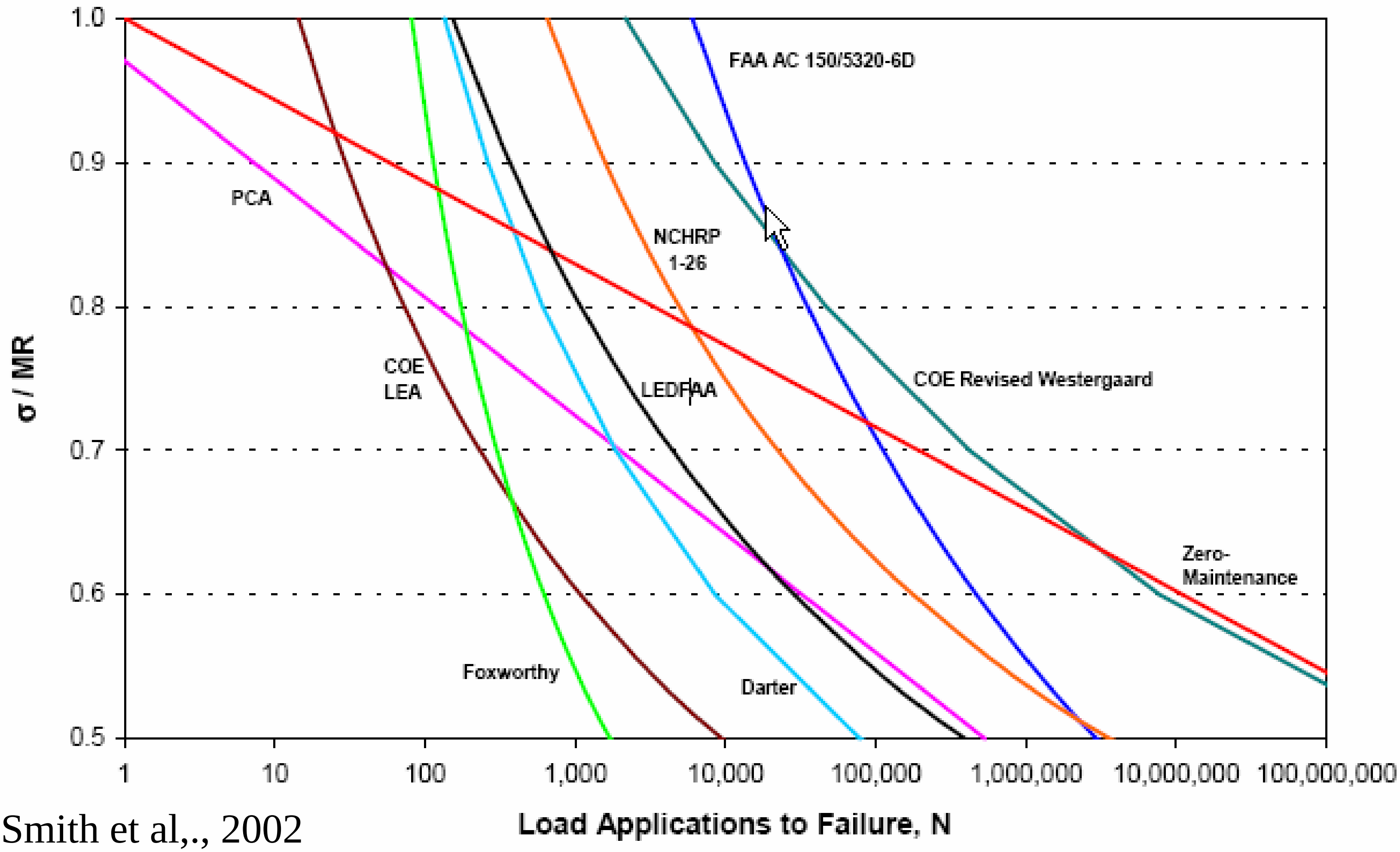
Rc = Modulus of rupture (flexural strength)

FAA Rigid Pavement Design
Westergaard Edge Load Analysis



FAA Rigid Pavement Design
Westergaard Edge Load Analysis

Various Rigid Pavement Fatigue Models



Smith et al,., 2002

FAA Rigid Pavement Design

Westergaard Edge Load Analysis

$$0.75 \times \sigma_{Hslab} \leq \frac{R_c}{1.3}$$

$$1.3 >= \frac{R_c}{\sigma_{Hslab} \times 0.75}$$

σ_{Hslab} = Maximum Tensile edge stress at the bottom of the slab for slab thickness Hslab

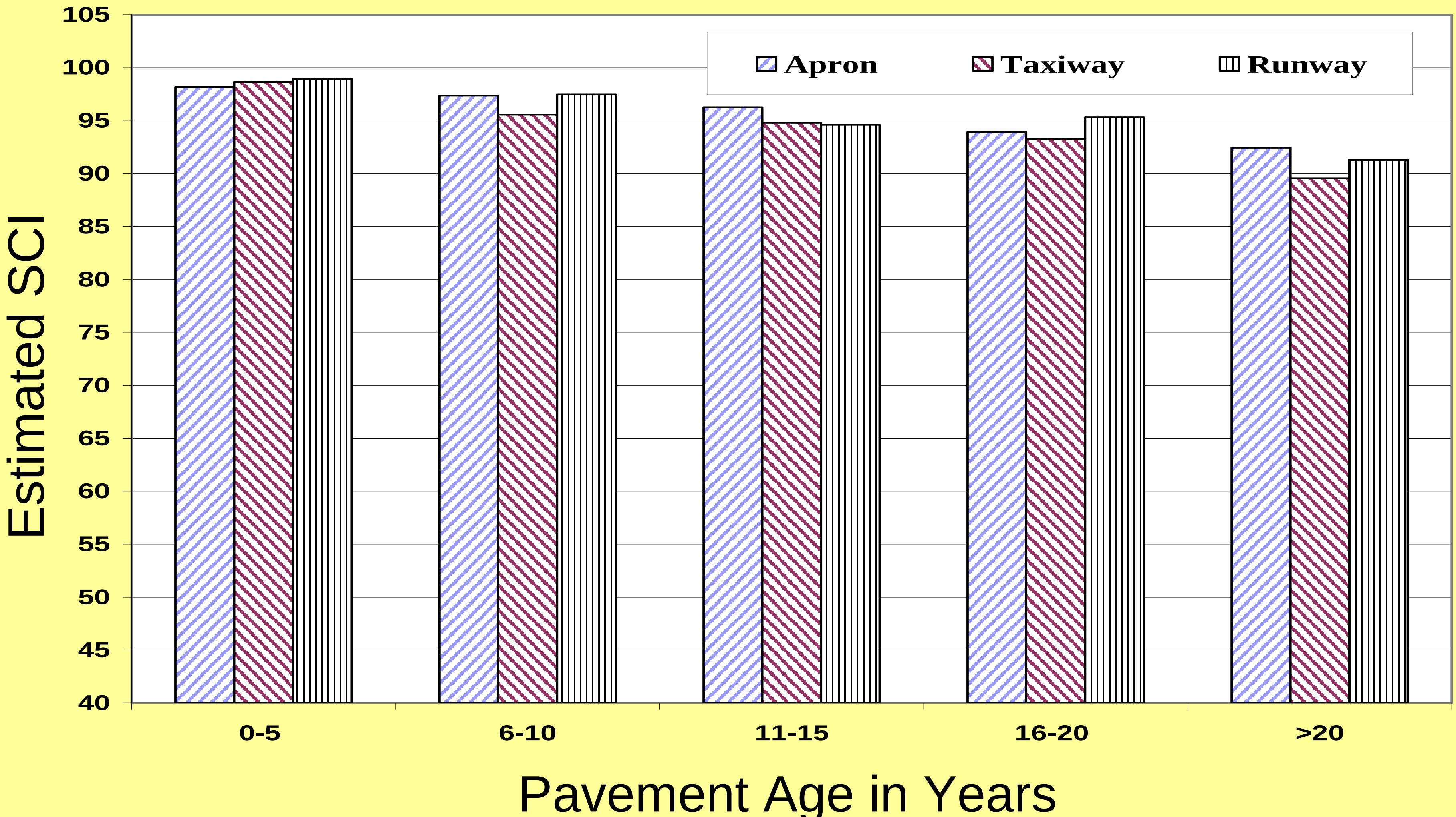
Rc = Flexural Strength of the PCC

1.3 = Safety Factor (77%)

0.75 = Reduction factor based on assumption that a joint transfers 25% of the load

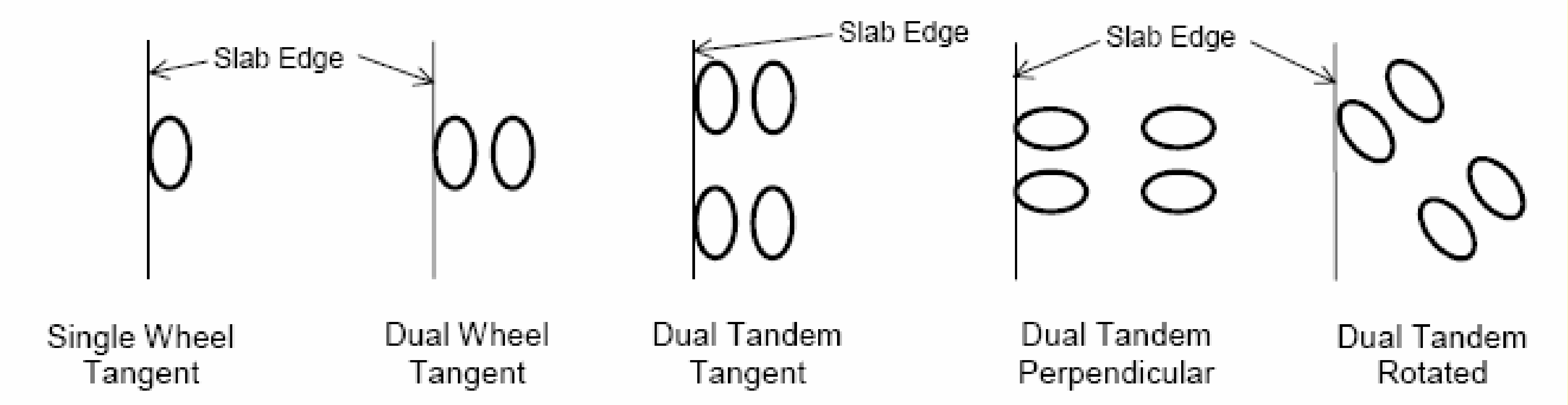
Recently validated in DIA Study

Is the FAA Model Sufficient for 20 Year Pavement Design?



FAA Rigid Pavement Design
Westergaard Edge Load Analysis

We must determine the most critical gear arrangement
i.e. maximum stress in slab



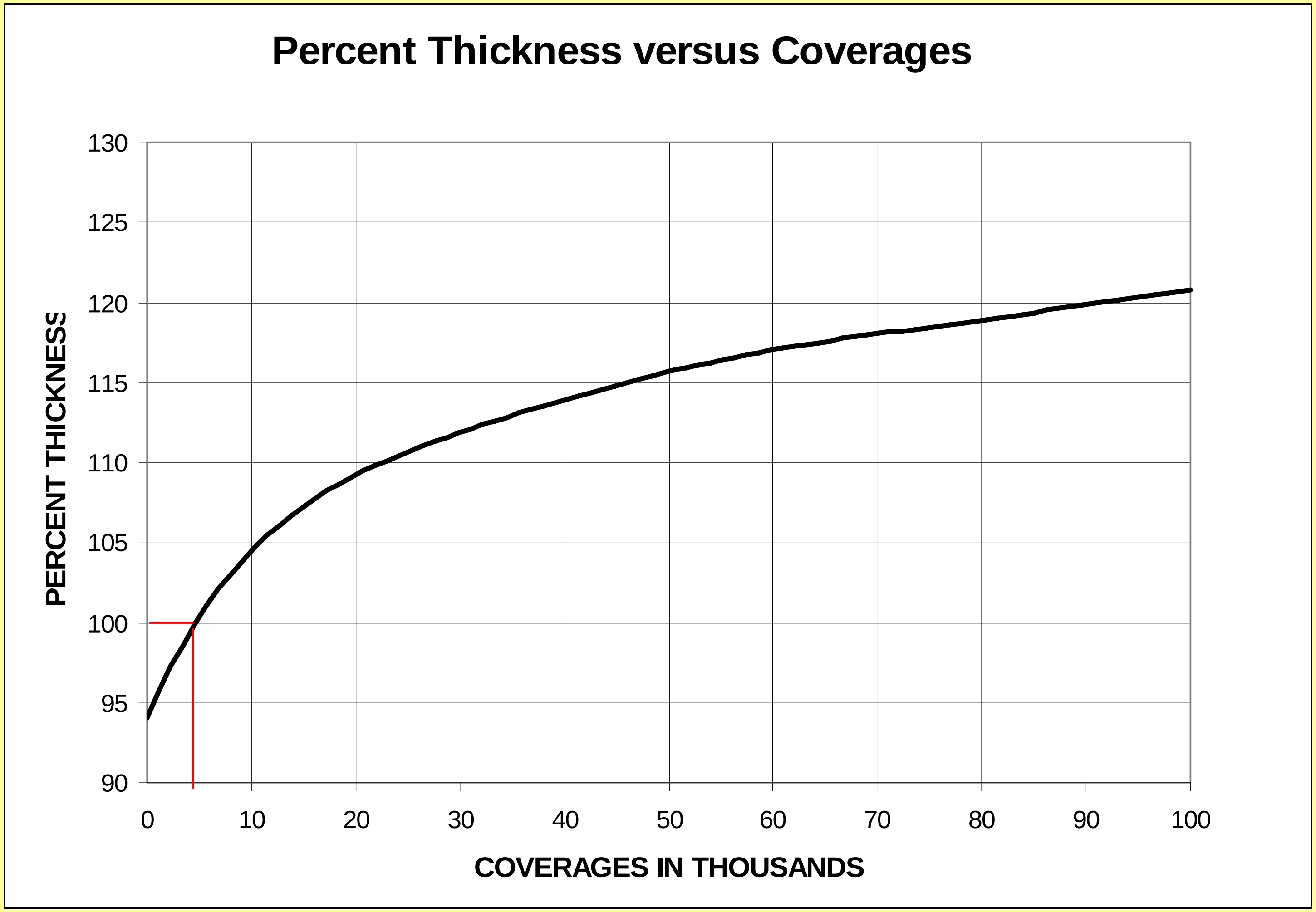
Alternate Design charts are provided in 5320-6D for Dual Tandem gears

Standard charts – Parallel

Alternate charts – Rotated 45 degrees

FAA Rigid Pavement Design
Westergaard Edge Load Analysis

We must also account for traffic levels higher than 5000 coverages



FAA Rigid Pavement Design
Westergaard Edge Load Analysis

Traffic levels other than 5000 coverages

Greater than 5000

$$COV = 5000 \times 10^{\left(\sqrt{\frac{R_F}{\sigma \times 1.3}} - 1\right) / 0.15603}$$

Less than 5000

$$COV = 5000 \times 10^{\left(\sqrt{\frac{R_F}{\sigma \times 1.3}} - 1\right) / 0.07058}$$

Rigid Pavement Design

Basic Design Parameters

- Concrete Flexural Strength
- Subgrade Support
  - Modulus (k-value)
- Design Aircraft
  - Gear type and Gross Load
- Traffic
  - Annual Departures

FAA Rigid Pavement Design
Concrete Flexural Strength

- Some debate over what flexural strength should be used in pavement design.
- AC 5320-6D Design on the strength available when opening to traffic.
  - Default strength – project specifications
  - Proposed Change 4 suggests design at 600 – 650 and spec at design - 5% (use 28 day)

Don’t play games like:

“I think the contractor will give me more strength than I ask for….”

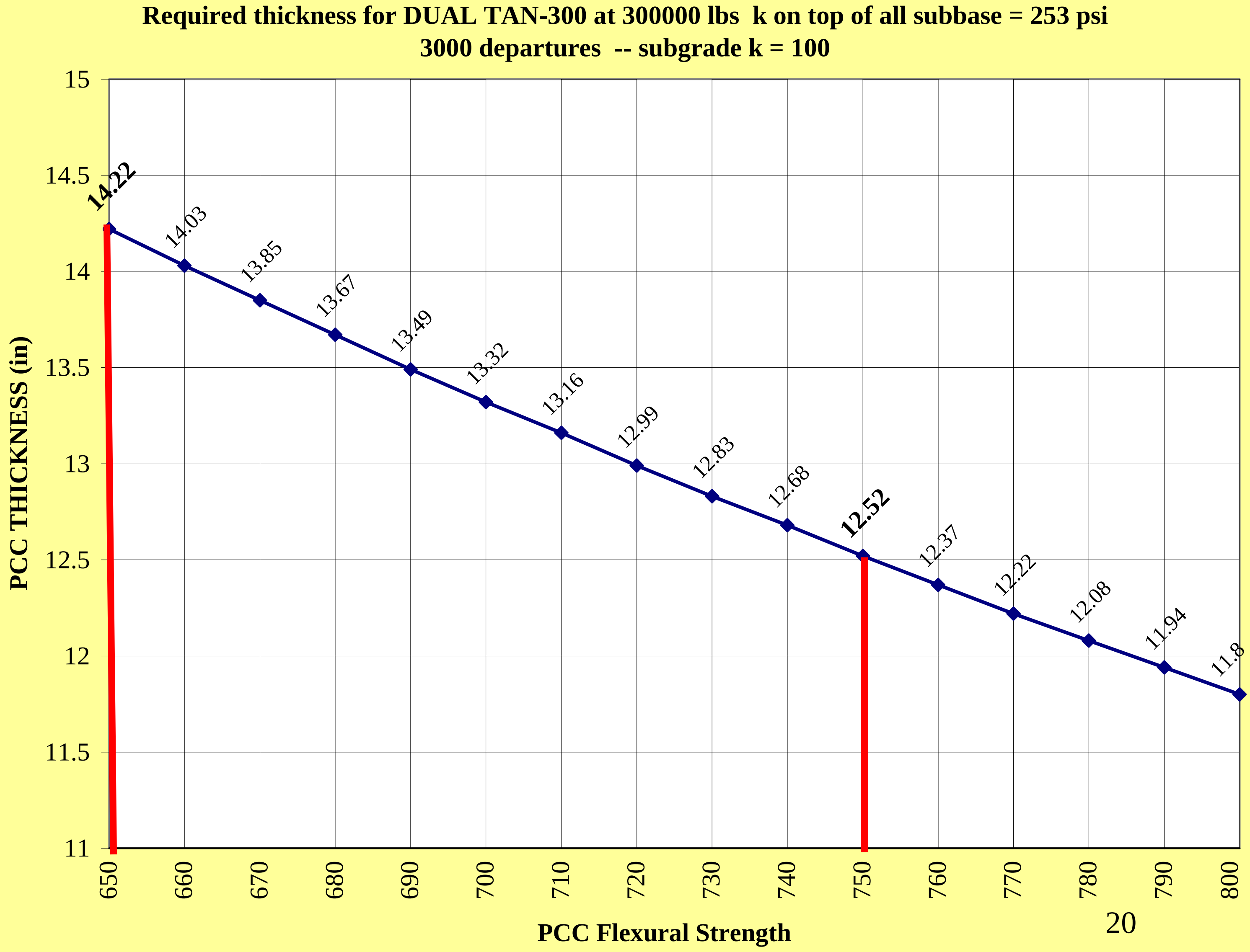
FAA Rigid Pavement Design

Concrete Flexural Strength

Suppose you ask for 650 but expect 750

You could reduce the thickness by ~1-1/2 inches

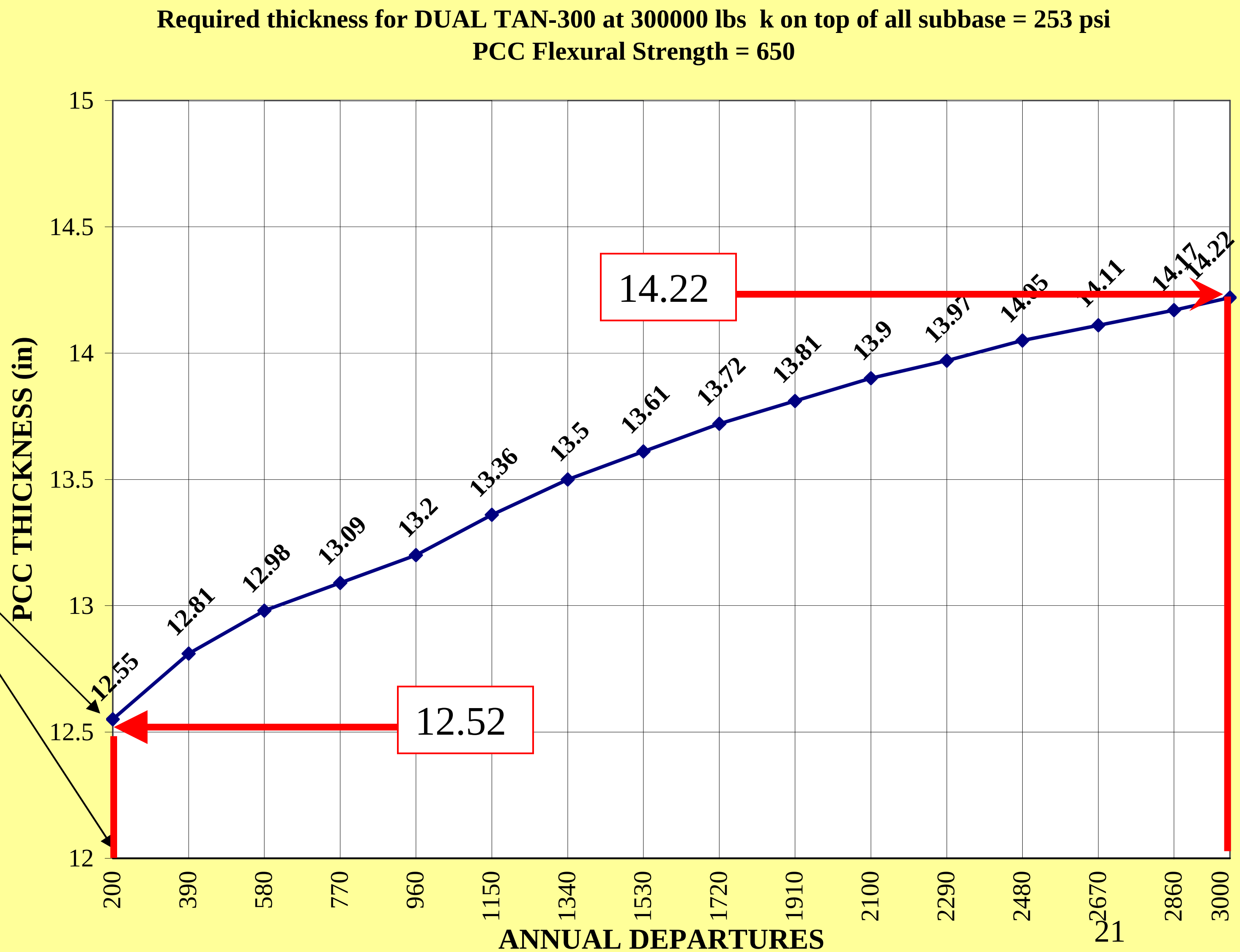
(14.22 - 12.52)



FAA Rigid Pavement Design

Concrete Flexural Strength

But if you don't get 750 and only get the requested 650 and you reduced the pavement thickness by 1-1/2 inches Then you reduced the departure count by a factor of 10

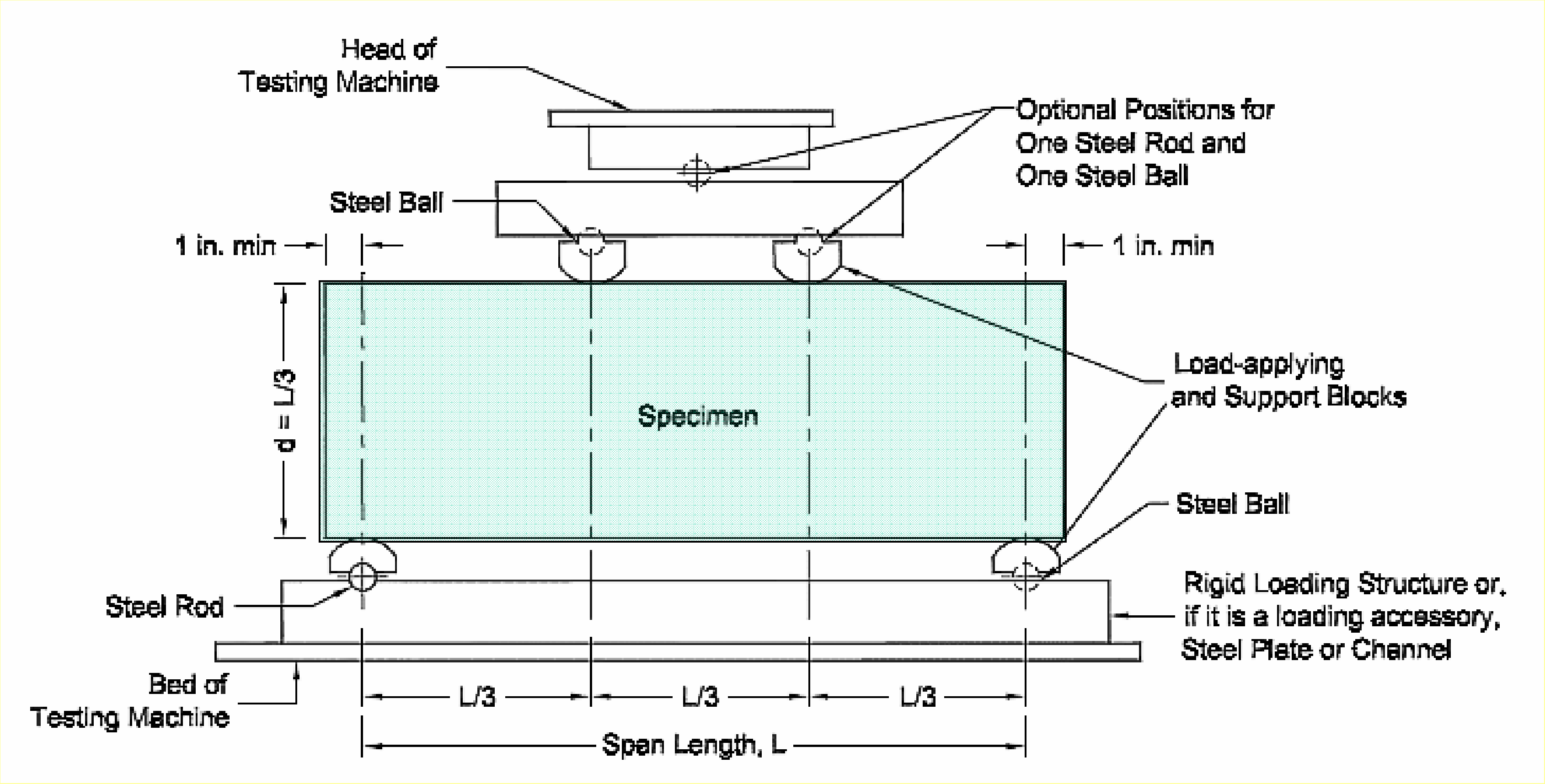


FAA Rigid Pavement Design

Concrete Flexural Strength

Flexural Strength is based on ASTM C 78

Third Point Loading



FAA Rigid Pavement Design

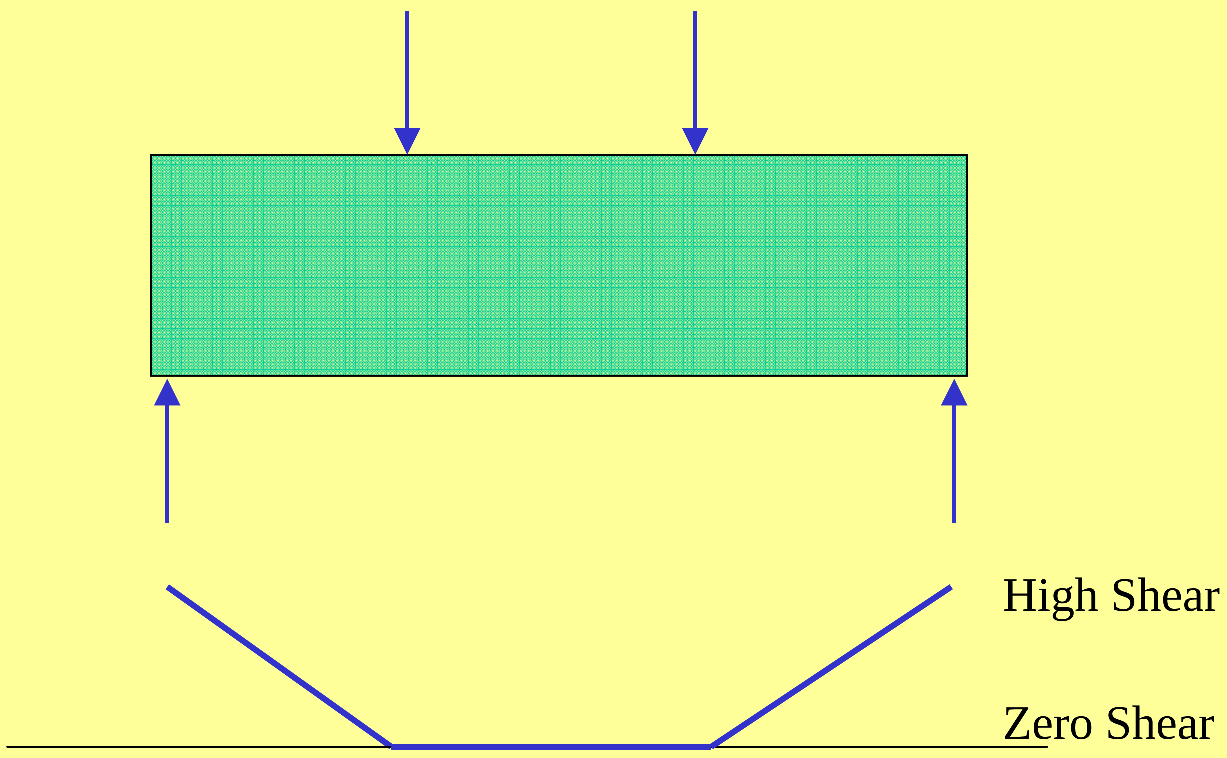
Concrete Flexural Strength

Flexural Strength is based on ASTM C 78

Third Point Loading

Center Point testing will produce Strength values approximately 15% lower than center point testing.

Be sure test results are third point



FAA Rigid Pavement Design
SUBGRADE SUPPORT

- Westergaard analysis assumes the foundation support as a “dense liquid”
- Stabilized layers may not support this assumption
- Some concern in the industry with stabilized layers becoming too strong.
  - Can lead to premature cracking

Stiff subbases require that we reduce the size of the concrete panels

FAA Rigid Pavement Design
SUBGRADE SUPPORT

- Panels sized by Radius of Relative Stiffness

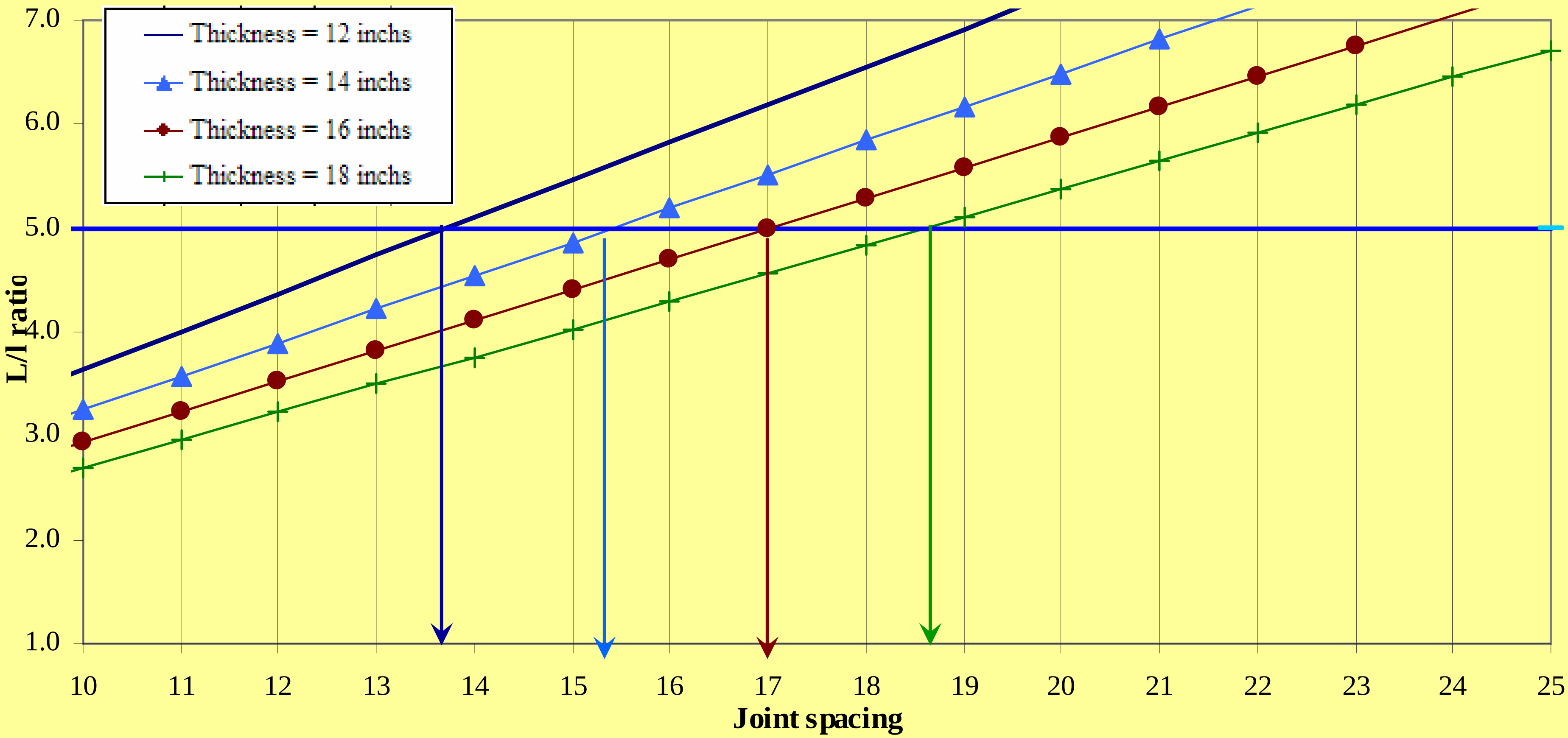
$$l = \left(\frac{Eh^3}{12(1 - u^2)k} \right)^{\frac{1}{4}}$$

l = Radius of Relative Stiffness, inches
E = modulus of elasticity of the concrete (usually 4 million psi)
h = Slab thickness, inches
u = Poisson's ratio for concrete, usually 0.15
k = modulus of subgrade reaction, pci

FAA Rigid Pavement Design
SUBGRADE SUPPORT

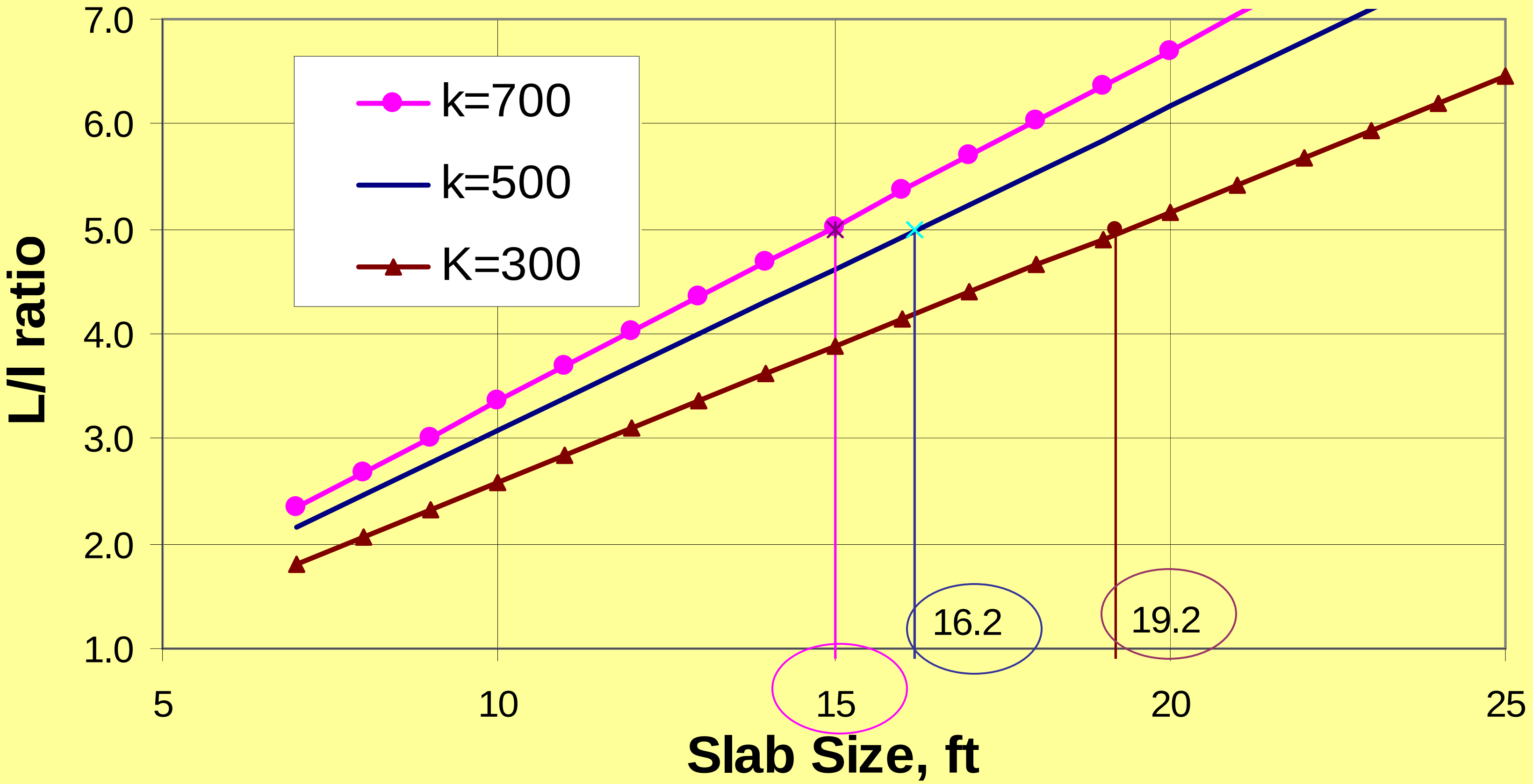
Panels sized by Radius of Relative Stiffness

Joint Spacing Limits with k=500, E = 4,000,000



FAA Rigid Pavement Design
SUBGRADE SUPPORT

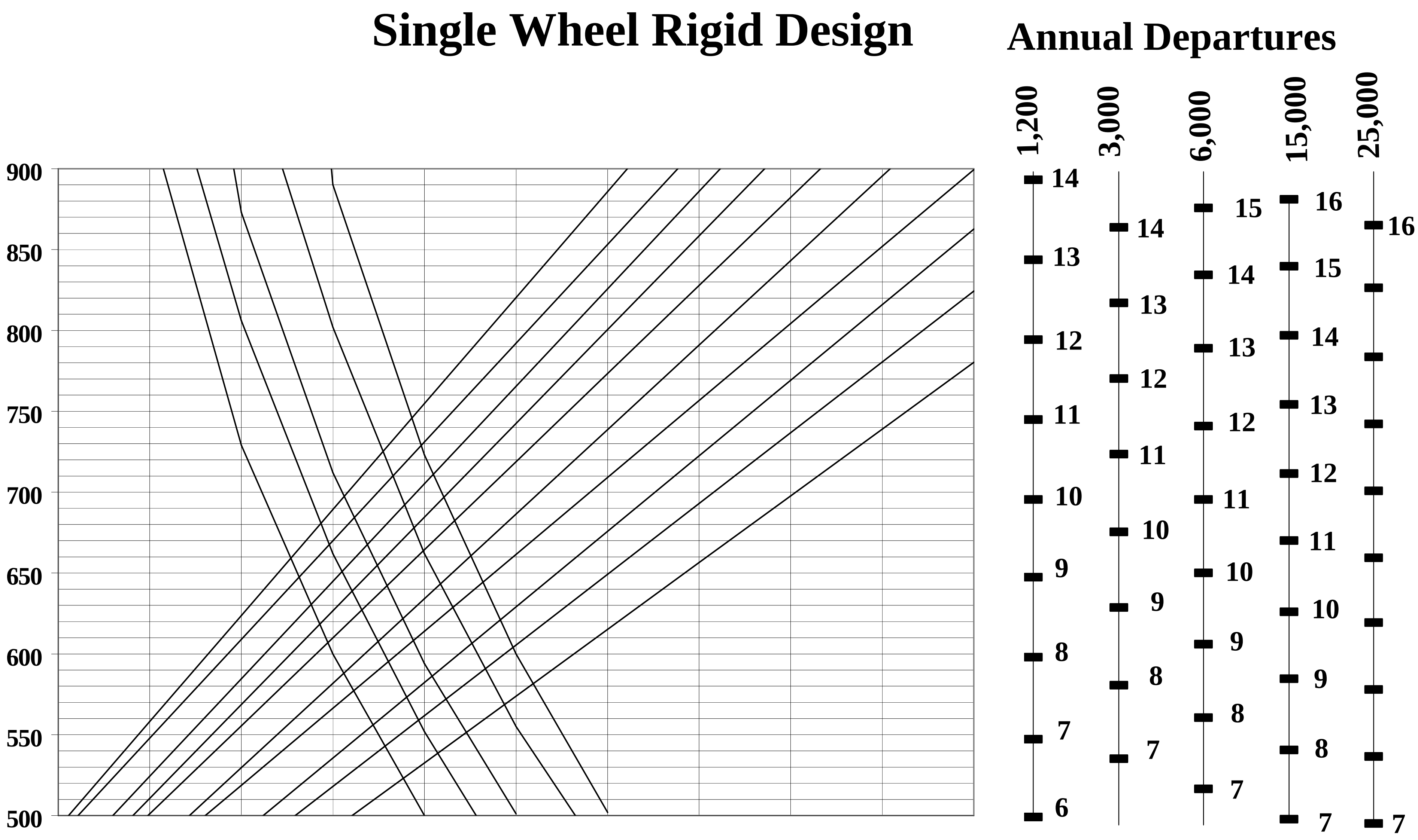
15" Thick Panels sized by Radius of Relative Stiffness



Rigid Pavement Design

Design Steps 150/5320-6D

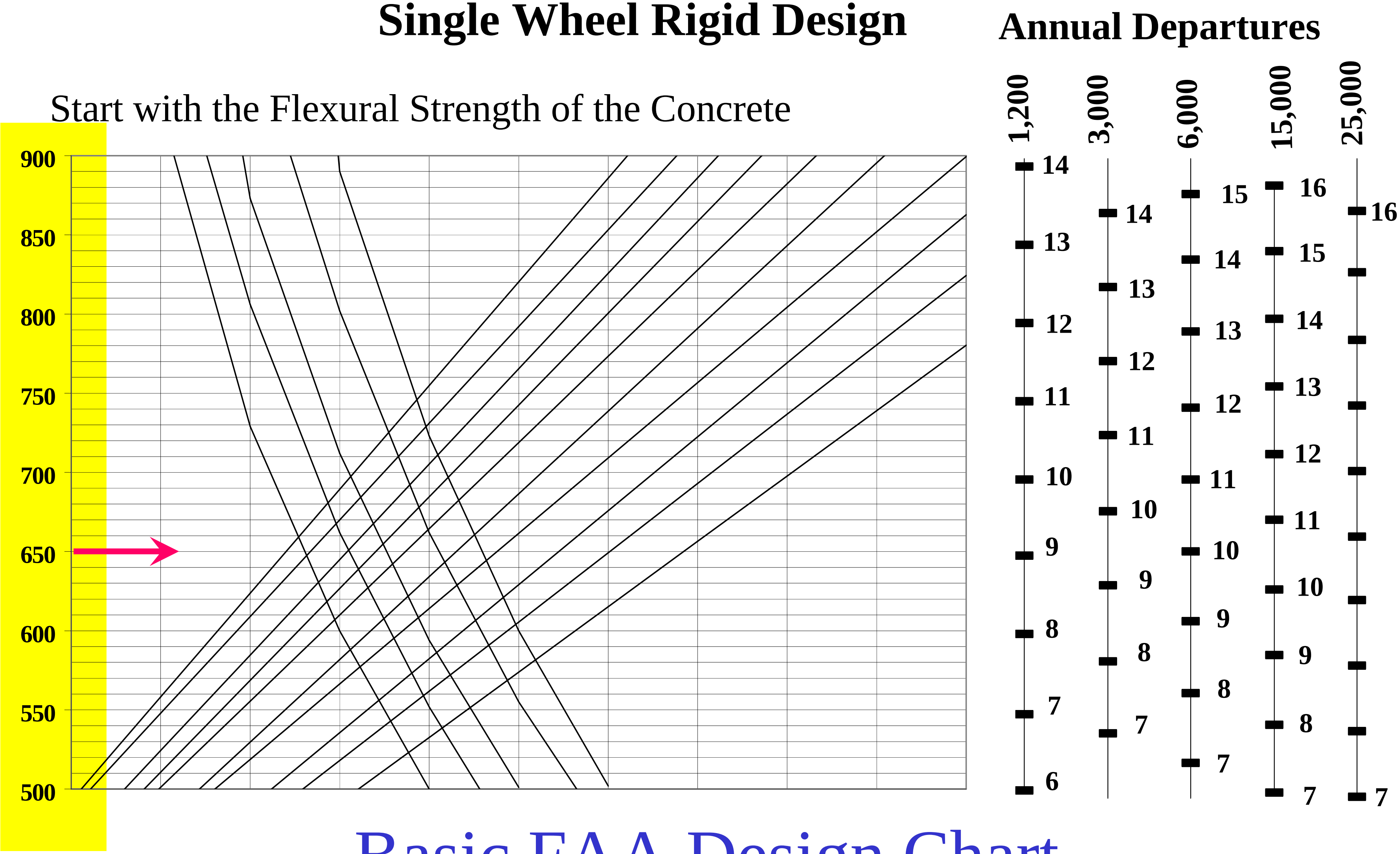
- Determine PCC Flexural Strength
  - Strength when traffic permitted
- Determine Subgrade Support
  - k-value
- Determine Design Aircraft
  - Determine Critical Aircraft
  - Determine Equivalent Annual Departures
- Determine PCC Thickness



Basic FAA Design Chart

Single Wheel Rigid Design

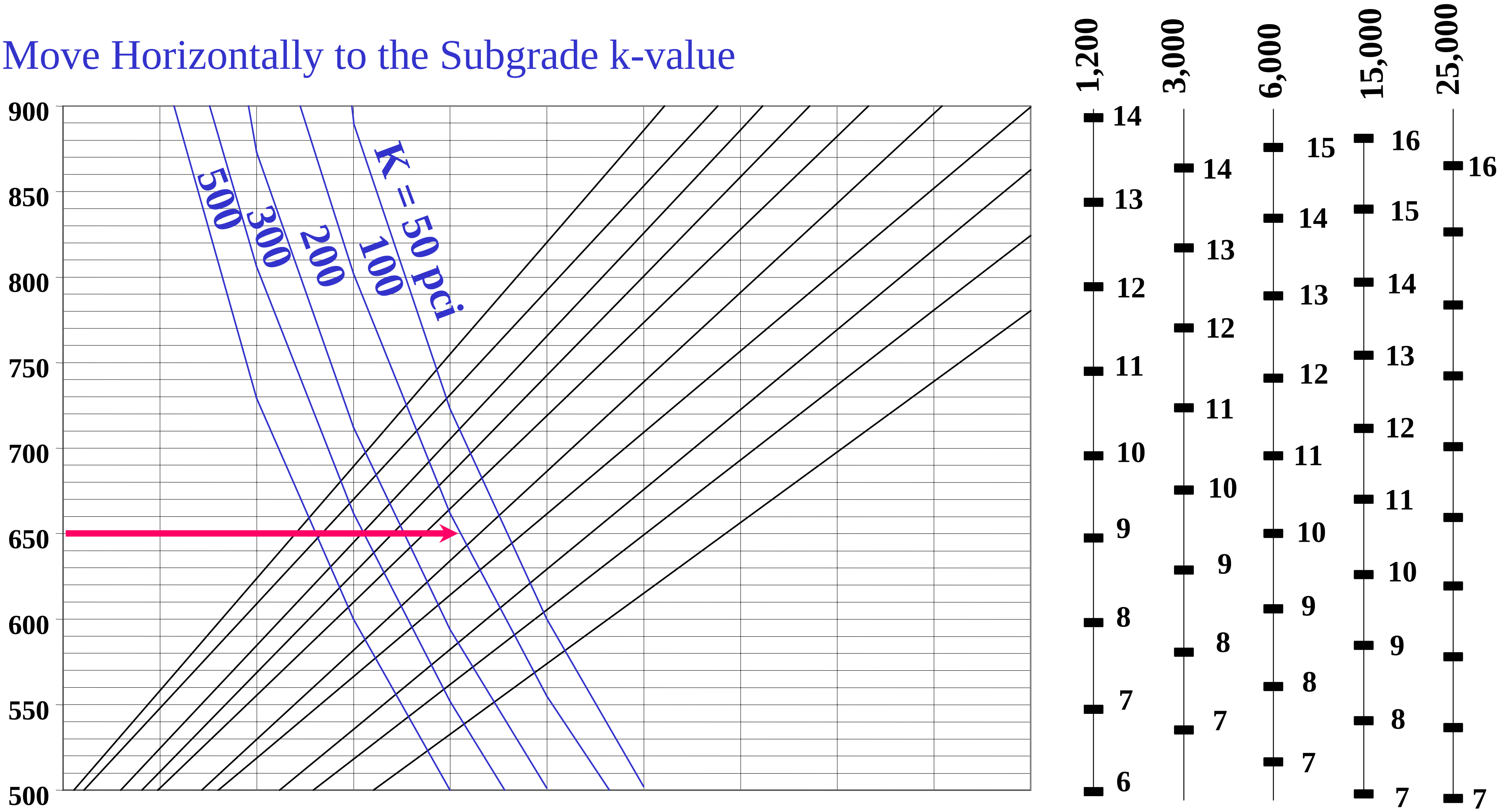
Start with the Flexural Strength of the Concrete



Basic FAA Design Chart

Single Wheel Rigid Design

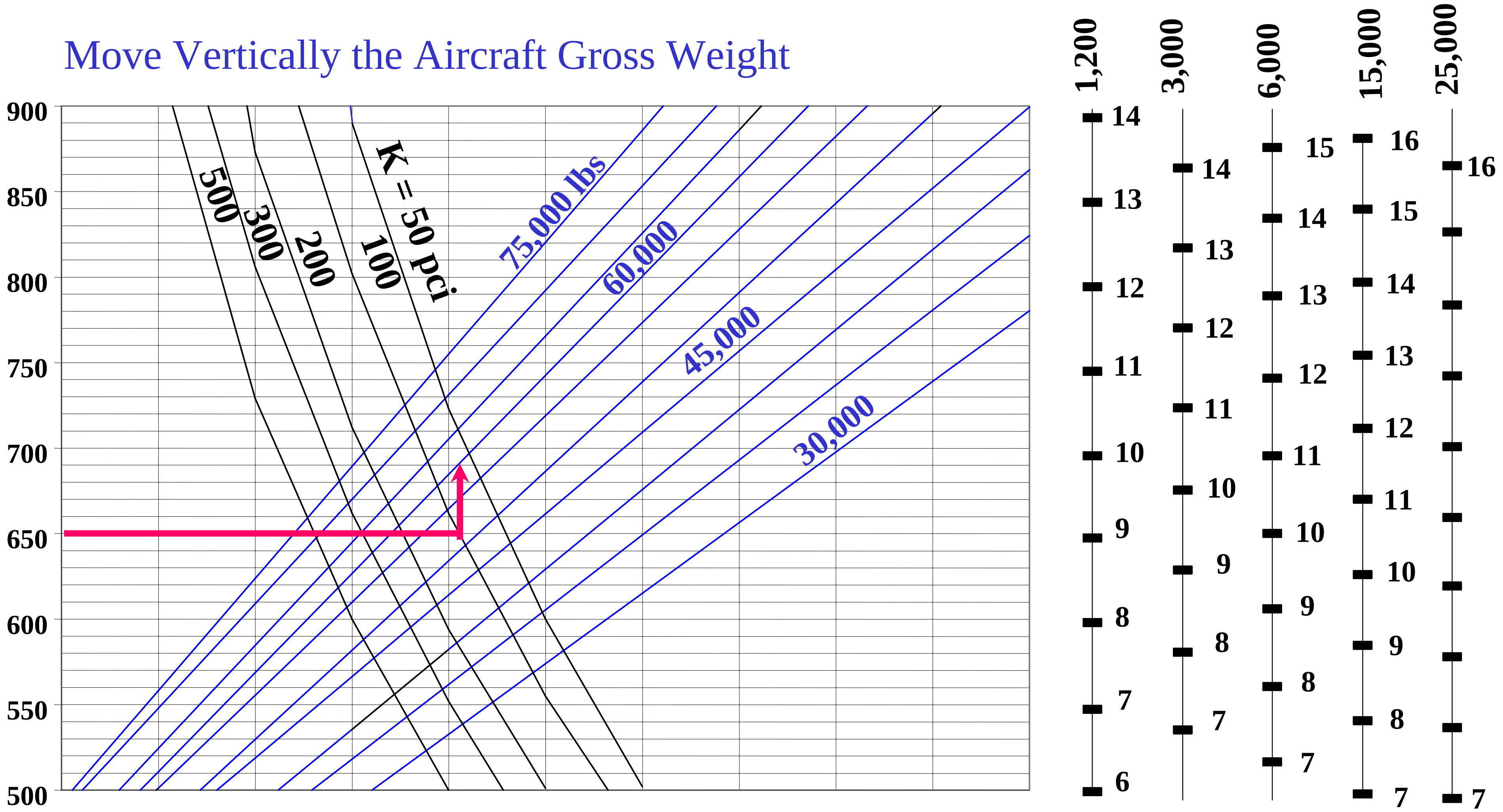
Move Horizontally to the Subgrade k-value



Basic FAA Design Chart

Single Wheel Rigid Design

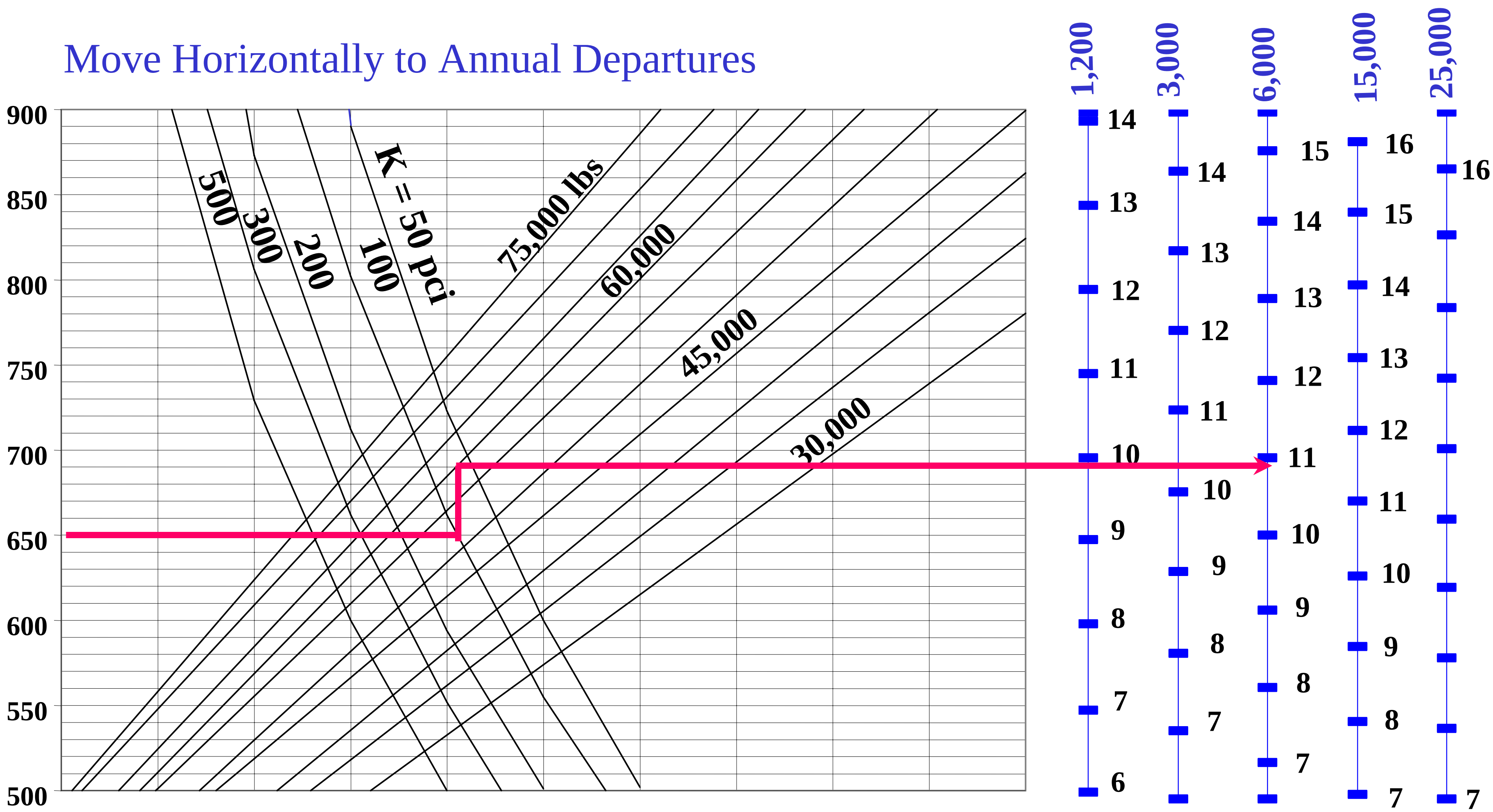
Move Vertically the Aircraft Gross Weight



Basic FAA Design Chart

Single Wheel Rigid Design

Move Horizontally to Annual Departures



Basic FAA Design Chart

Design Example
Determine Design Aircraft

- Single Wheel Aircraft
  - 60,000 Pound Gross Load
  - 6,000 Annual Departures

AND

- Dual Wheel Aircraft
  - 120,000 lbs
  - 3000 Annual Departures

Design Example
Determine Design Aircraft

- How are we going to select a concrete strength for design purposes?

Design Example
Determine Subgrade Support value

- How do you determine the subgrade support value?

  K-value ?

Design Example
Determine Subgrade Support Value

- Recognize this equipment?

Design Example
Determine Design Aircraft

Geotech report provided 12 CBR Points

3.1, 4.8, 3.7, 3.1,

3.5, 3.8, 3.8, 3.3,

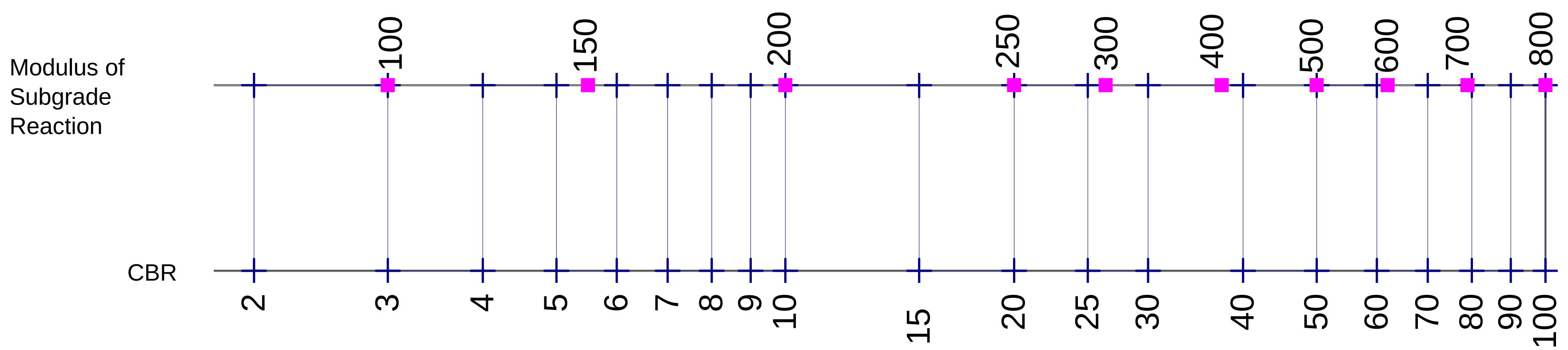
4.3, 4.0, 2.8, 4.0

5320-6D suggests using average minus one standard deviation

Average	3.53
Standard Deviation	0.532
Avg- 1(Std)	3.00

Design Example
Determine Design Aircraft

- Using CBR of 3
  - Approximate Subgrade Modulus of Reaction



Correlation from PCA Engineering Bulletin – Design of Concrete Airport Pavement

Design Example
Determine Design Aircraft

First Case

- Single Wheel Aircraft
  - Concrete Flexural Strength of 650 psi
  - Subgrade k = 100 pci
    - 6” aggregate plus 6” stabilized layer
  - 60,000 Pound Gross Load
  - 6,000 Annual Departures

Design Example
Determine Design Aircraft

Subbase Requirements

Minimum 4” requirement under all pavements
Except Gravel soils and non-frost sands

Stabilized subbase required when gross aircraft weight exceeds 100,000 lbs

Design Example
Determine Design Aircraft

Effective k value

Subbase layers will improve the k-value seen by the concrete layer.

Use figure 2-4 for aggregate layers

Use figure 3-16 for stabilized materials

Figure 2-4

Bank-run Sand and Gravel PI < 6

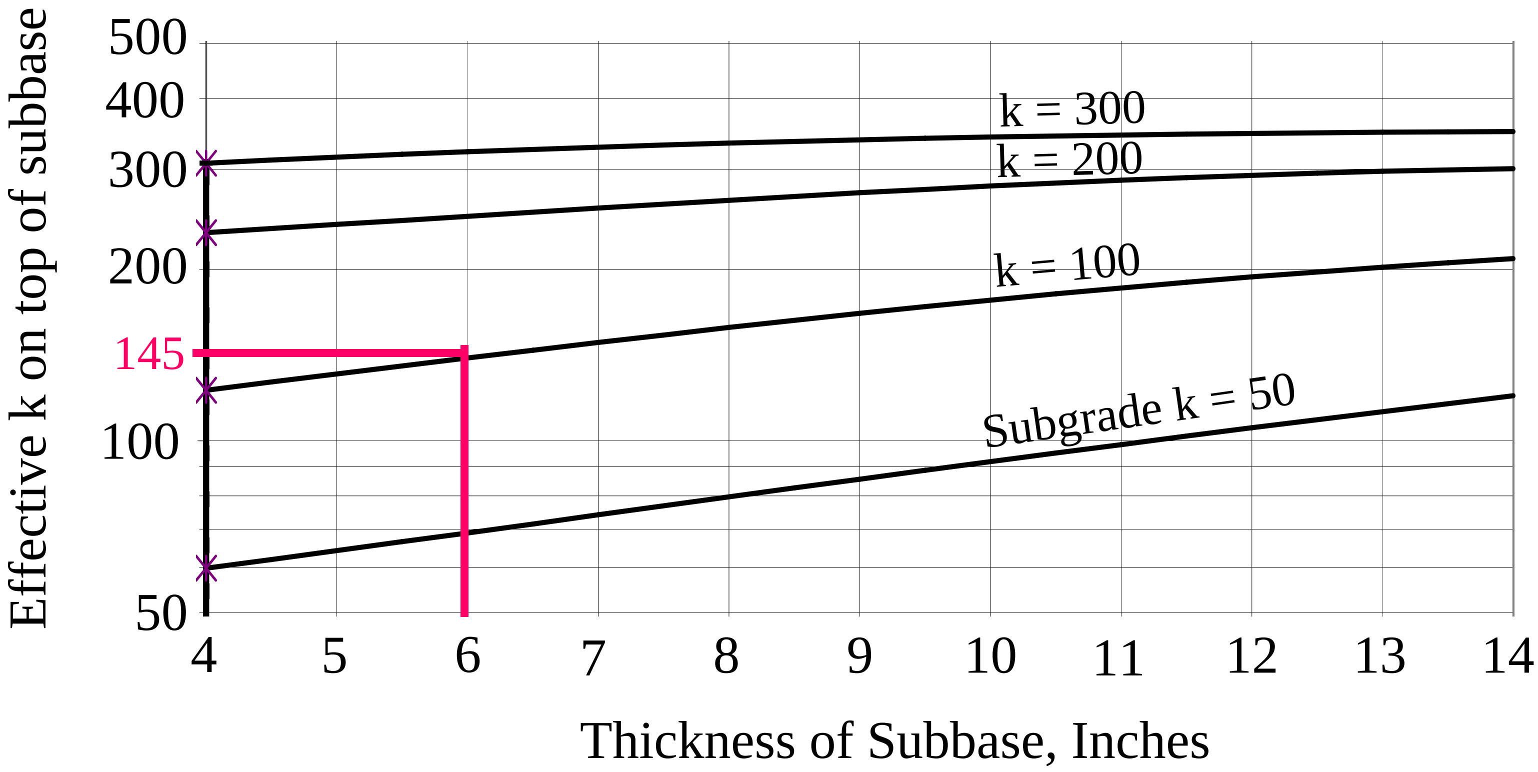


Figure 2-4

Well-Graded Crushed Aggregate

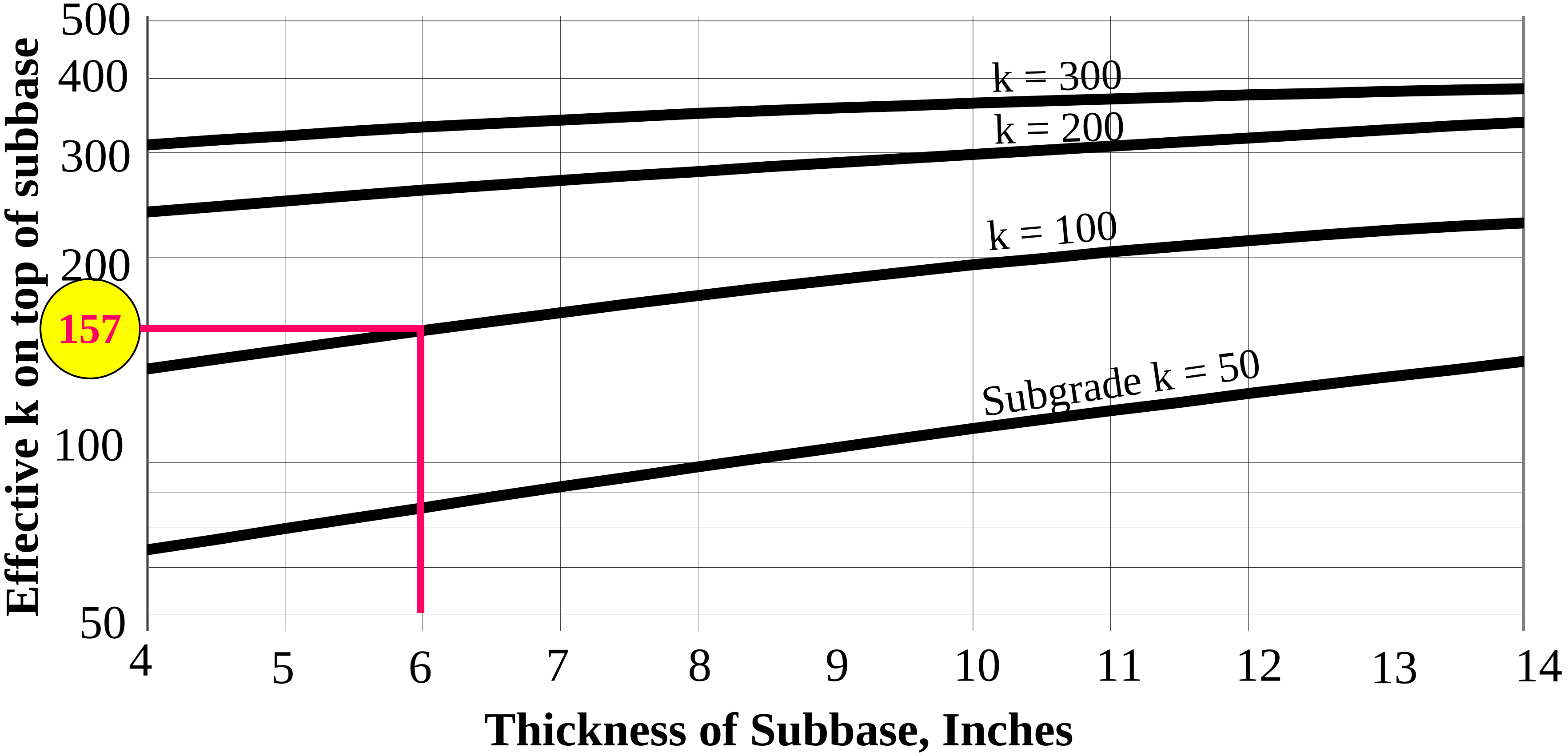
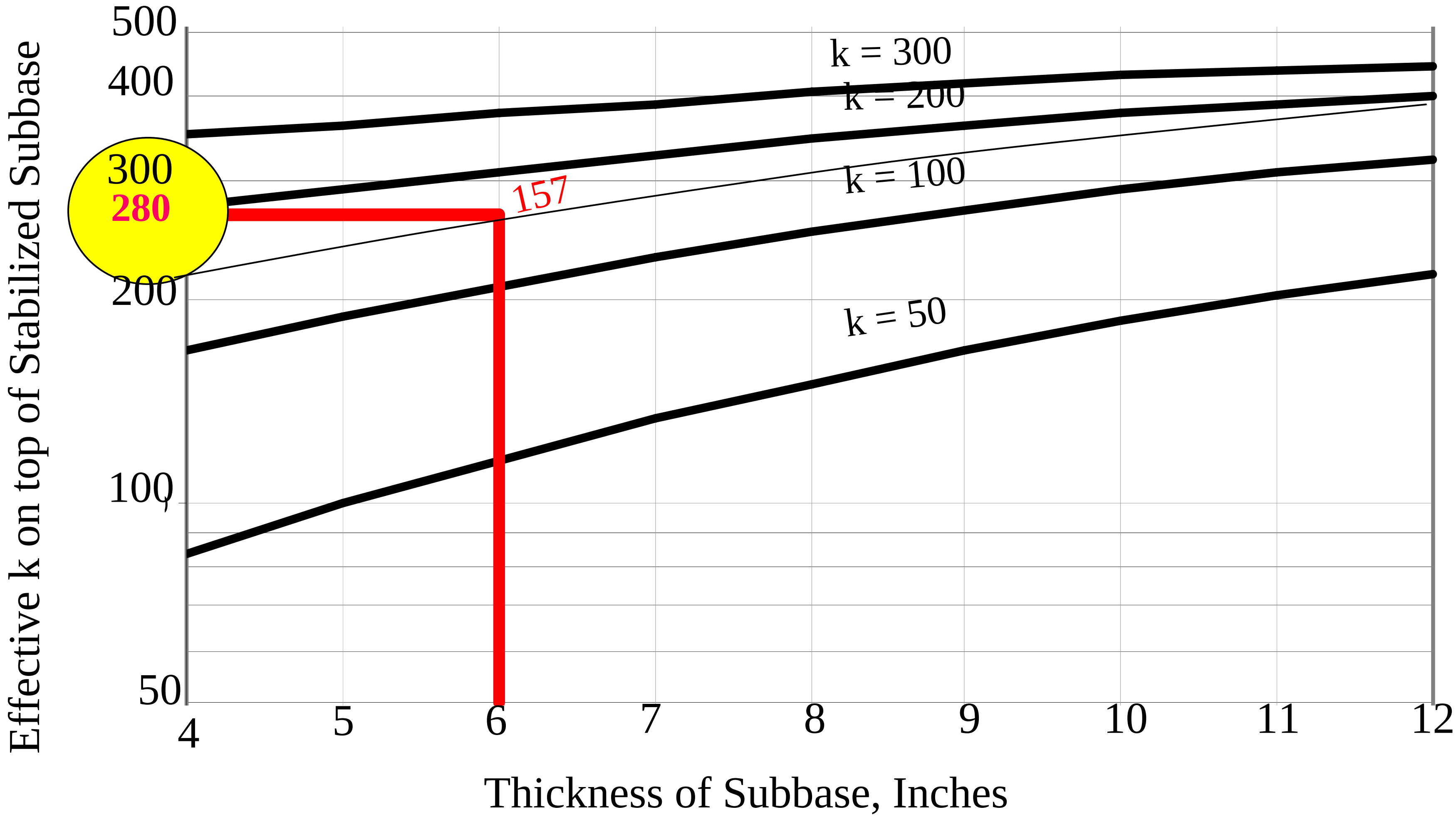
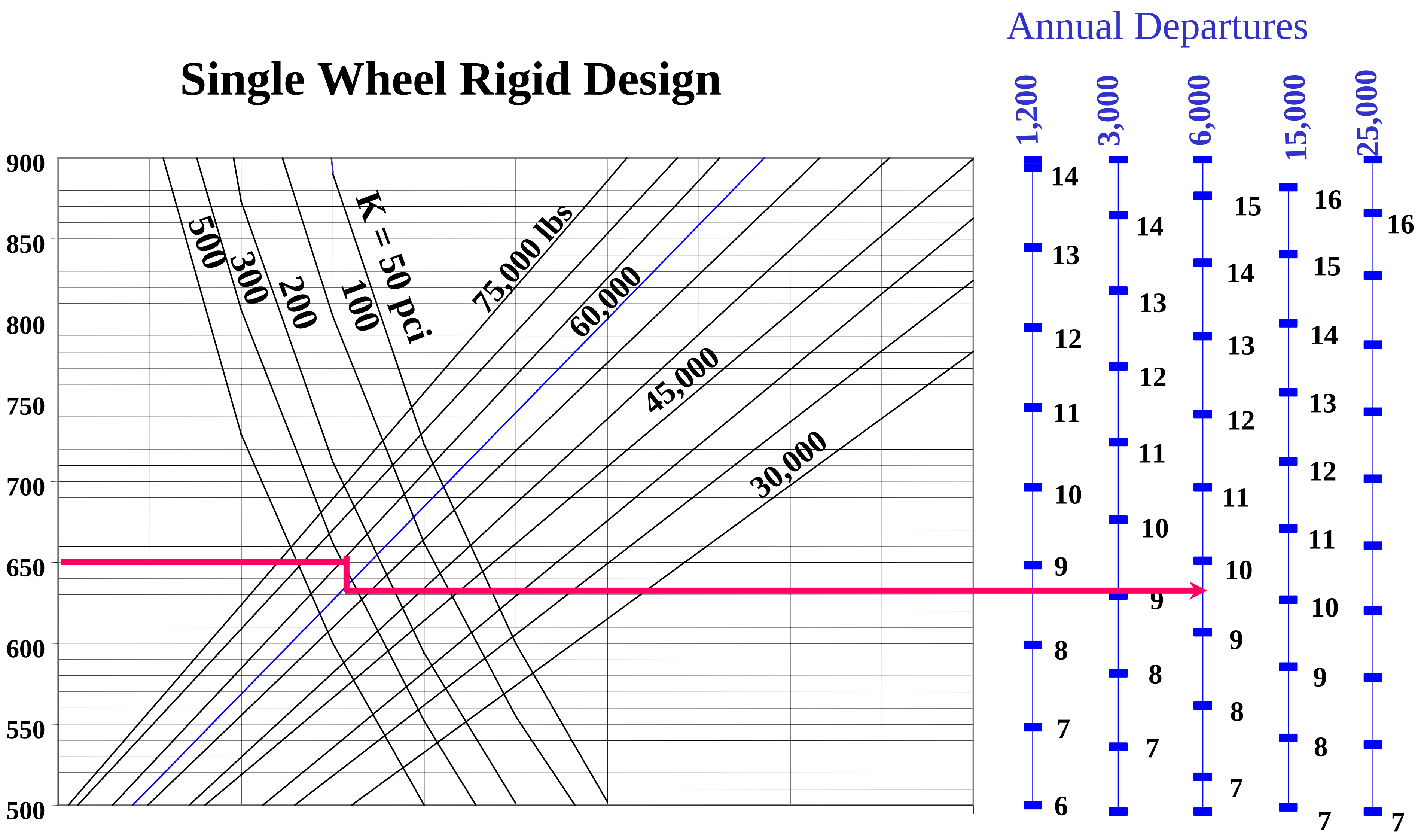


Figure 3-16 Effect of Stabilized Subbase on Subgrade Modulus



Single Wheel Rigid Design



Design Example
Determine Design Aircraft

First Case

- Single Wheel Aircraft
  - Concrete Flexural Strength of 650 psi
  - Subgrade k = 100 pci (improved k = 280)
    - 6” aggregate plus 6” stabilized layer
  - 60,000 Pound Gross Load
  - 6,000 Annual Departures

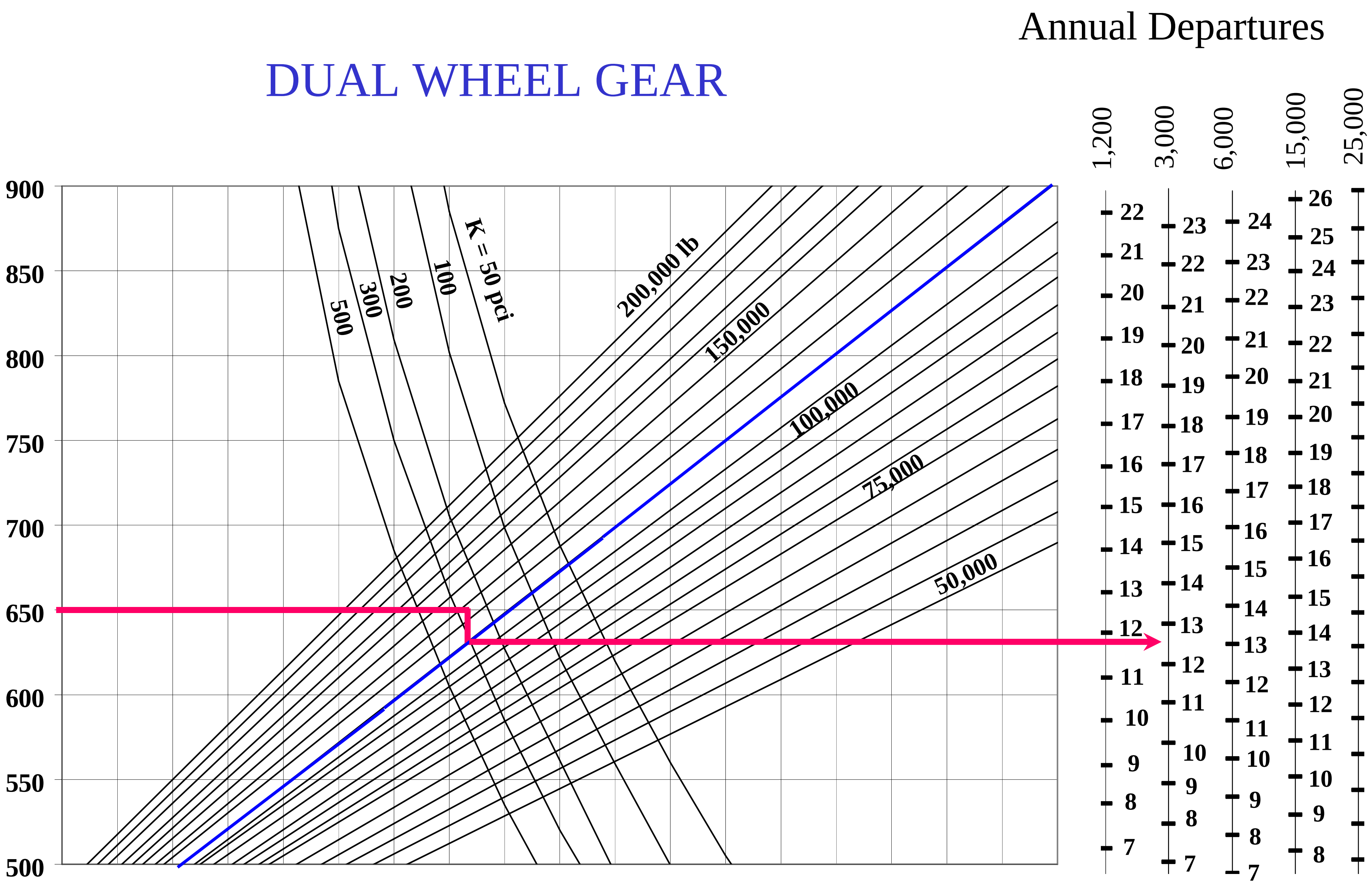
Concrete Thickness of 9.63 inches

Design Example
Determine Design Aircraft

Second Case

- Dual Wheel Aircraft
  - – Concrete Flexural Strength of 650 psi
  - – Subgrade k = 100 pci (improved k = 280)
    - 6” Aggregate plus 6” stabilized layer
    - Improved K of 280 pci
  - – 120,000 Pound Gross Load
  - – 3,000 Annual Departures

DUAL WHEEL GEAR



Design Example
Determine Design Aircraft

Second Case

- Dual Wheel Aircraft
  - Concrete Flexural Strength of 650 psi
  - Subgrade k = 100 pci
    - 6” Aggregate plus 6” stabilized layer
    - Improved K of 280 pci
  - 120,000 Pound Gross Load
  - 3,000 Annual Departures

Concrete Thickness of 12.76 inches

Design Example
Determine Design Aircraft

- Single Wheel Aircraft
  - 60,000 Pound Gross Load
  - 6,000 Annual Departures

9.63 inches

Or

- Dual Wheel Aircraft
  - 120,000 lbs
  - 3000 Annual Departures

12.76 inches

Becomes The Design Aircraft

Design Example
Convert Aircraft to Design Aircraft

To Convert From	To	Multiply Departures by
single wheel	dual wheel	0.8
single wheel	dual tandem	0.5
dual wheel	dual tandem	0.6
double dual tandem	dual tandem	1.0
dual tandem	single wheel	2.0
dual tandem	dual wheel	1.7
dual wheel	single wheel	1.3
double dual tandem	dual wheel	1.7

$$6{,}000 \times 0.8 = 4{,}800$$

Design Example
Convert Aircraft to Design Aircraft

$$\log R_1 = \log R_2 \times \left(\frac{W_2}{W_1} \right)^{1/2}$$

R_1 = equivalent annual departures by the design aircraft

R_2 = annual departures expressed in design aircraft landing gear

W_1 = wheel load of the design aircraft

W_2 = wheel load of the aircraft in question

Design Example
Convert Aircraft to Design Aircraft

Wheel Load equals 95% of gross weight divided by number of wheels

Dual wheel == 0.95 * 120,000 / 4 = 28,500

Single wheel == 0.95 * 60,000 / 2 = 28,500

Design Example
Convert Aircraft to Design Aircraft

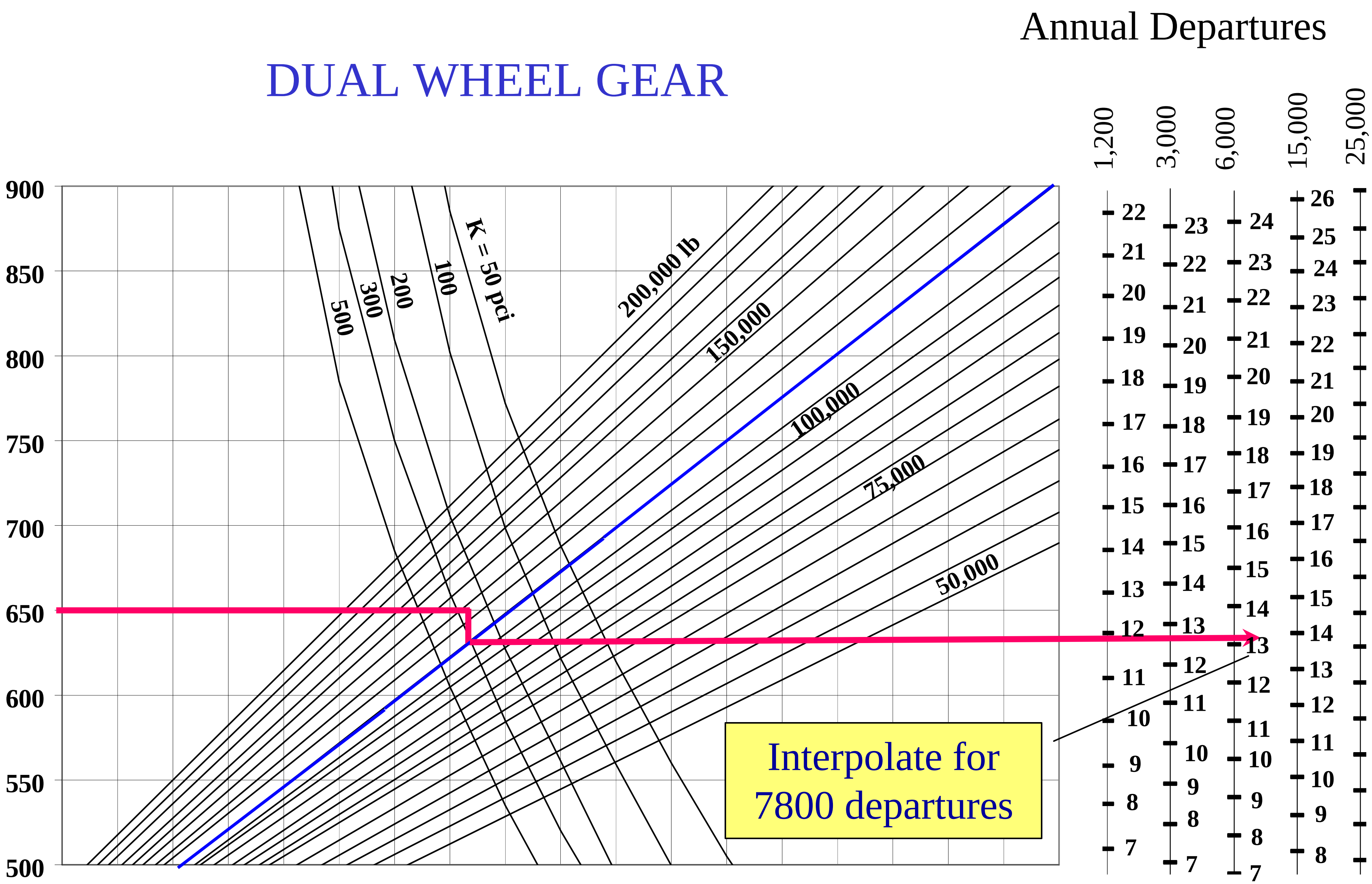
$$\log R_1 = \log 4800 \times \left(\frac{28500}{28500} \right)^{1/2}$$

R_1 = 4800 equivalent annual departures

Total Departures of Dual wheel

3000 + 4800 = 7800

Nomograph for "Design Aircraft" with equivalent annual departures



Design Example
Determine Total Thickness

Based on Dual Wheel Design Aircraft

120,000 lbs

7800 equivalent annual departures

k=100

Flexural Strength = 650

Required Total Thickness = 13.5 inches

Design Example
Determine Recommended Slab size

Calculate Radius of Relative Stiffness

$$l = \left(\frac{Eh^3}{12(1-u^2)k} \right)^{\frac{1}{4}} \Rightarrow l = \left(\frac{4,000,000(13.5)^3}{12(1-0.15^2)280} \right)^{\frac{1}{4}}$$

l = 41.61 ⇒ L/l = 41.61x5 /12 = (41.61x5/12")= 17.3 feet

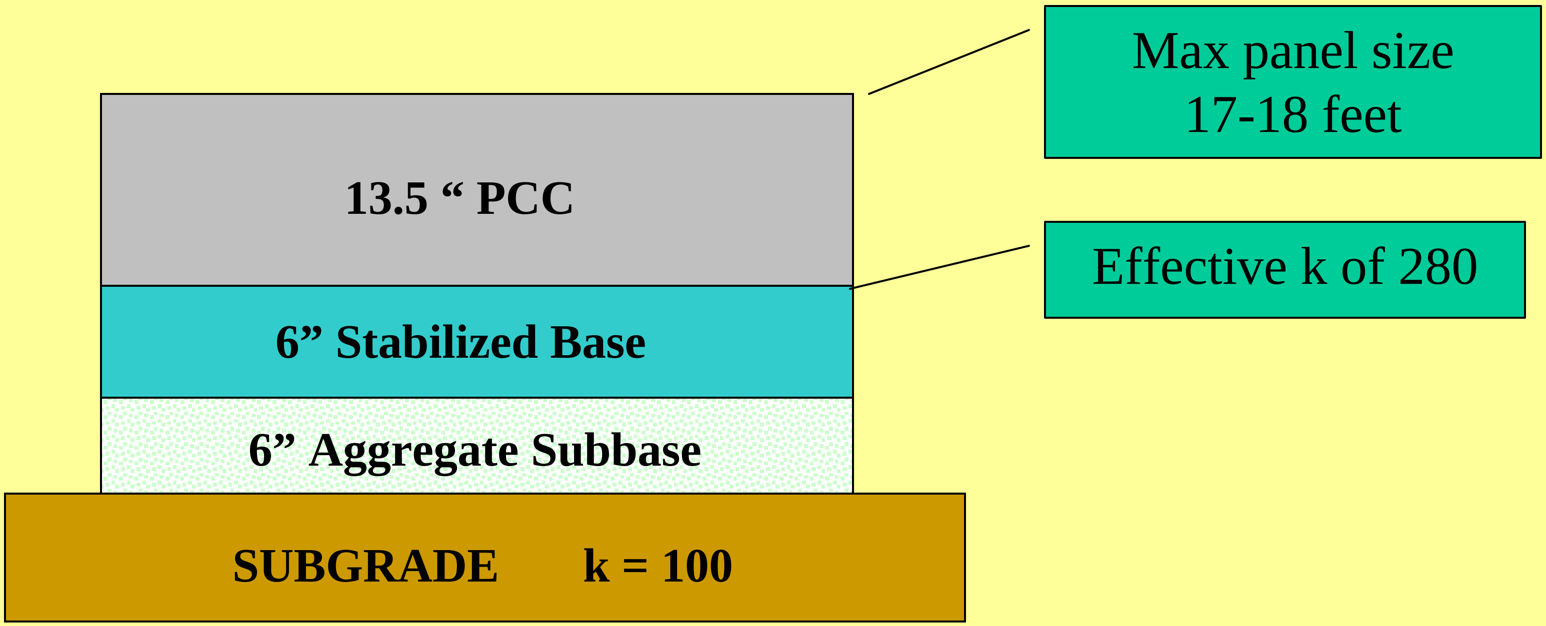
17 =>	4.9
18 =>	5.2
19 =>	5.5
20 =>	5.8

What spacing are you going to accept?

What is the pavement width?

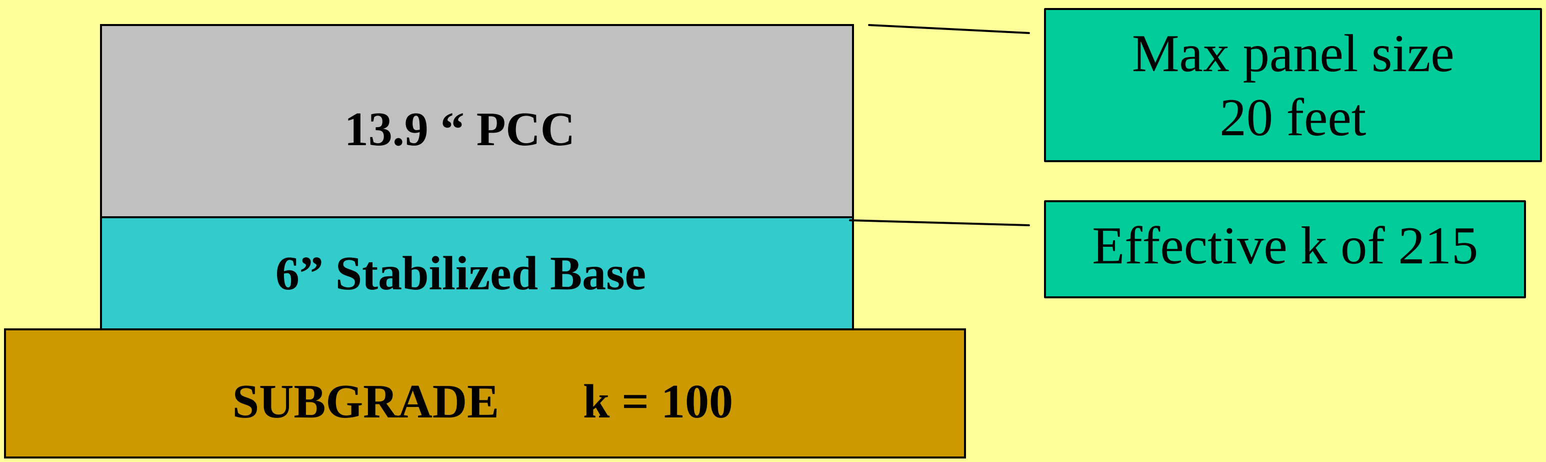
Design Example
Basic Pavement Section

Final New Pavement Section



Design Example
Basic Pavement Section

What if we dropped the 6” aggregate layer



For a 9,000 foot runway

100,000 Sq yd aggregate layer at $7.50/sy =	$750,000
Approx. 80 transverse joints = 8000 ln ft at $1.50 =	$12,000
Total Savings =	$762,000
VERSUS	
½ inch PCC = 1,388 CY at $65/cy =	$90,300
Saved approx.	$670,000

Airport Pavement Design

Airfield Pavement Design Spreadsheets

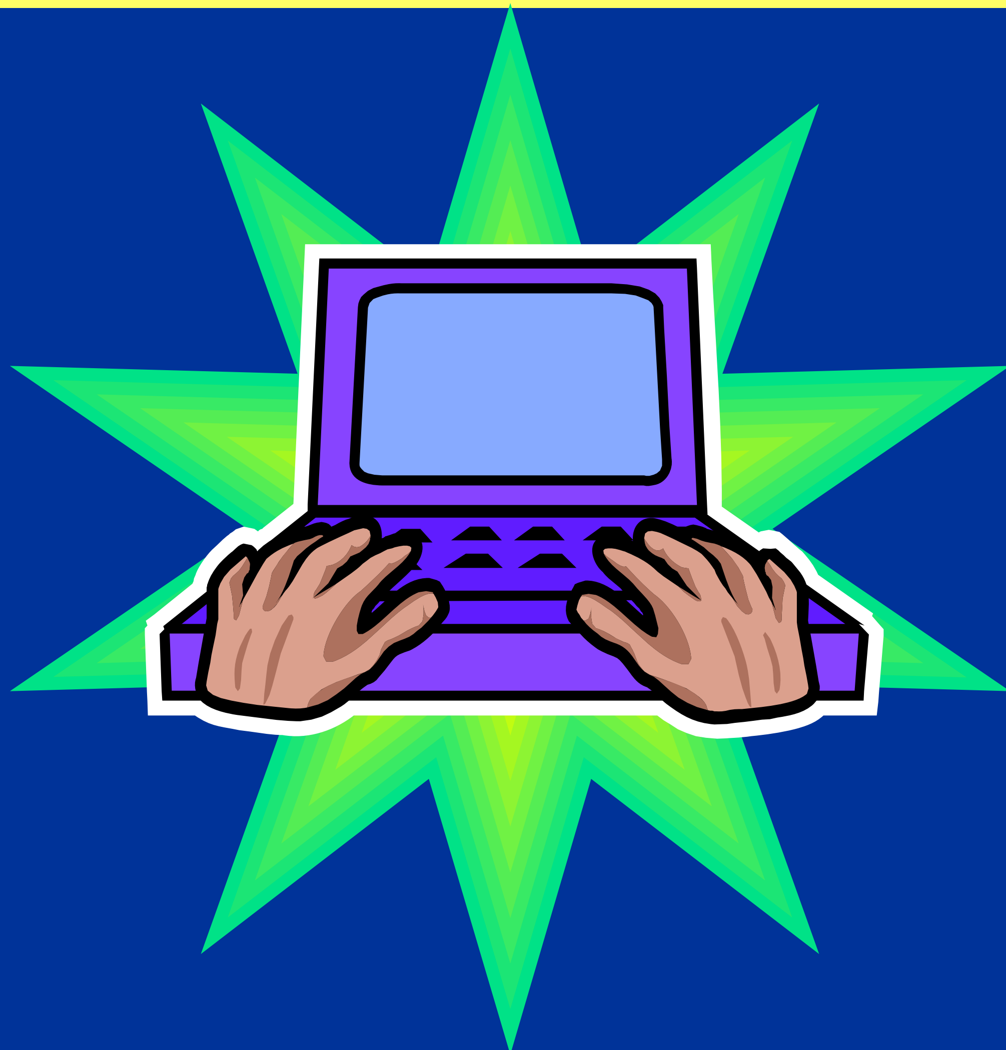
Microsoft Excel

Visual Basic macro system

Available at

http://www.faa.gov/airports_airtraffic/airports/construction/design_software/

Software Demonstration



Rigid Design

Program Date 5/09/02

Rigid Pavement Design For

AC Method

Airport Name:	Any Airport
Associated City:	Anywhere, USA
Design Firm:	Engineer's Are Us
AIP Number:	3-XX-XXX-XX

Date: today's date

Designer: Joe Engineer

New Pavement Section Required

Stabilized Subbase Is Required

13.5	PCC Thickness	650 psi	New Concrete Flexural Strength
6.0	Stabilized Base		
6.0	Subbase		
0.0	Non-Frost Layer (free draining material)		

Large Aircraft Parallel to Joints (standard design)

Overlay Sections

18.81"	Asphalt Overlay Thickness	8"	Existing Slab Thickness
9.3"	Unbonded PCC **without** leveling course	13.52"	PCC needed for existing section
11.33"	Unbonded PCC **with** leveling course	6"	Existing Stabilized Subbase
5.52"	Bonded PCC	6"	Existing Aggregate Subbase
		650 psi	Existing Slab Flexural Strength
		1	F- Factor used in design
		0.85	Cr Factor
		0.75	Cb Factor

Frost Considerations (for new pavement section)

Dry Unit Weight of Soil (lb/cf)	100
Degree Days ºF	250
Soil Frost Code	Non-Frost
Frost Depth Penetration (in)	22.53
k value on top of stabilized layer	280
k value on top of subbase layer	157
Original subgrade k value	100

Subgrade k-value was not modified for frost

Design Aircraft Information

DUAL WH-100

120000 lbs	Gross Aircraft Weight
7,800	Equivalent Annual Departures

20 Design Life (years)

Rigid Design

New Pavement Thickness Requirements

New Pavement Section Required

Stabilized Subbase Is Required

13.5	PCC Thickness	650 psi	New Concrete Flexural Strength
6.0	Stabilized Base		
6.0	Subbase		
0.0	Non-Frost Layer (free draining material)		

Large Aircraft Parallel to Joints (standard design)

Program Date 5/09/02

Rigid Pavement Design For

AC Method

Airport Name: Any Airport

Date: today's date

Associated City: Anywhere, USA

Design Firm: Engineer's Are Us

Designer: Joe Engineer

AIP Number: 3-XX-XXX-XX

New Pavement Section Required

Stabilized Subbase Is Required

13.5	PCC Thickness	650 psi	New Concrete Flexural Strength
6.0	Stabilized Base		
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		0.85	Cr Factor
		0.75	Cb Factor

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Design Aircraft Information

DUAL WH-100

20 Design Life (years)

120000 lbs	Gross Aircraft Weight
7,800	Equivalent Annual Departures

Rigid Design

Frost and Subgrade Parameters

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Rigid Design

Frost and Subgrade Parameters

Frost Considerations (for new pavement section)

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Degree Days ºF	250	
Soil Frost Code	Non-Frost	Subgrade k-value was not modified for frost
Frost Depth Penetration (in)	22.53	
k value on top of stabilized layer	280	
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Rigid Design

Frost and Subgrade Parameters

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Dry Unit Weight of Soil (lb/cf)	100
Degree Days ºF	250
Soil Frost Code	Non-Frost
Frost Depth Penetration (in)	22.53
k value on top of stabilized layer	280
k value on top of subbase layer	157
Original subgrade k value	100

NON-FROST DESIGN

Subgrade k-value was not modified for frost

Frost Considerations (for new pavement section)

Dry Unit Weight of Soil (lb/cf)	100
Degree Days ºF	250
Soil Frost Code	FG-3
Frost Depth Penetration (in)	22.53
k value on top of stabilized layer	101
k value on top of subbase layer	43
Original subgrade k value	100

FG-3 FROST DESIGN

25 Frost group k-value

Program Date 5/09/02

Rigid Pavement Design For

AC Method

Airport Name:	Any Airport	Date:	today's date
Associated City:	Anywhere, USA		
Design Firm:	Engineer's Are Us	Designer:	Joe Engineer
AIP Number:	3-XX-XXX-XX		

New Pavement Section Required

Stabilized Subbase Is Required

13.5	PCC Thickness	650 psi	New Concrete Flexural Strength
6.0	Stabilized Base		
6.0	Subbase		
0.0	Non-Frost Layer (free draining material)		

Large Aircraft Parallel to Joints (standard design)

Overlay Sections

18.81"	Asphalt Overlay Thickness	8"	Existing Slab Thickness
9.3"	Unbonded PCC **without** leveling course	13.52"	PCC needed for existing section
11.33"	Unbonded PCC **with** leveling course	6"	Existing Stabilized Subbase
5.52"	Bonded PCC	6"	Existing Aggregate Subbase
		650 psi	Existing Slab Flexural Strength
		1	F- Factor used in design
		0.85	Cr Factor
		0.75	Cb Factor

Frost Considerations (for new pavement section)

Dry Unit Weight of Soil (lb/cf)	100
Degree Days ºF	250
Soil Frost Code	Non-Frost
Frost Depth Penetration (in)	22.53
k value on top of stabilized layer	280
k value on top of subbase layer	157
Original subgrade k value	100

Subgrade k-value was not modified for frost

Design Aircraft Information

DUAL WH-100

20 Design Life (years)

120000 lbs	Gross Aircraft Weight
7,800	Equivalent Annual Departures

Rigid Design

Design Aircraft Information

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Rigid Design

Overlay Pavement Thickness Requirements

Overlay Sections

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		0.75	Cb Factor

Rigid Design

INPUT VALUES											
Design Aircraft --- /--- Additional aircraft	Widebody?	Aircraft grouping ---- Gear type AC 150/5320-6D	Max Takeoff weight MTOW	Annual Departures	Gear Type (code)	% load on main ge	MTOW used by design	Departures of equiv gear	Computed wheel Load of aircraft	Equiv. annual departures of design Aircraft
	n	DUAL WH-100	120,000	3,000	2	0.95	120,000	3,000	28,500	3,000
	n	SINGLE WH-60	60,000	6,000	1	0.95	60,000	4,800	28,500	4,800
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
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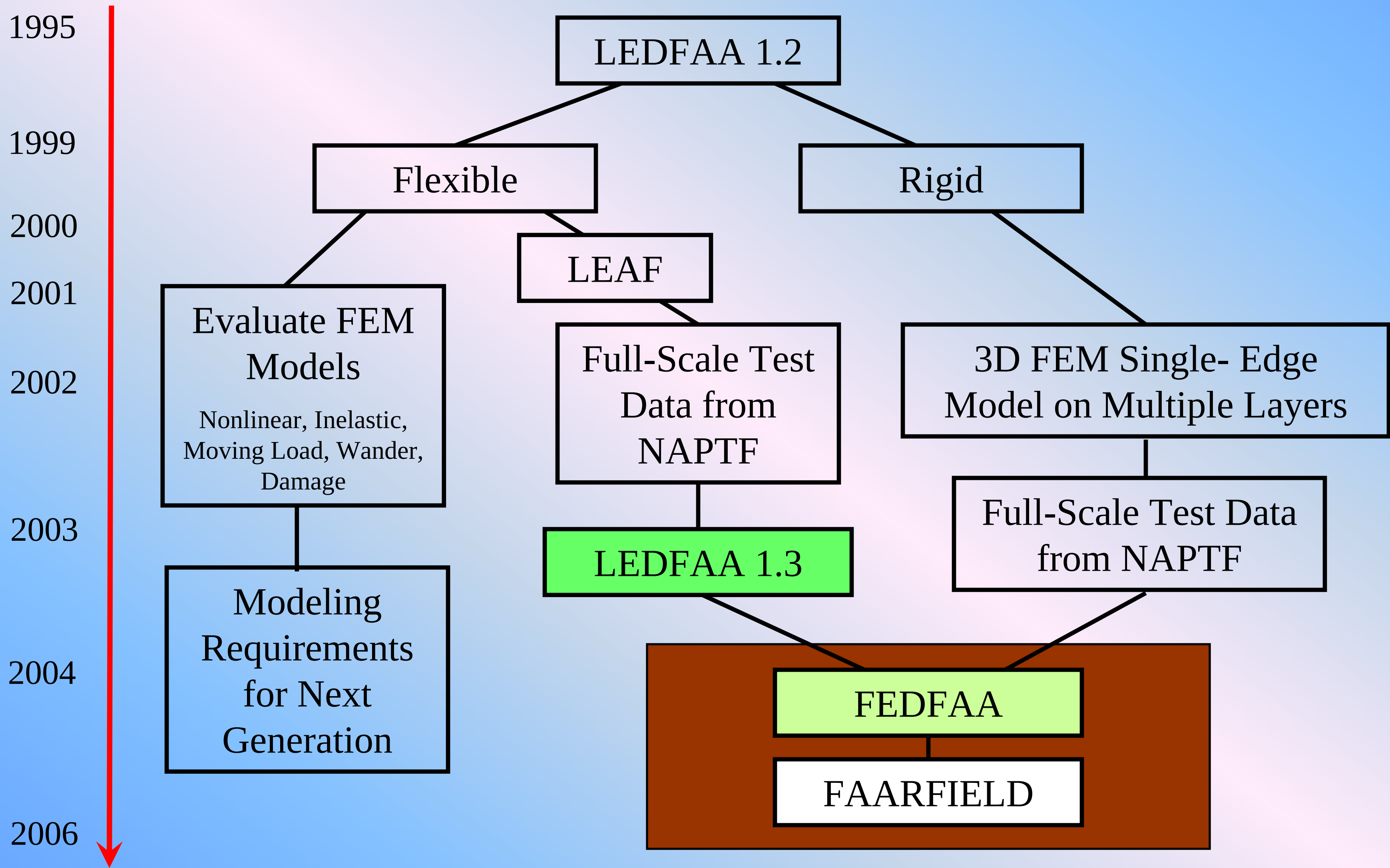
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
	n	None	0	0	0	0.00	0	0	0	0
					Equivalent Annual Departures of the DUAL WH-100					7,800

Where are we headed with Rigid Pavement Design?

Development of FAA Standards for Airport Pavement Thickness Design



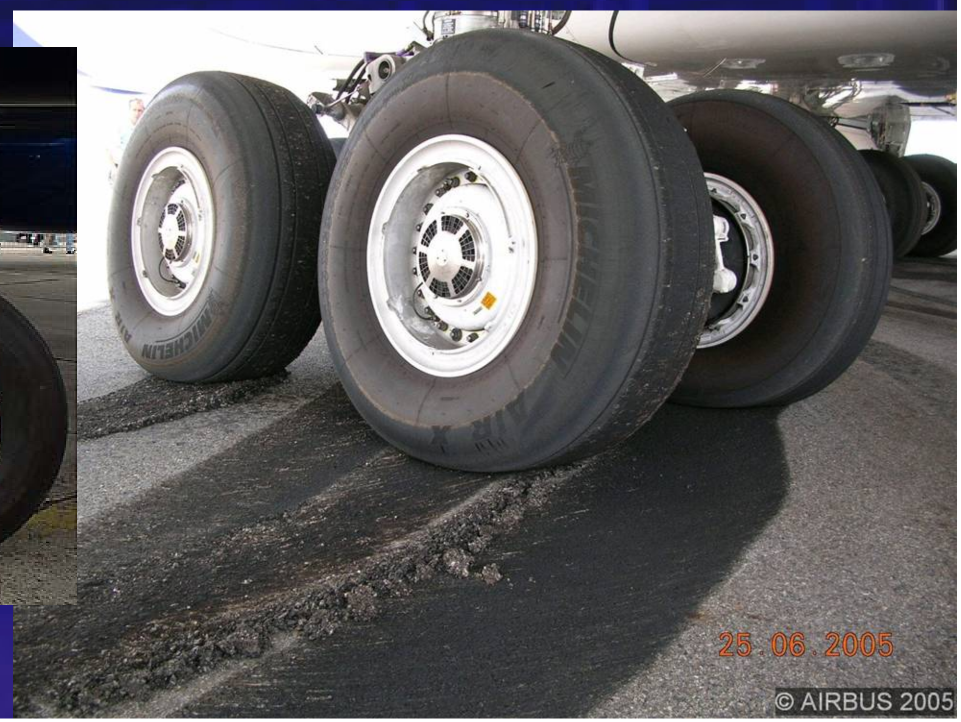
Why do we need a new pavement design procedure?

Airfield Pavement Research and Development

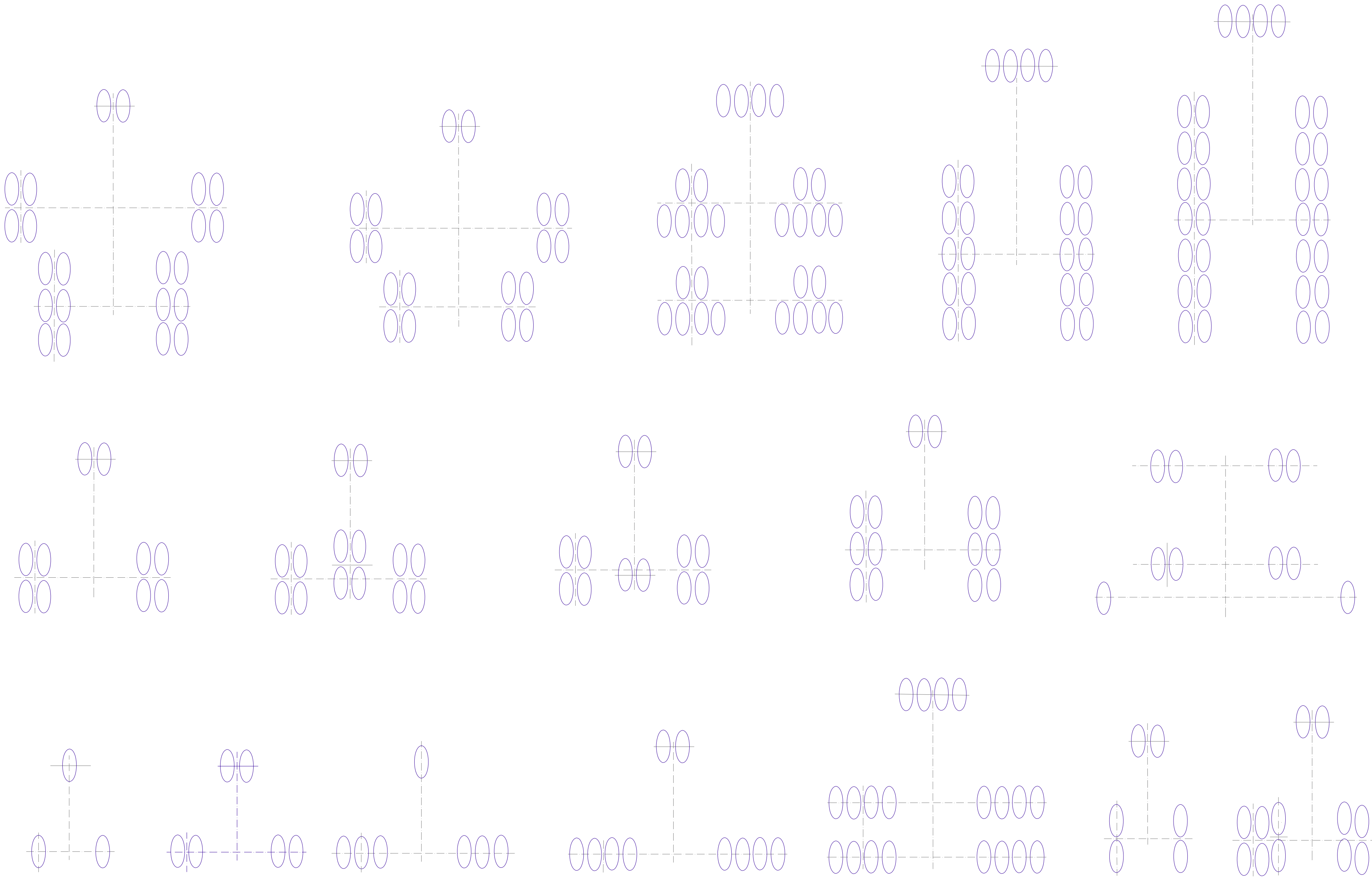
Pavement Issues with New Aircraft

New Aircraft are larger and heavier which increases the damage on airfield pavements.

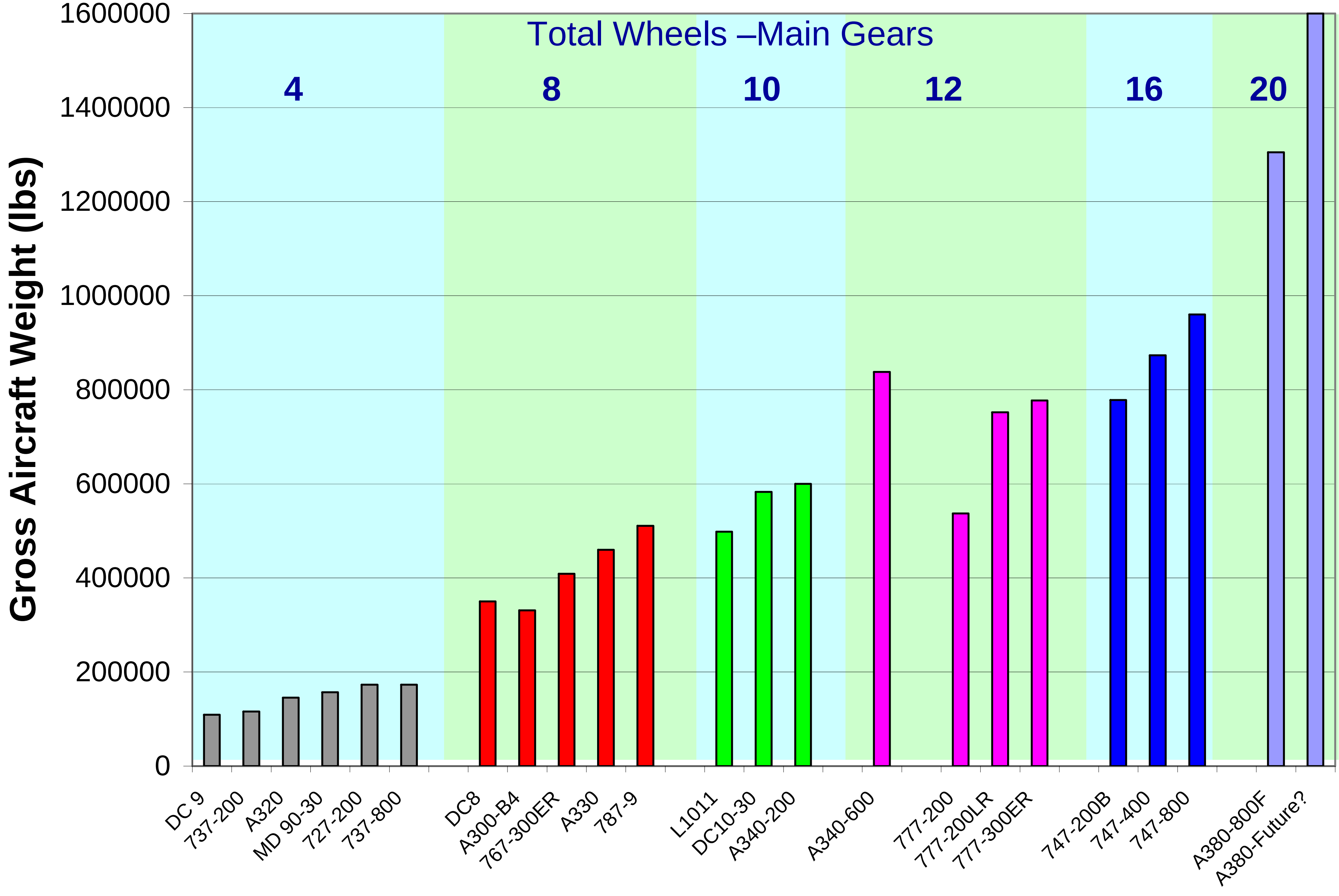
In addition to gross weight increases, aircraft manufacturers are exploring new complex gear geometries.


MICHELIN
25 06 2005
© AIRBUS 2005

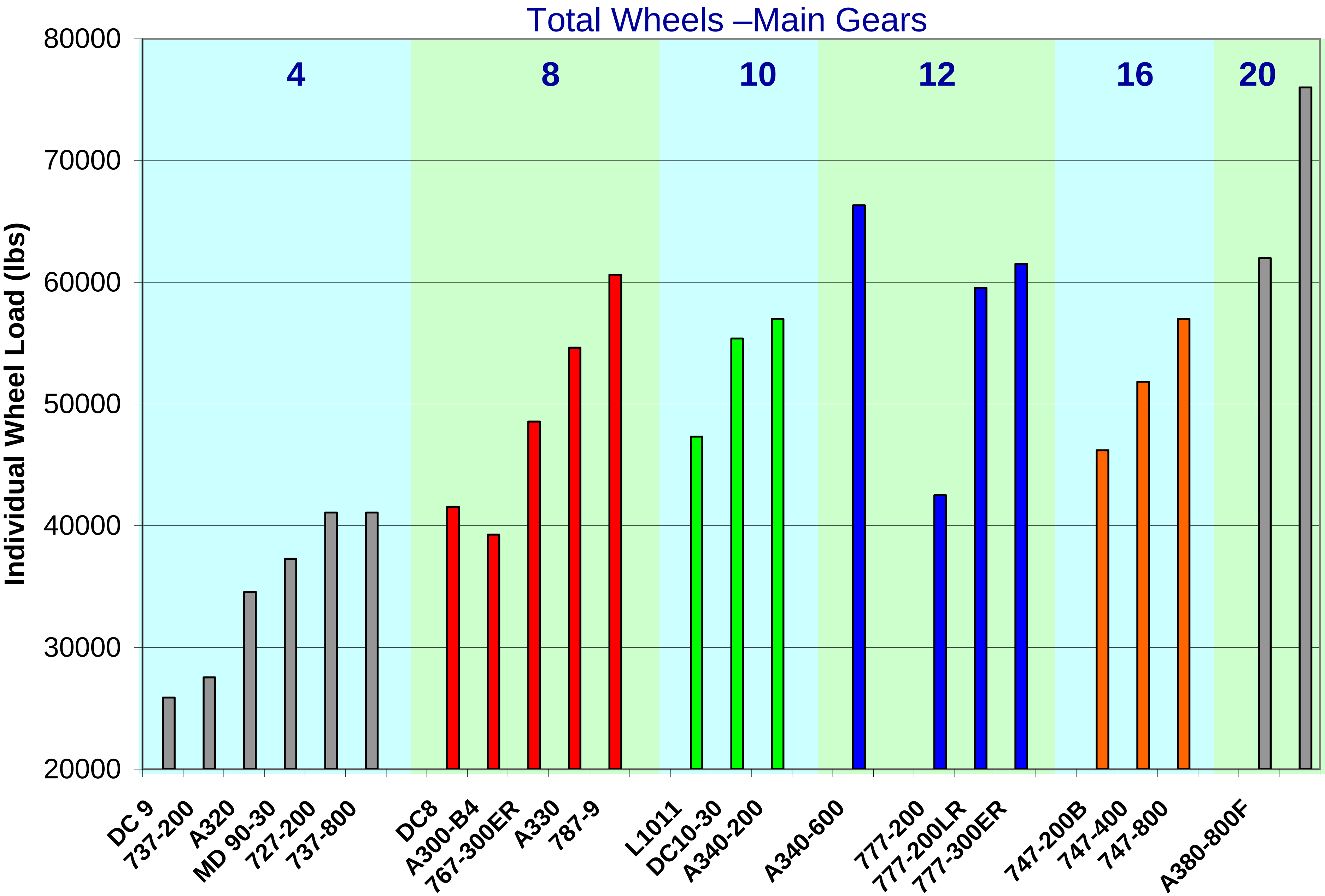
Gear Configurations



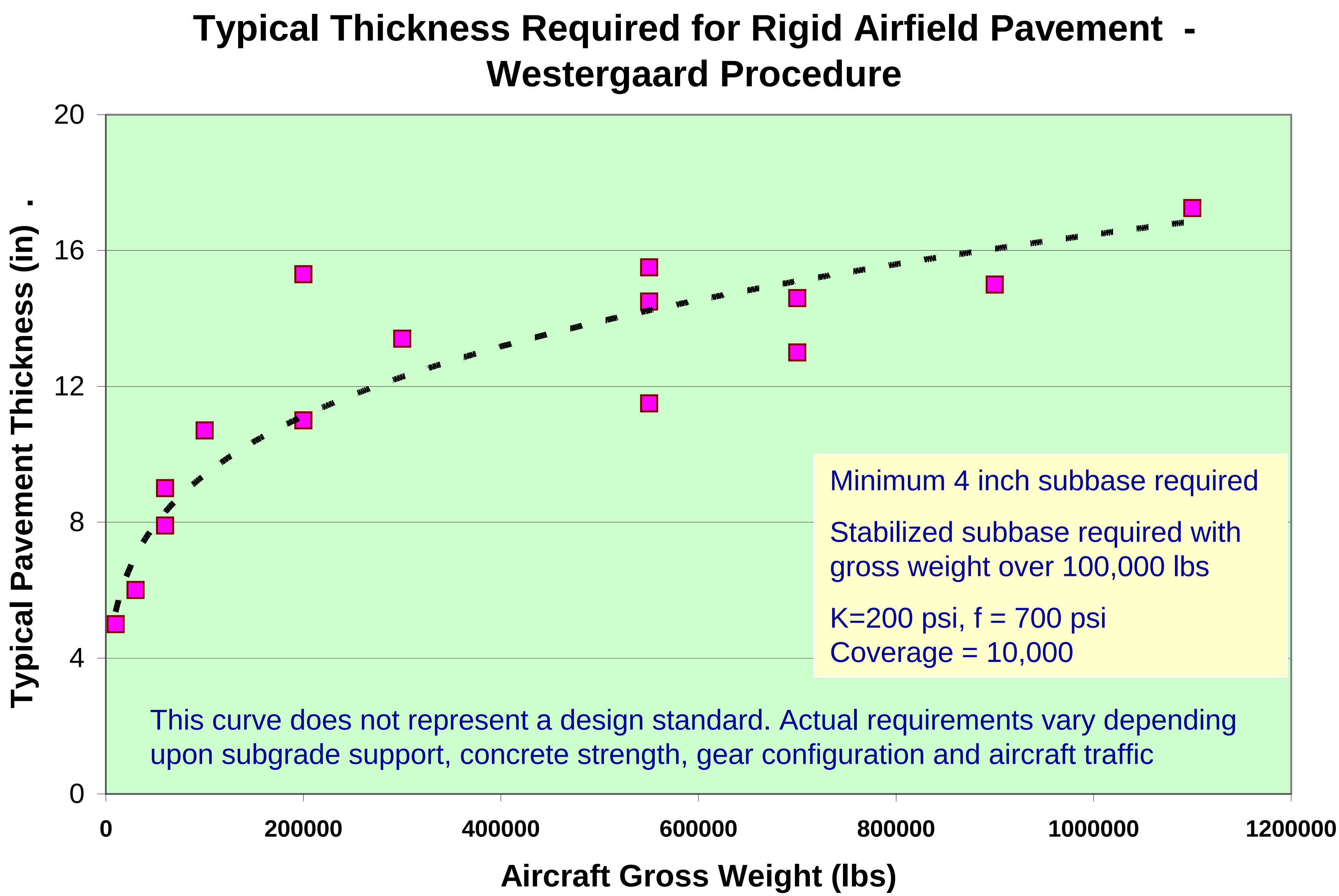
Gross Aircraft Weights



Aircraft Individual Wheel Weights



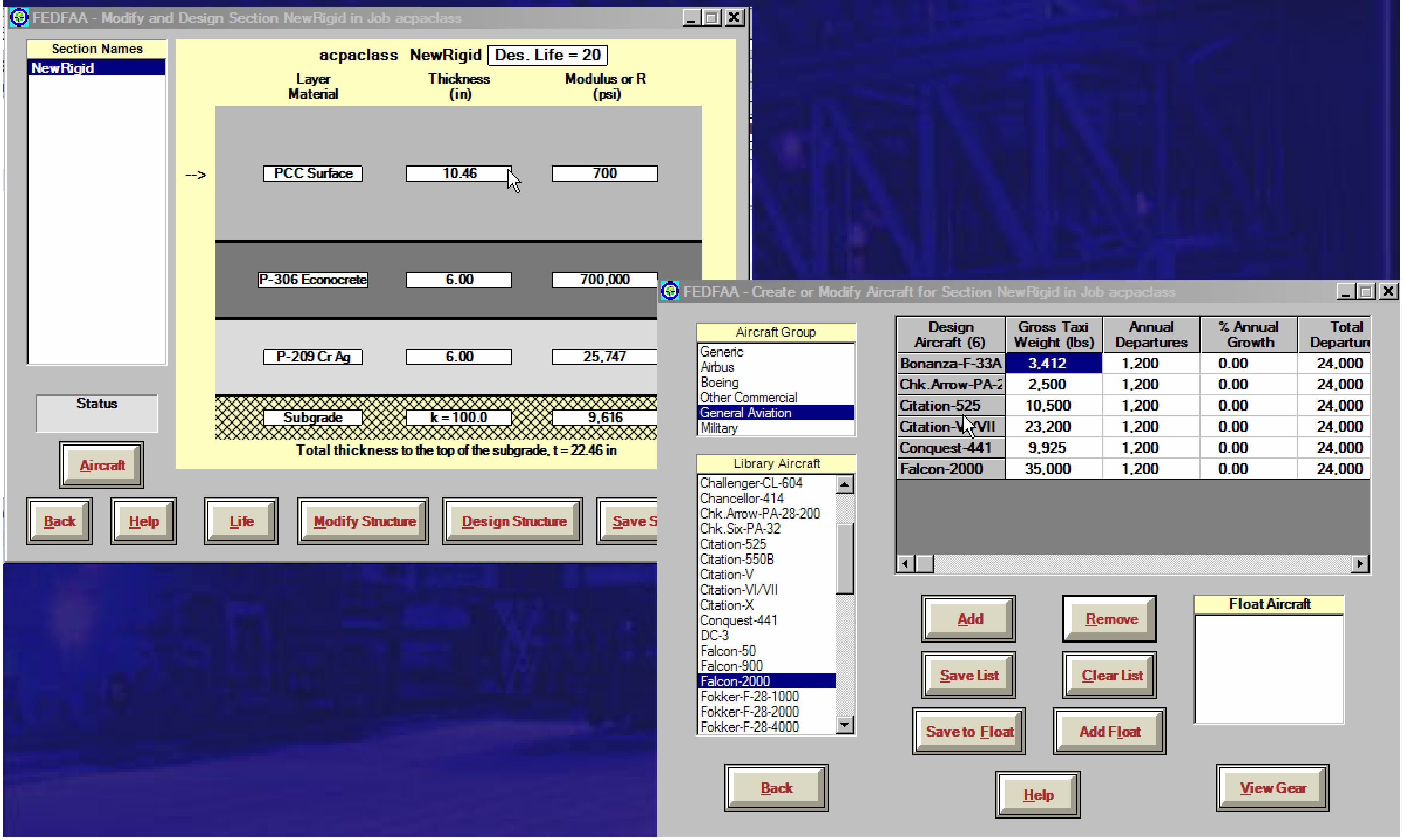
Typical Pavement Sections



FAA - Future Rigid Pavement Design

- Finite Element Procedure
- Calibrate to NAPTF and historical test results
- Available in FEDFAA 2.0 software (Feb 2006)
- Final product in FAARFIELD software (late 2006)
  - Slab edge stresses computed directly using 3D-FEM.
  - Revised rigid pavement failure model based on analysis of NAPTF CC2 and historical full-scale test data.
  - Improved rigid overlay design procedures.

FAA - Future Rigid Pavement Design



What is 3D Finite Element?

3D Finite Element is:

- A method of structural analysis.
- Applicable to a wide range of physical structures, boundary and loading conditions.

3D Finite Element is <u>not</u>:

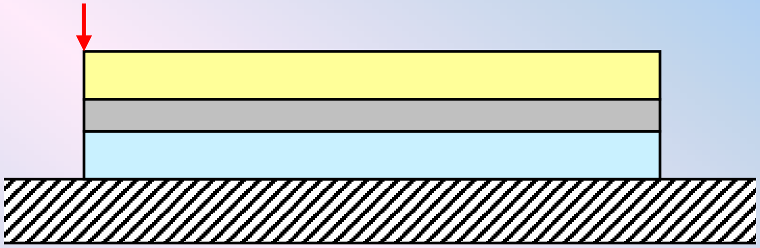
- A design method or procedure.
- An exact mathematical solution.
- Always preferable to other analysis models.

Structures and Models

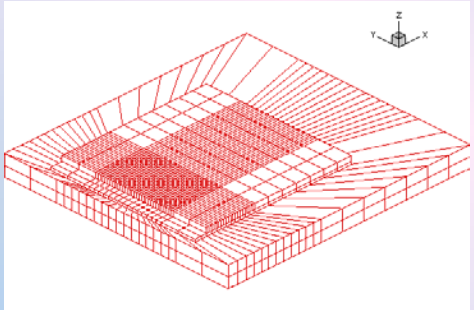
In finite element analysis, it is important to distinguish:

The physical structure

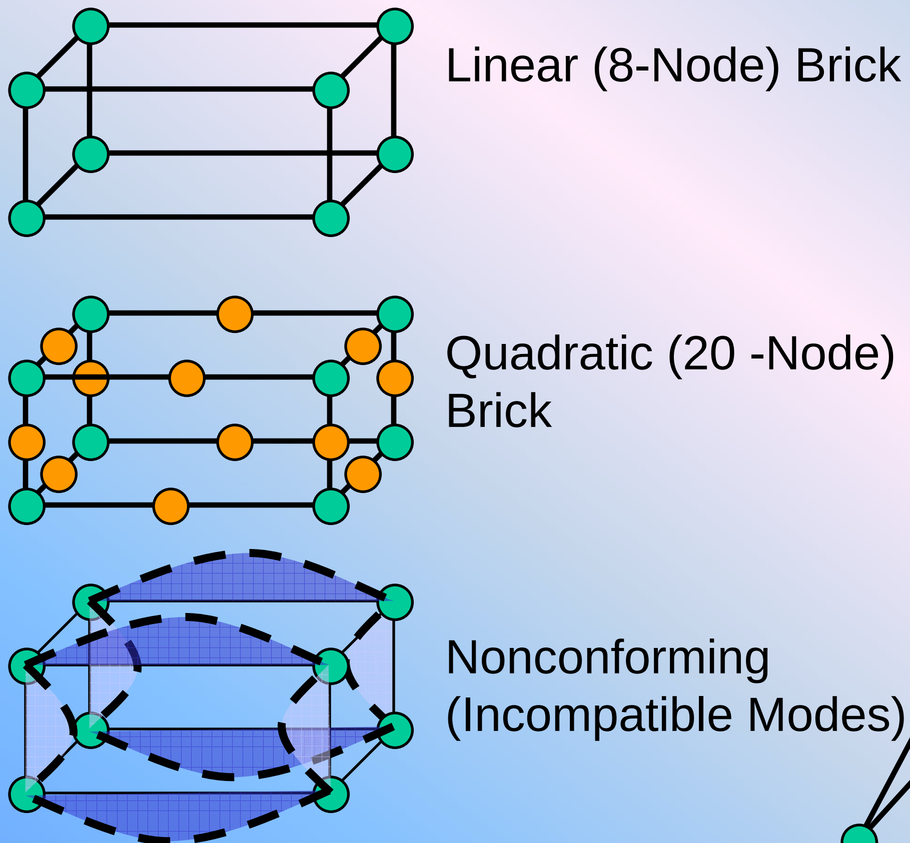
The idealized model

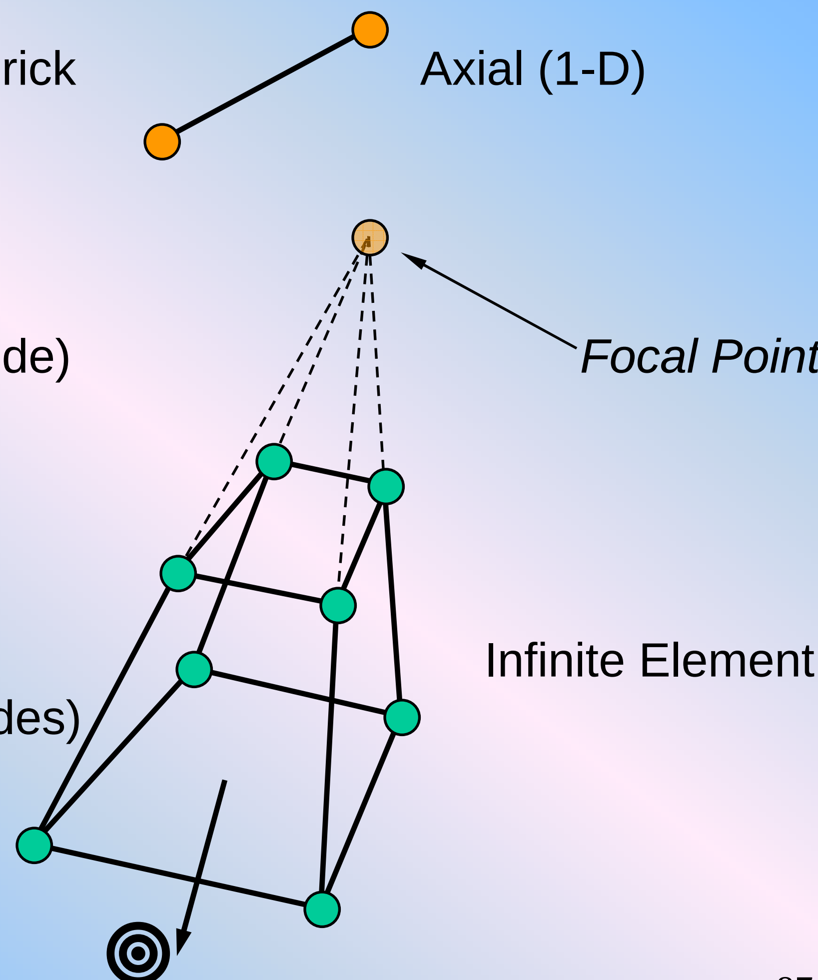


The discretized (approximate) model

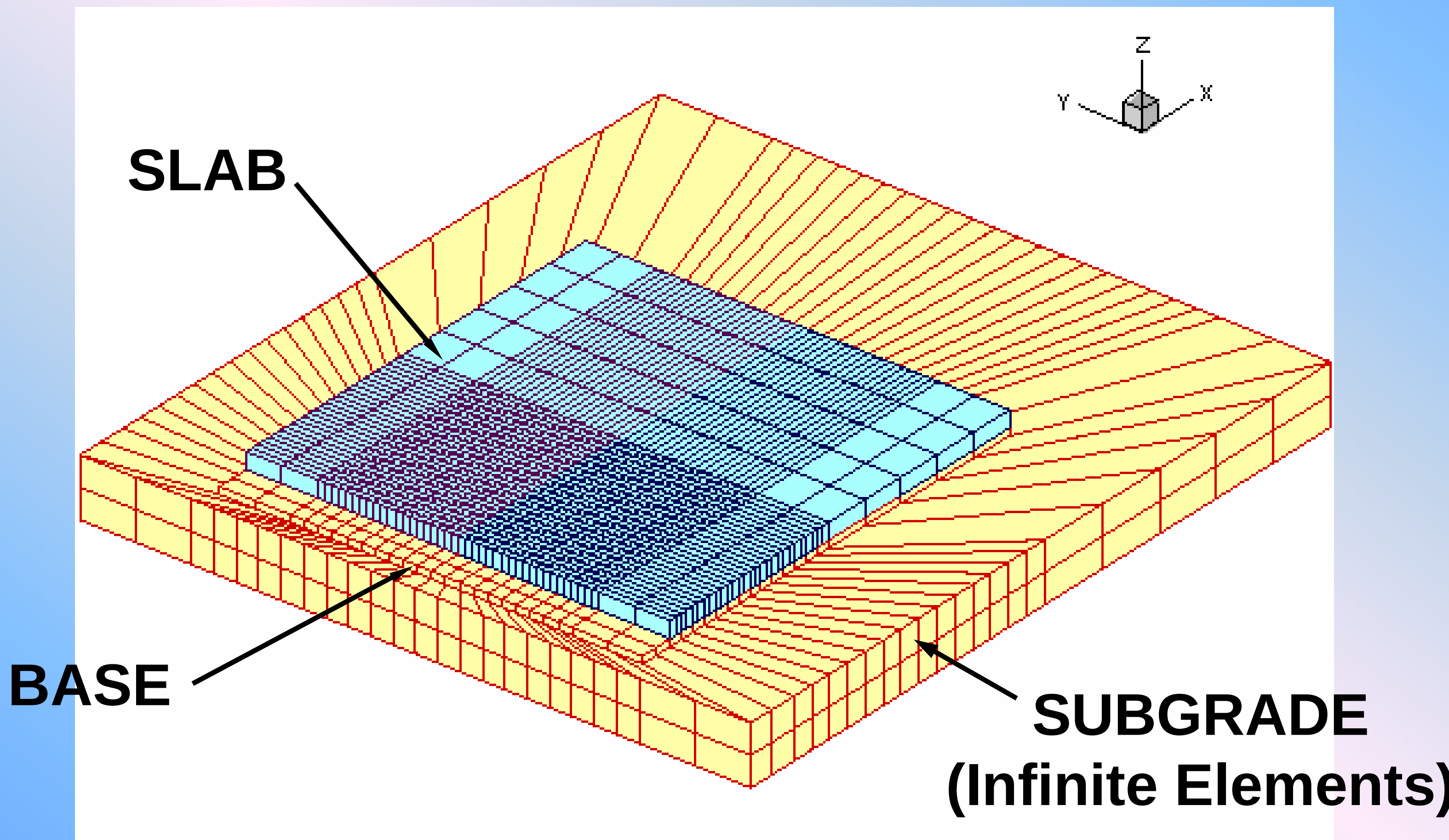


Types of 3D Elements

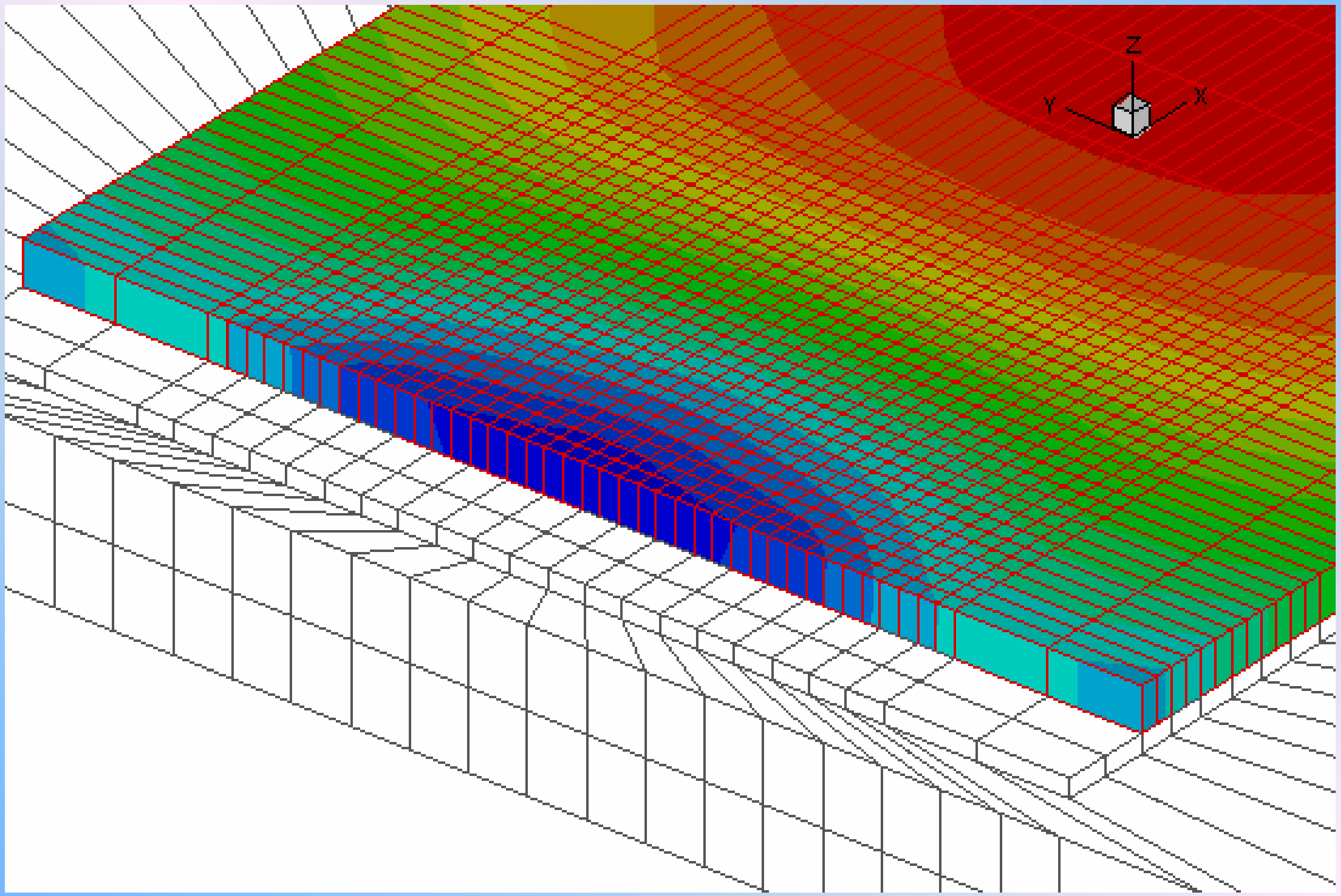




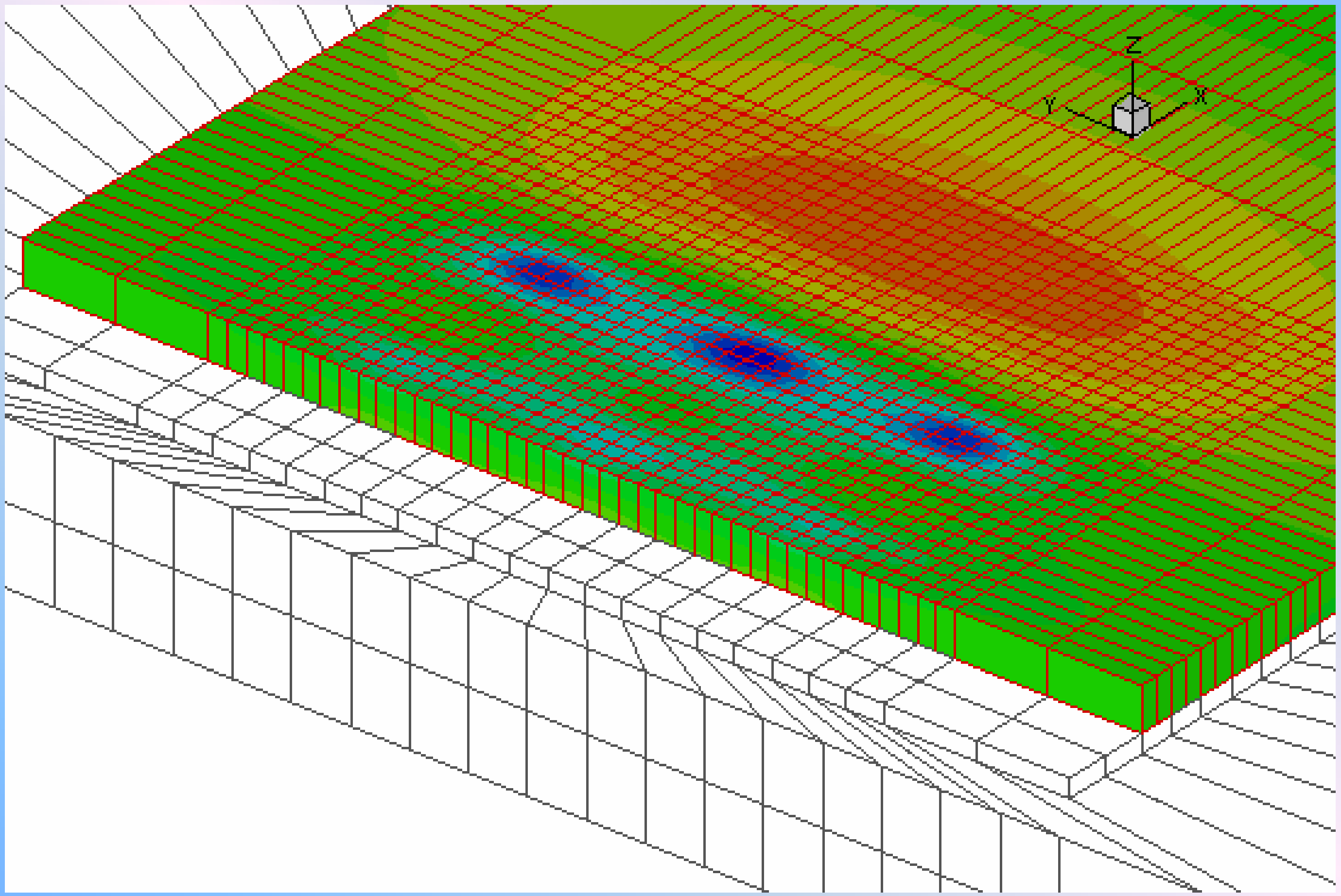
Discretized Model of Rigid Airport Pavement



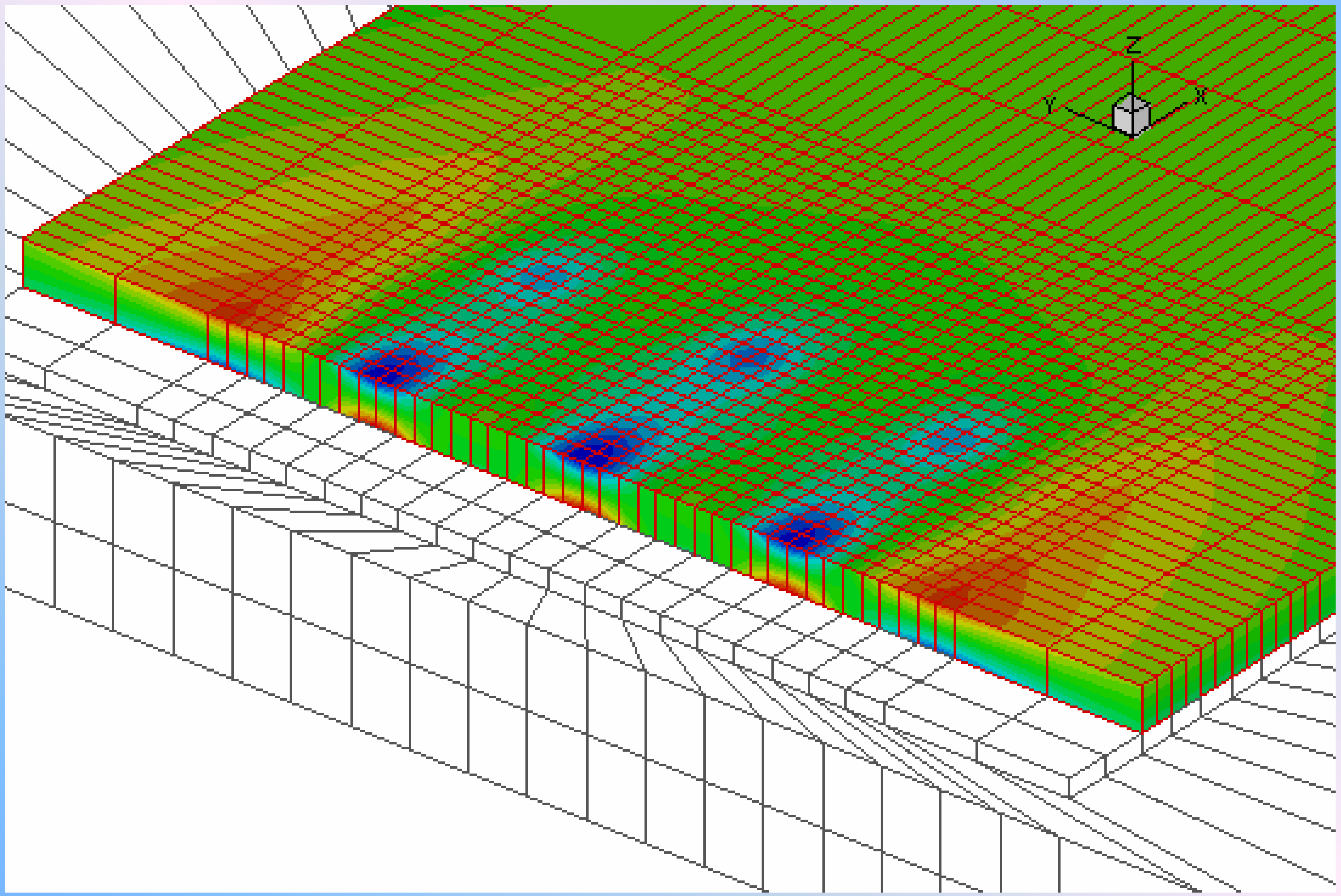
3D-FEM Solution - Deflection



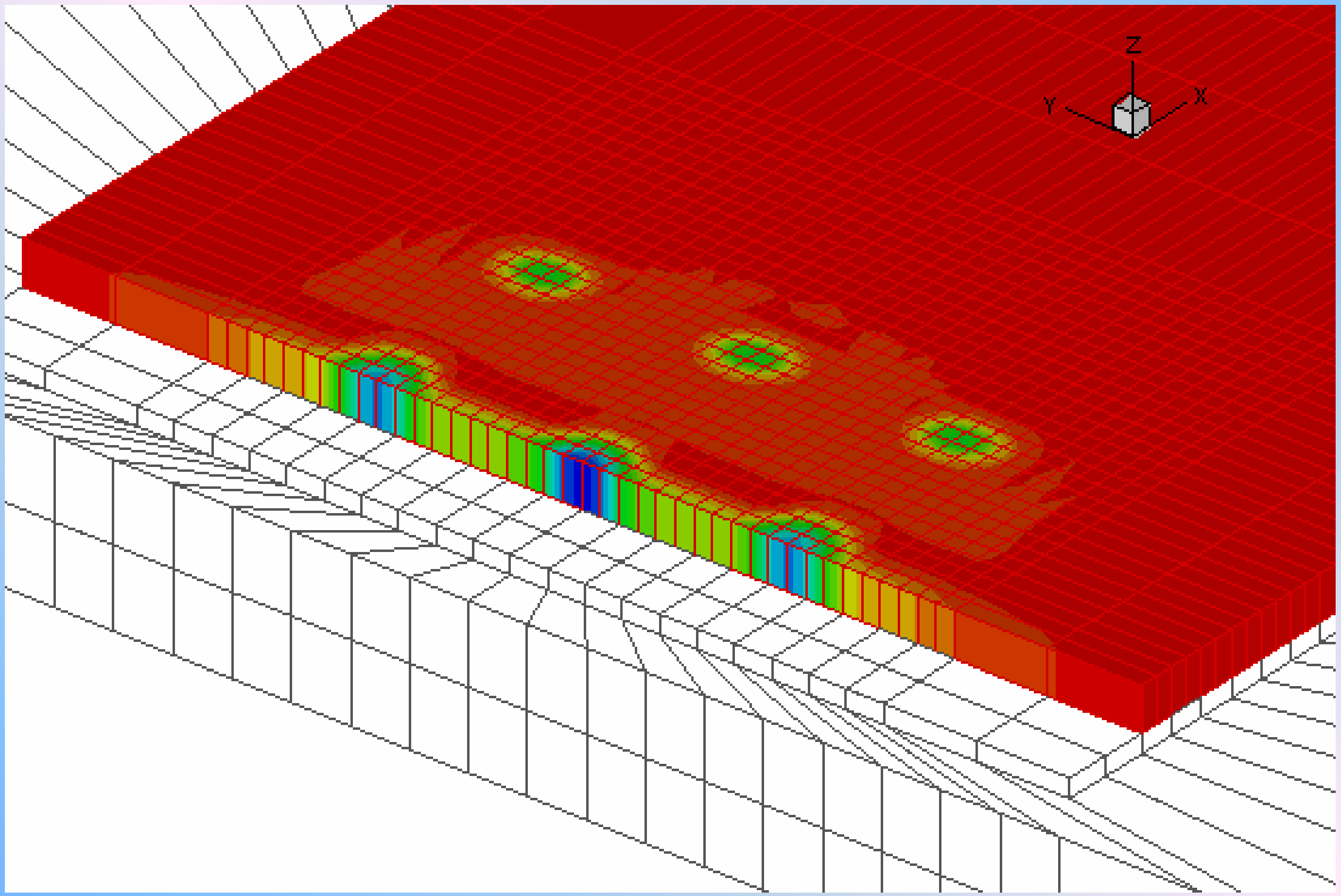
3D-FEM Solution - Stress σ_{xx}



3D-FEM Solution - Stress σ_{yy}



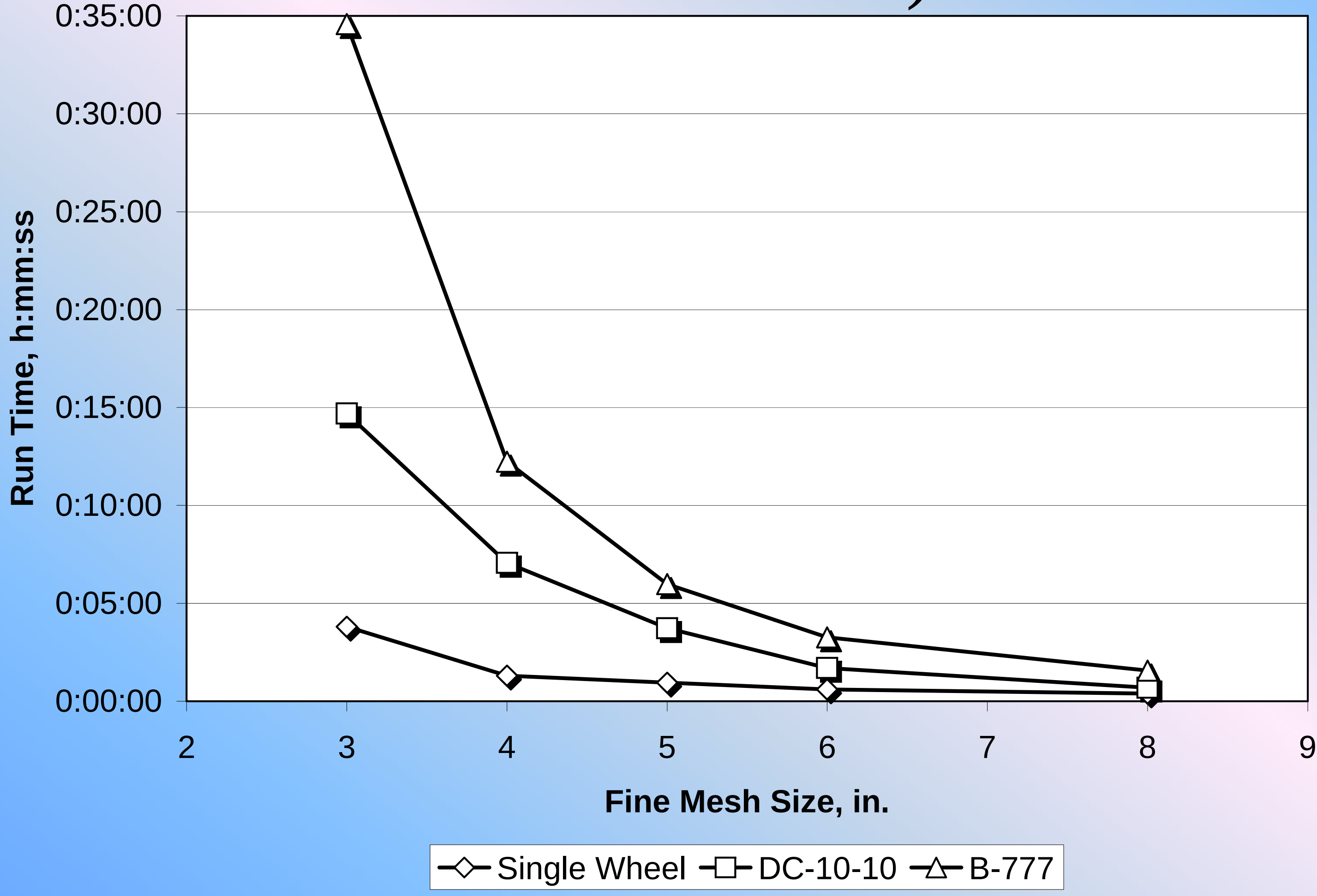
3D-FEM Solution - Stress σ_{zz}



Improvement in Solution Time

- Approximate time for B-777 stress solution:
  - July 2000: 4 - 5 hours
  - July 2001: 30 minutes
    (single slab with infinite element foundation)
  - May 2002: 2 - 3 minutes
    (implement new incompatible modes elements)
  - Current version implemented in FEDFAA:
    <10 seconds

Effect of Mesh Size on Run Time (Using Windows XP, Pentium-4, 512MB)



Key Advantages of 3D-FEM

- Correctly models rigid pavement features including slab edges and joints.
- Provides the complete stress and displacement fields for the analyzed domain.
- Handles complex load configurations easily.
- No inherent limitation on number of structural layers or material types.
- Not limited to linear elastic analysis.

Disadvantages of 3D-FEM

- May require long computation times.
- Pre-processing and post-processing requirements.
- Solution may be mesh-dependent.
  - In theory, the solution can always be improved by refining the 3D mesh.
  - Improvement comes at the expense of time.

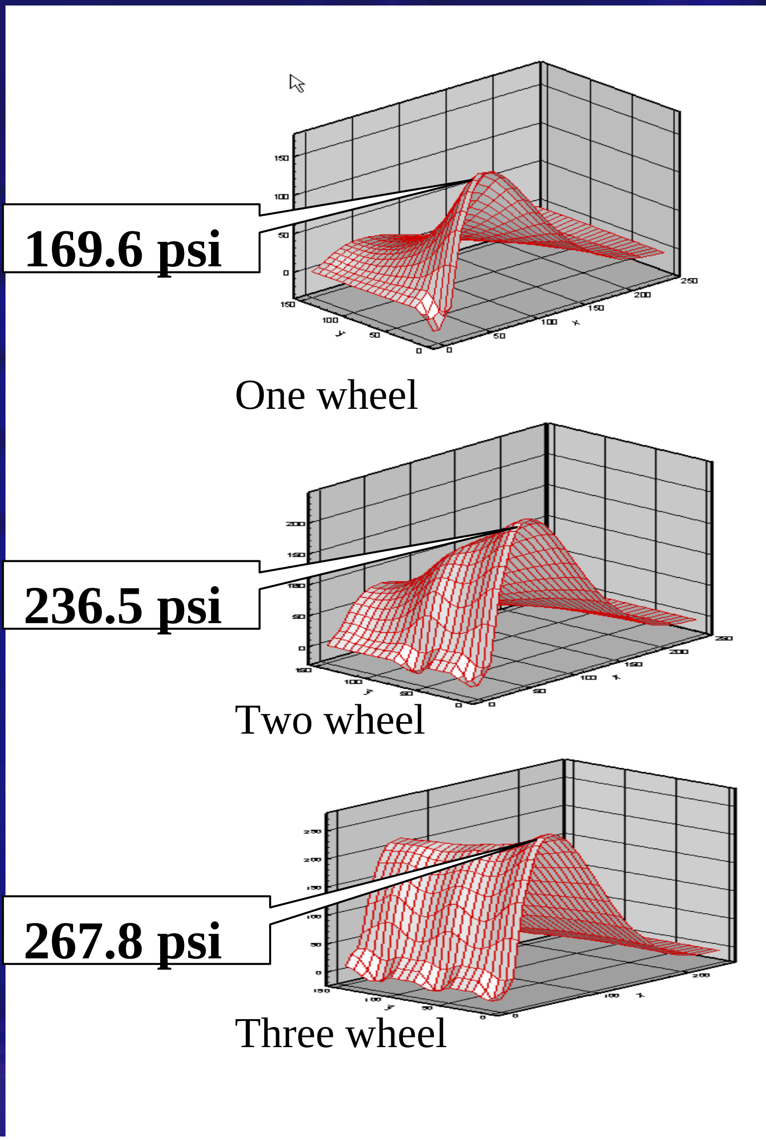
FAA - Future Rigid Pavement Design

Future Issues with Rigid Pavement Design

Traditional Models assume “bottom-up” cracking due to tensile stress in the bottom of the slabs.

FAA NAPTF and Airbus research suggest “top-down” cracking may be of equal concern with multi-wheel aircraft.

FAA - Future Rigid Pavement Design



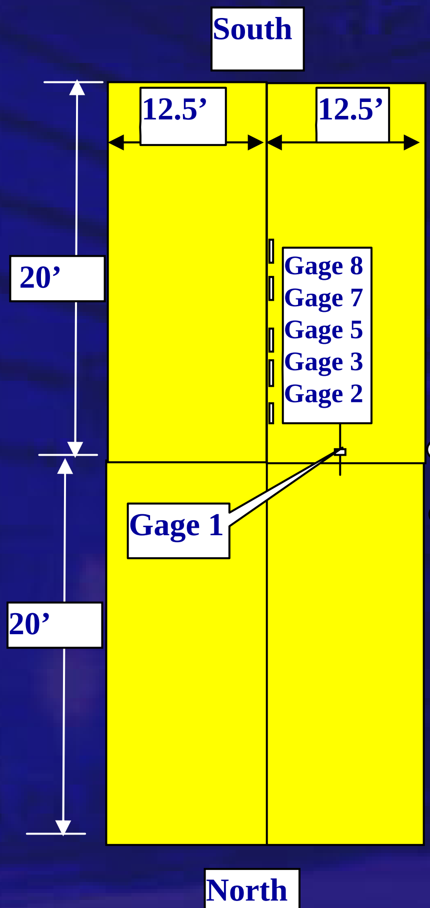
Stress at Top of Slab under One, Two and Three Wheels

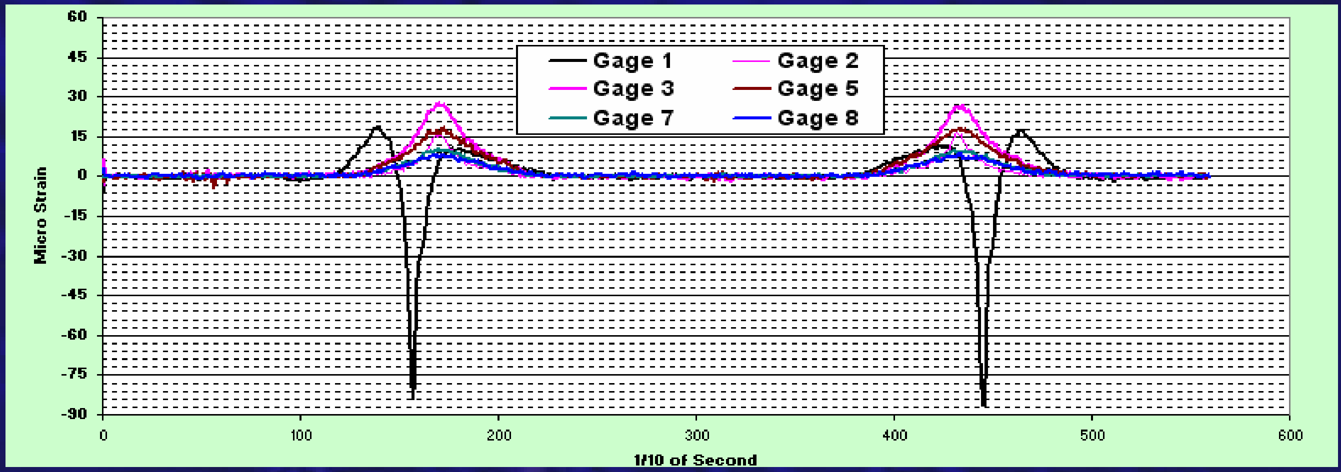
Airbus and NAPTF research suggest that the existing failure mode of “center slab – bottom up cracking” may not the critical failure mode with multi-wheel gear aircraft.

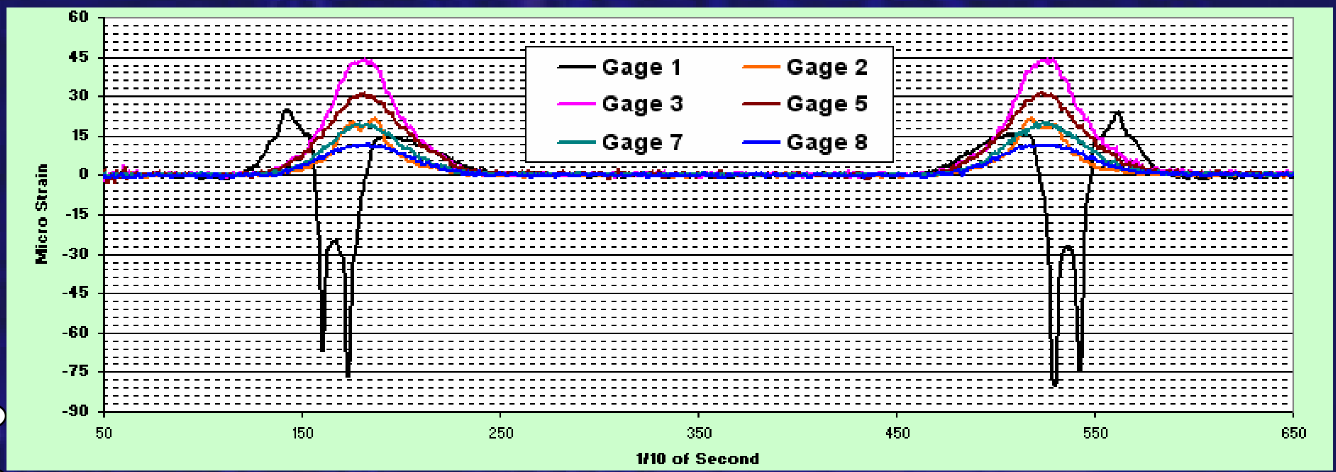
Future refinement of FAArfield will attempt to address this concern

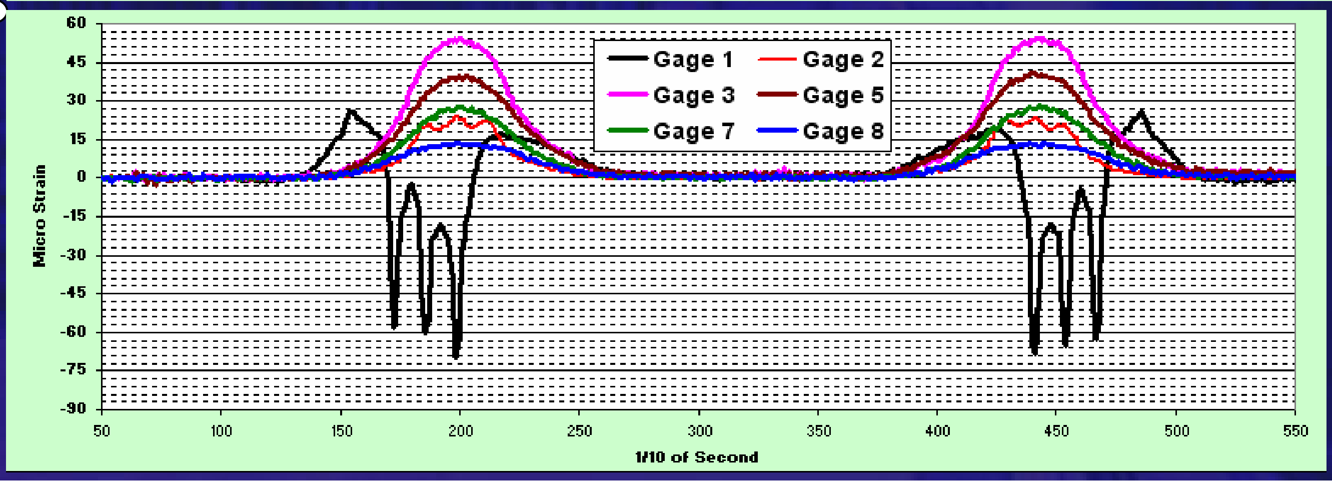
March, 2005

17” transition sections

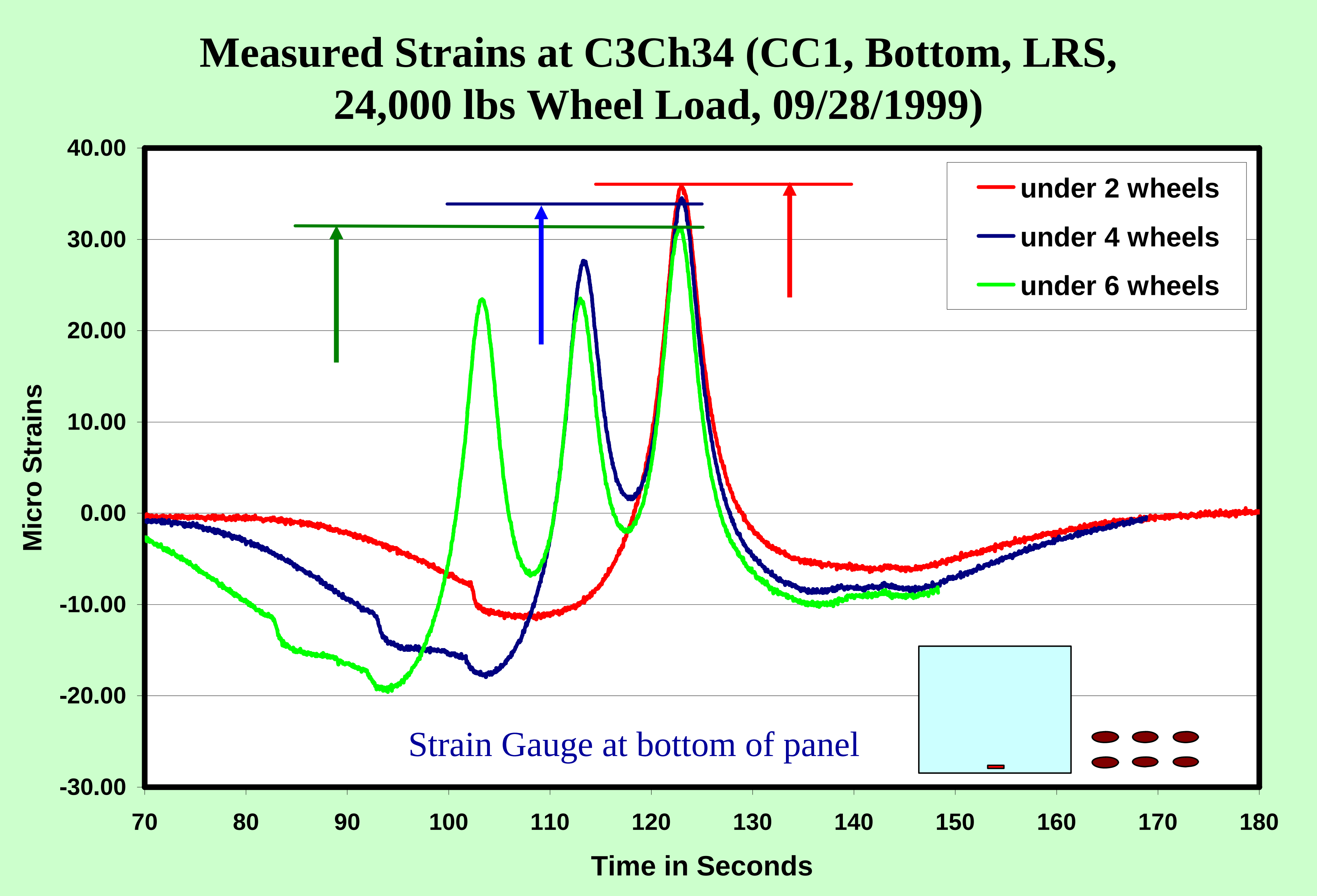




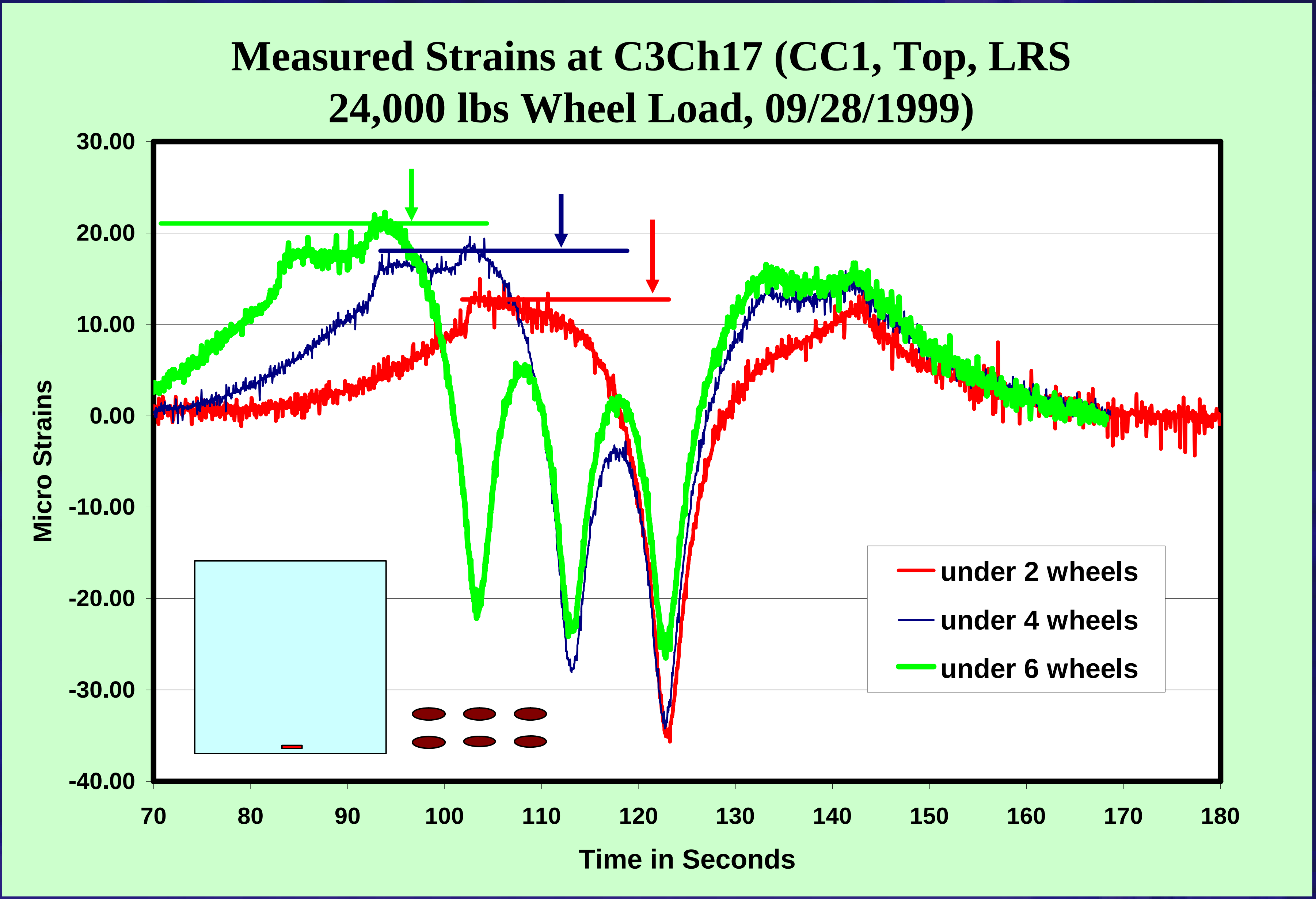




Bottom-up Critical Strains:
2 wheels > 4 wheels > 6 wheels



Top-Down Critical Strains:
6 wheels > 4 wheels > 2 wheels

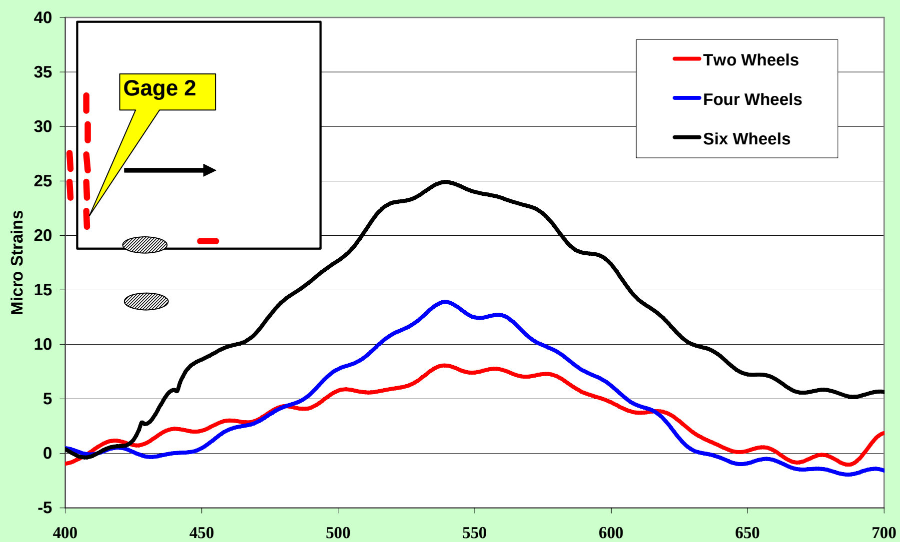


FAA - Future Rigid Pavement Design

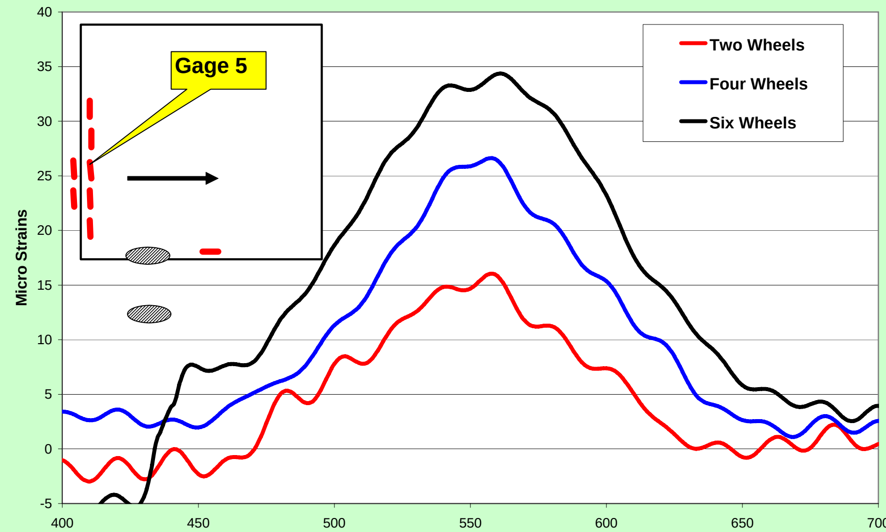
A bottom-up crack perpendicular to a LONGITUDINAL JOINT is mainly dominated by wheel load while a top-down crack is mainly dominated by gear load

Critical Strains: 6 Tires > 4 Tires > 2 Tires

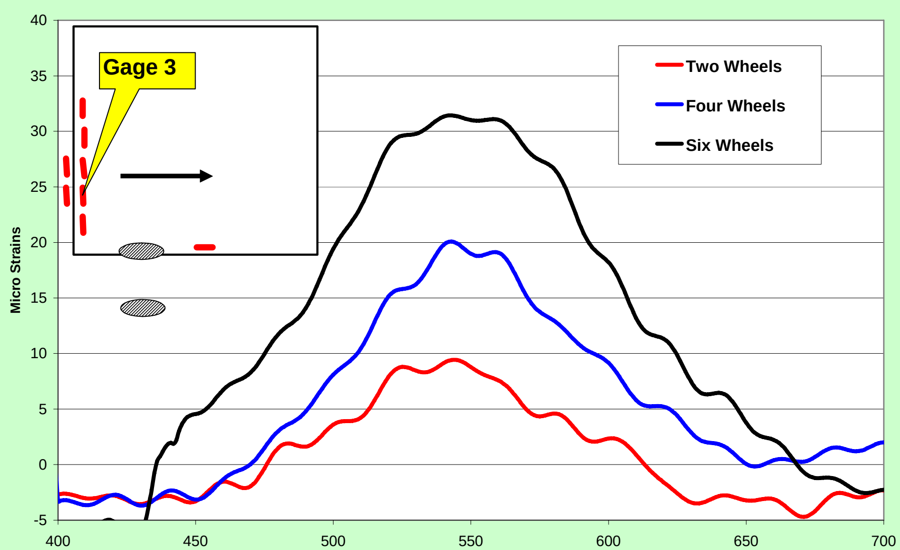
Test Three Gage 2



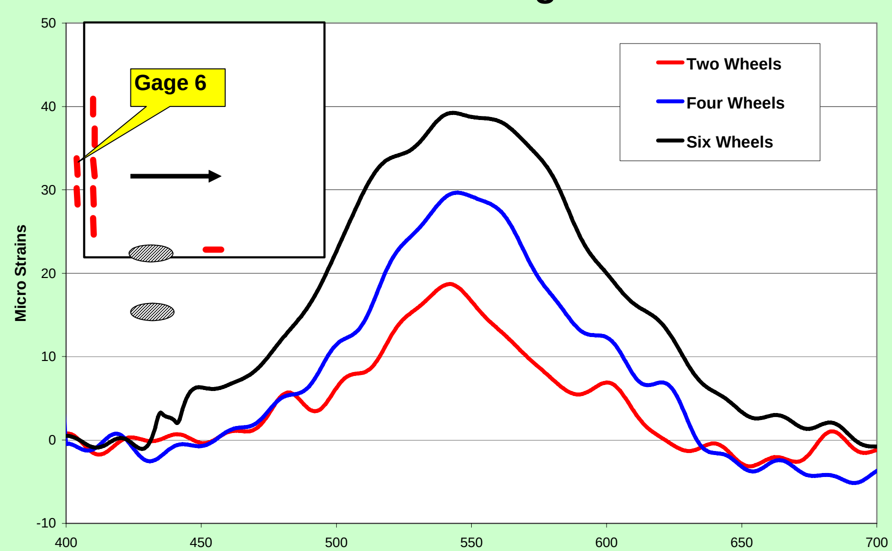
Test Three Gage 5



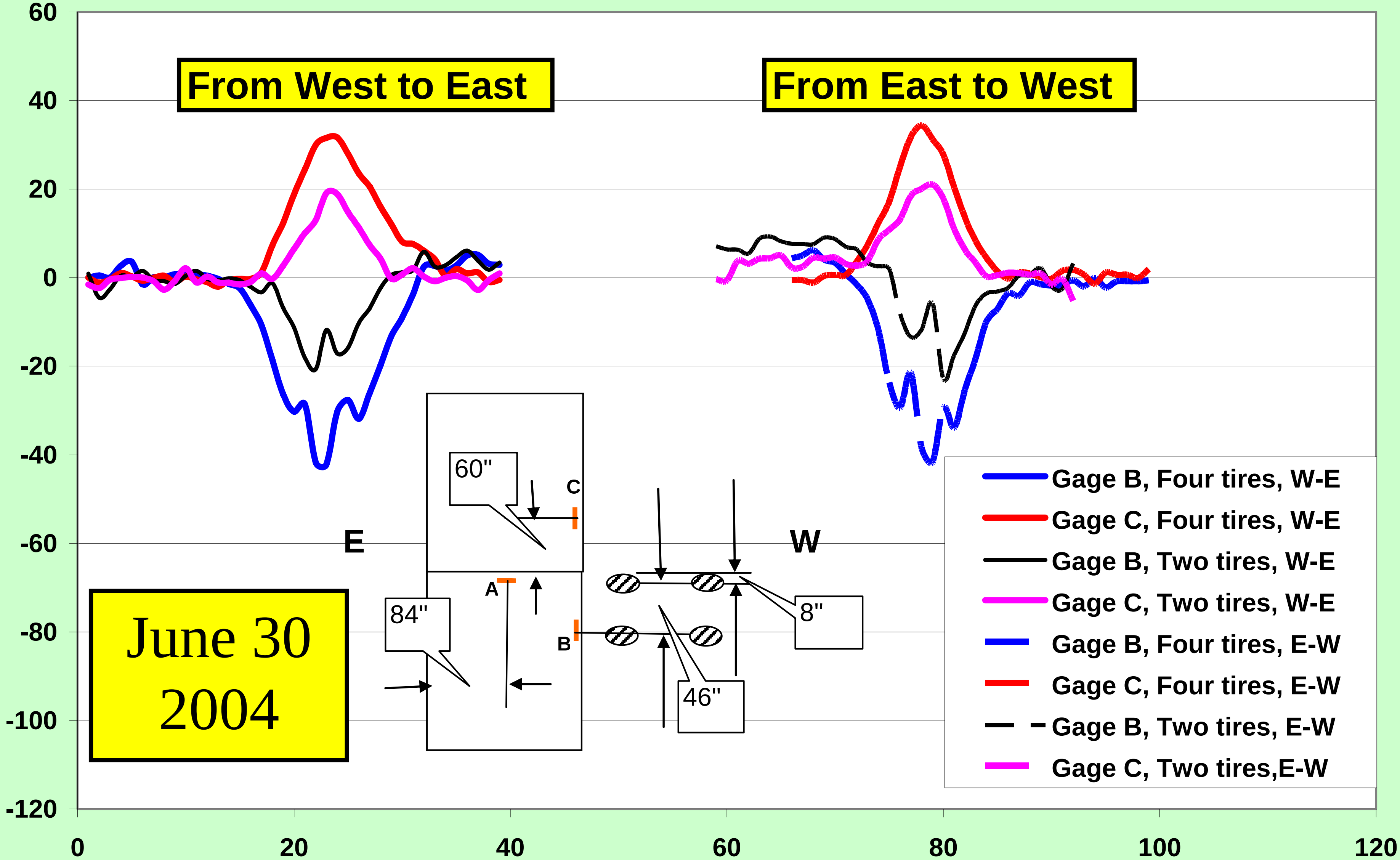
Test Three Gage 3



Test Three Gage 6



Comparison of Critical Strains At the Transverse Joint



FAA - Future Rigid Pavement Design

Both bottom-up and top-down crack perpendicular to a TRANSVERSE JOINT is mainly dominated by gear load

FAA - Future Rigid Pavement Design

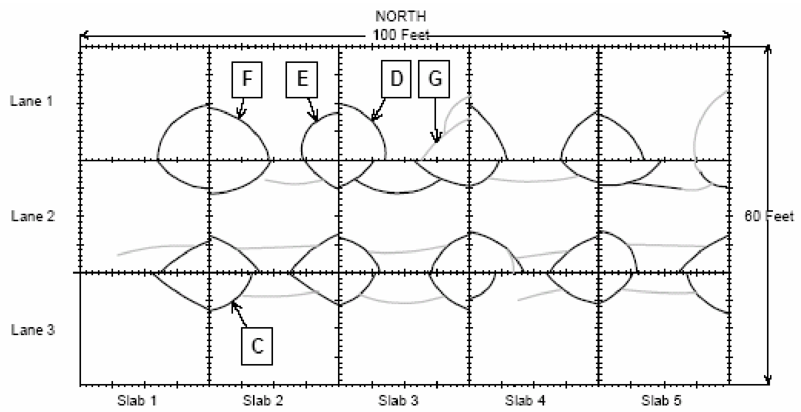
Finding from Full Scale Test Observations

- The mechanisms of bottom-up and top-down cracks at longitudinal and transverse joints are different. Therefore, the critical bottom-up stress can not appropriately predict the top-down crack risk.

- Both top-down and bottom-up cracks are influenced by pavement structure and gear configurations.

FAA - Future Rigid Pavement Design

- Based on NAPTF test results, we recognize the importance of slab curling (and more generally, top-down cracking).
  - 3D-FEM gives us the ability to model critical top-down stresses at a distance from the load.
  - Currently developing the ability to model slab curling stresses & load in NIKE3D.
- Top-down stress mode will not be included the initial release of FAARFIELD (but could be in future versions).

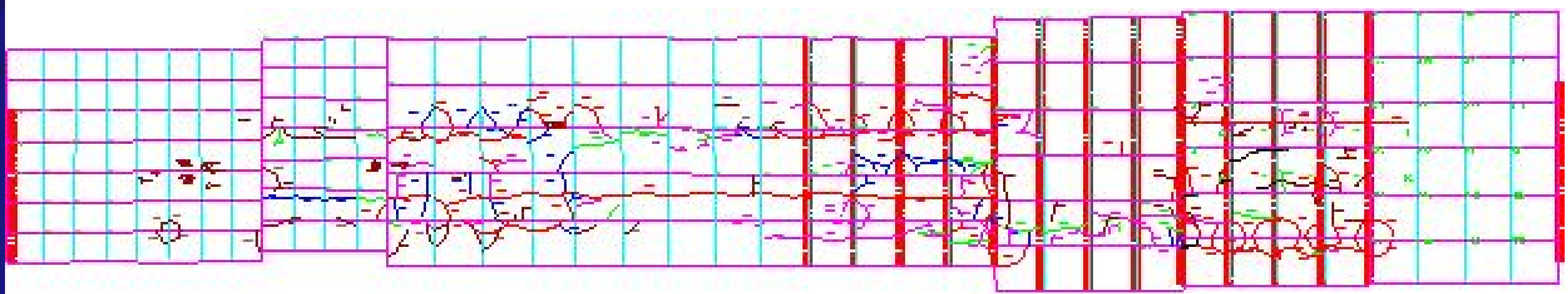


Slab cracking experienced at NAPTF due to loading during curled condition

FAA - Future Rigid Pavement Design

Pavement Test by AIRBUS

Corner cracking and longitudinal panel cracking




Thank You