Heavy Vehicle Simulator International Alliance Sept 2006

ERDC-WES Update

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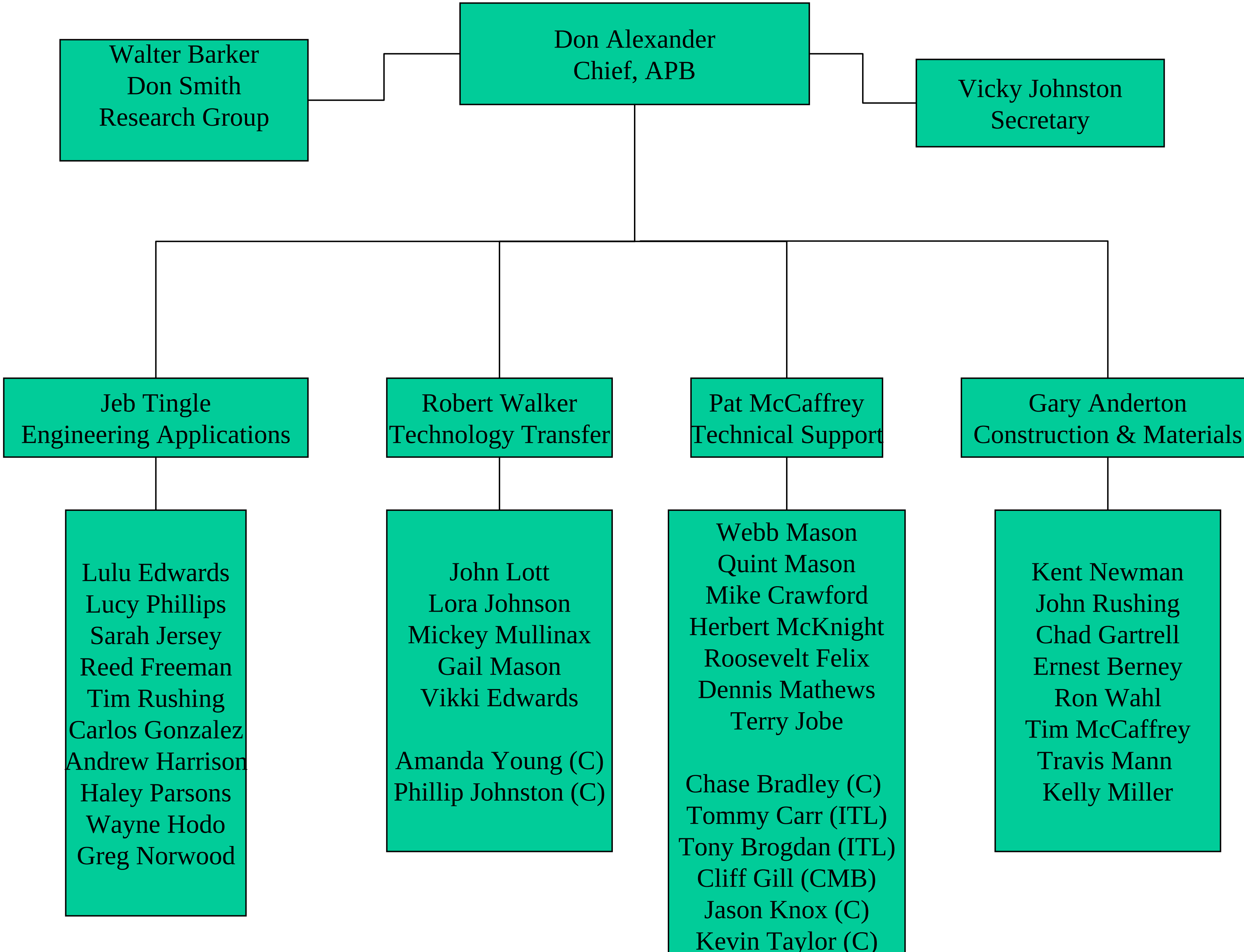
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Technology Transfer
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Technical Support
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Kent Newman
John Rushing
Chad Gartrell
Ernest Berney
Ron Wahl
Tim McCaffrey
Travis Mann
Kelly Miller

Heavy Vehicle Simulator - Aircraft

- Largest In The World
  - Length - 119 ft
  - Width - 14 ft
  - Height - 13.5 ft
  - Capacity - 10 to 100 Kips
- 300+ Repetitions per hour
- Single or Dual wheel gear
- Railroad carriages, scaled trailers, etc.
- Delivered November 1998
- Operational January 1999

Focus on Contingency/Expedient Pavements

Airfield Damage Repair

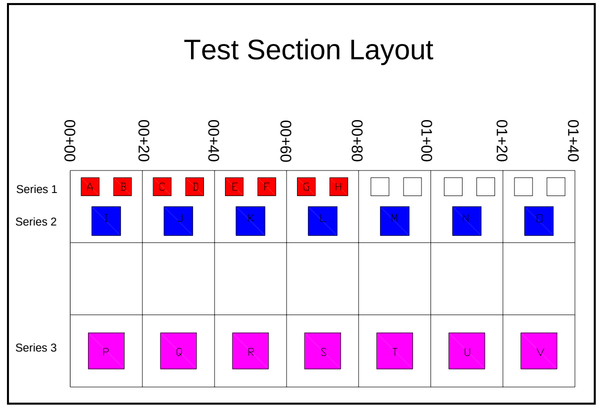
ERDC PROJECTS:

- **Small Crater Repair: (<10 ft Diameter)**
  - **Rapid Fill Materials – Closed-Cell Polyurethane Foam**
  - **Rapid Setting Cementitious Materials for Small Volumes**
- **Large Crater Repair: (>10 ft Diameter)**
  - **Rapid Setting Cementitious Materials for Large Volumes**
- **ADR Kit Upgrades:**
  - **Advanced Composite FOD Covers with Aramid Fibers**
  - **Rapidly Installed Earth Anchors**
- **Rapid Temporary Asphalt Repair:**
  - **Innovative Polymeric Topical Coatings**
- **Evaluation of Deteriorated Asphalt:**
  - **Portable Deflectometer**
  - **Portable Seismic Pavement Analyzer**
- **Evaluation of Folded Fiberglass Mat Serviceability:**
  - **Thermal Imaging**
  - **Acoustic Imaging**

FULL-SCALE TESTING

ANCHOR BOLTS:

SMALL CRATERS:

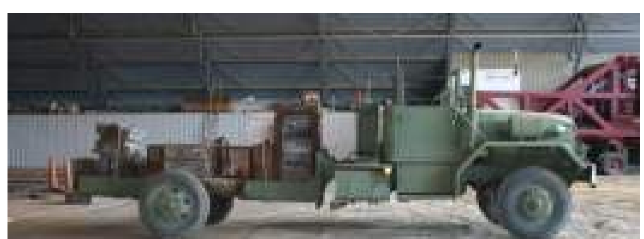


LARGE CRATERS:

SPALL REPAIR: C-17

INSTRUMENTATION:

LOAD CART: F-15E



C-17 Semi-Prepared Runway Operations

SPRO2 C-17 Test Program

TEAM MEMBERS

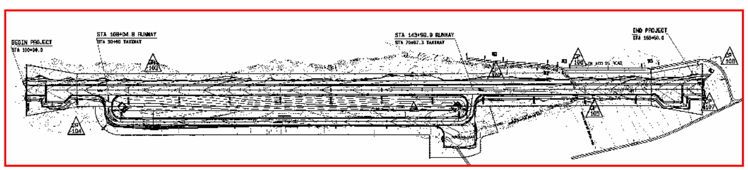
Geotechnical and Structures Laboratory (GSL)
Cold Regions Research & Engineering Laboratory (CRREL)
Information Technology Laboratory (ITL)
Air Force Civil Engineer Support Agency (AFCESA)
Air Force Research Laboratory (AFRL)
NASA Langley Research Center (LRC)
The Boeing Company
USACE Transportation Center for Expertise
USACE Omaha/Tulsa Districts
National Guard Bureau

418th Flight Test Squadron
18th Airborne Corps
958th EN BN
229th EN BN
458th EN BN
420th EN BDE
Fort Hunter Liggett
Fort McCoy
Fort Chaffee
416th/412th ENCOMs

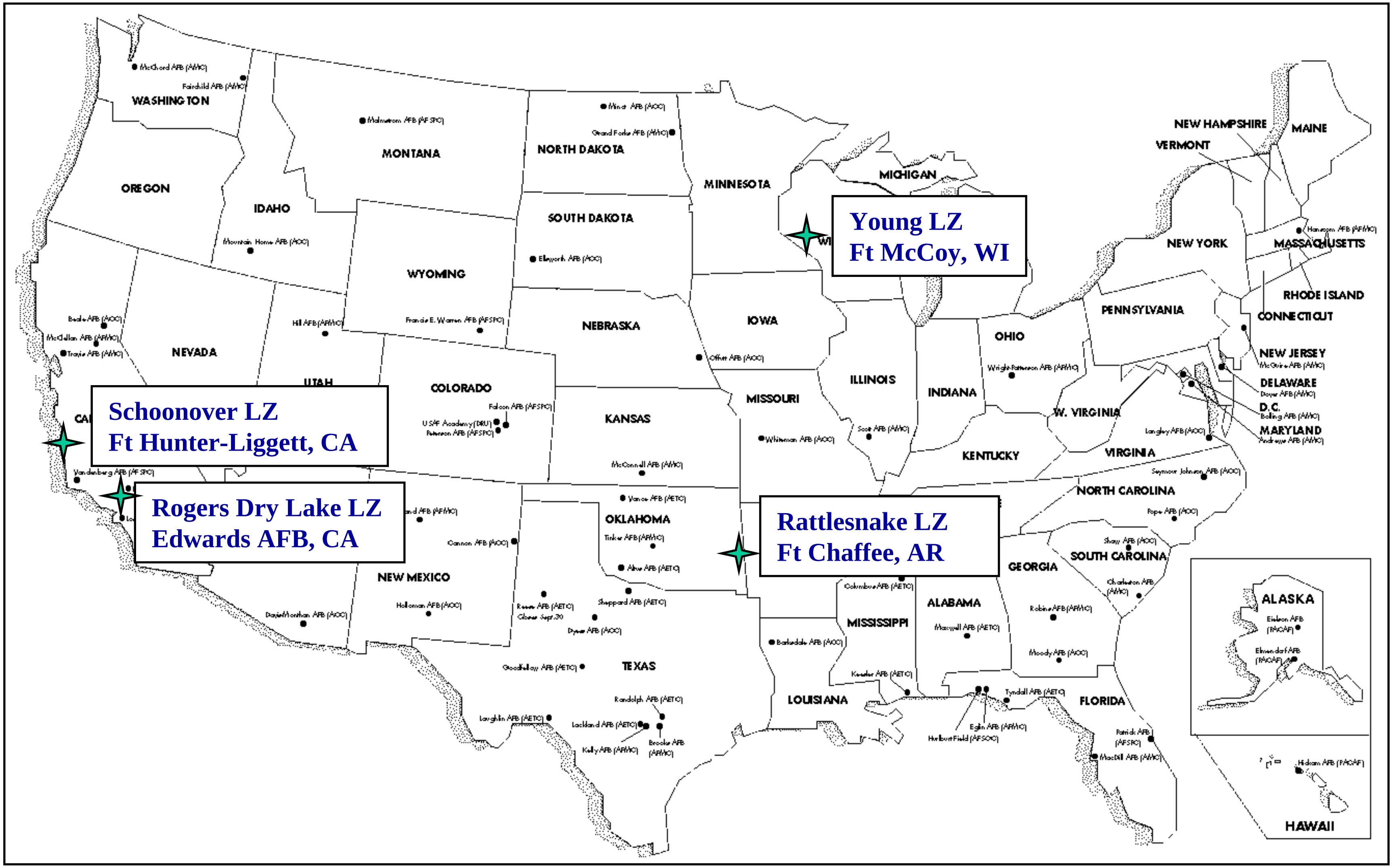
C-17 Semi-Prepared Runway Operations

OBJECTIVES:

- Develop Methods for Predicting Runway Condition Rating (RCR)
- Develop Methods for Predicting Rolling Friction Factor (RFF)
- Develop Methods for Predicting SPRO Deterioration Rates
- Develop Models for Predicting Aircraft Roughness
- Evaluate Ability to Increase Maximum Allowable Gross Weight



Test Sites



Young LZ
Ft McCoy, WI
Schoonover LZ
Ft Hunter-Liggett, CA
Rogers Dry Lake LZ
Edwards AFB, CA
Rattlesnake LZ
Ft Chaffee, AR
WASHINGTON
OREGON
IDAHO
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
MICHIGAN
WYOMING
NEVADA
UTAH
COLORADO
NEBRASKA
IOWA
ILLINOIS
INDIANA
OHIO
KANSAS
MISSOURI
KENTUCKY
OKLAHOMA
NEW MEXICO
TEXAS
LOUISIANA
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
W. VIRGINIA
PENNSYLVANIA
NEW YORK
NEW HAMPSHIRE
VERMONT
MAINE
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
NEW JERSEY
DELAWARE
D.C.
MARYLAND
ALASKA
HAWAII

Construction at Ft Hunter Liggett

C-17 Semi-Prepared Runway Operations

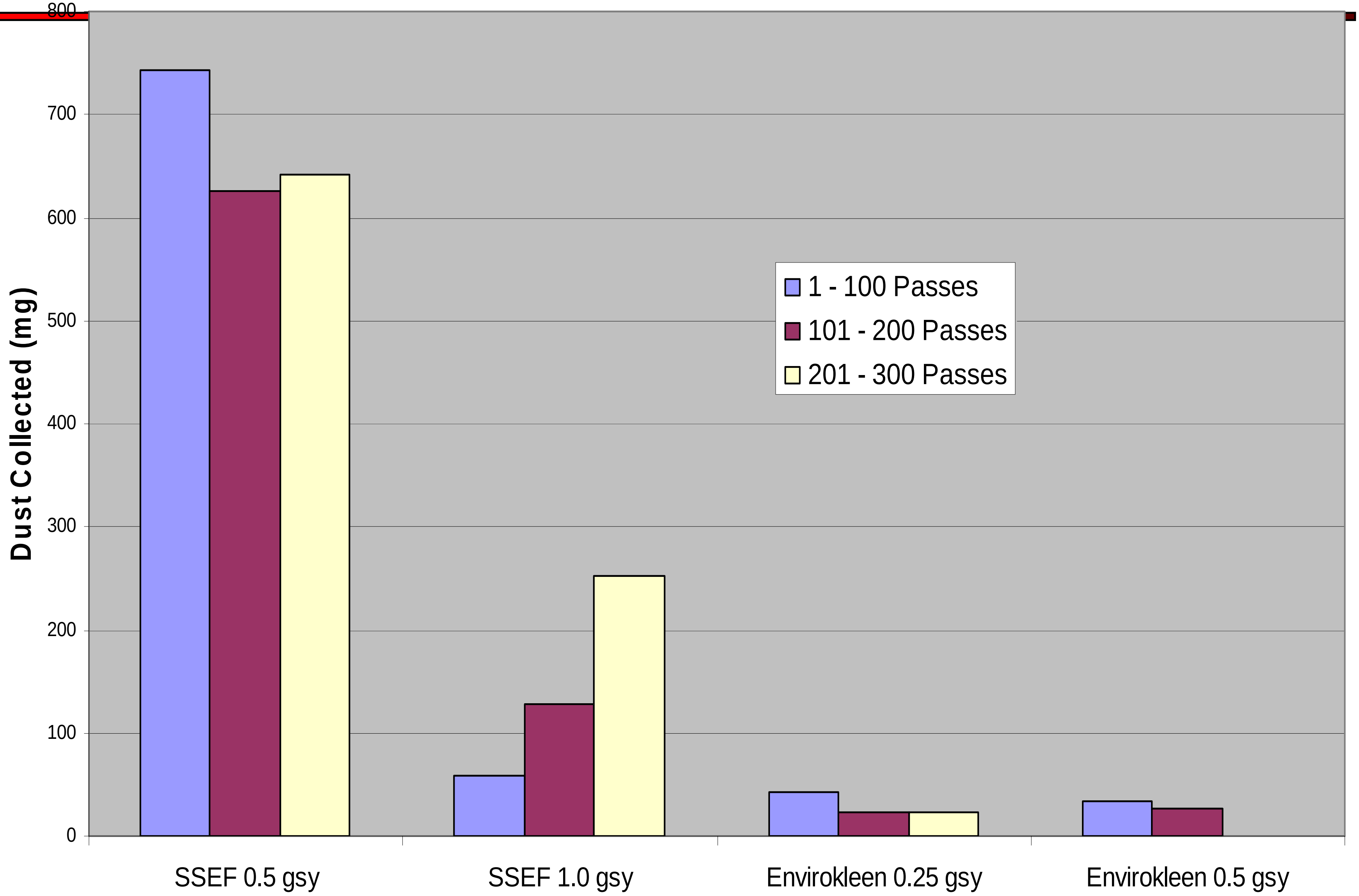
Dust Mitigation

Dust Control Studies

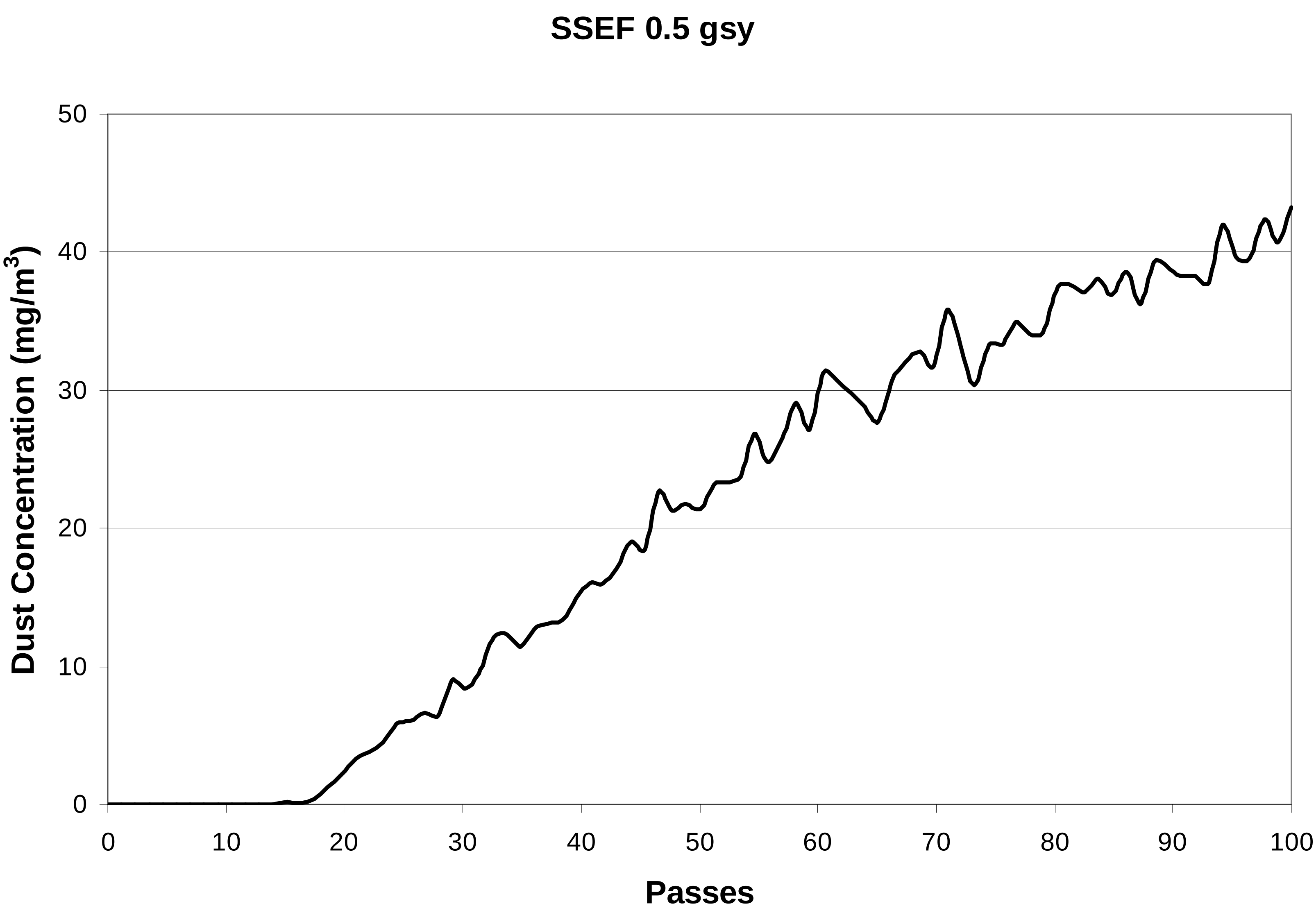
- Objective – Determine quantitative effectiveness of emulsion polymer versus synthetic oils on fiber-cement stabilized soil under C-17 traffic

- Approach – Use vacuum dust collectors and dust particle monitors to evaluate dust generation during C-17 traffic of stabilized soil. Soil is an SM with a high dust potential.

- Conclusions for this stabilized soil type
  - Low to moderate levels of polymer emulsion (below 0.5 gallon/yd^2 = 2.18 l/m^2) were not effective for dust control
  - Low to moderate levels of synthetic oil (below 0.5 gallon/yd^2 = 2.18 l/m^2) were very effective for dust control
  - High dosage levels of polymer emulsion (one gallon/yd^2 = 4.36 l/m^2) were needed to effective abate dust
  - High dosage levels of synthetic oil (above 0.5 gallon/yd^2 = 2.18 l/m^2) softened the surface and resulted in rutting


800
700
600
500
400
300
200
100
0
Dust Collected (mg)
1 - 100 Passes
101 - 200 Passes
201 - 300 Passes
SSEF 0.5 gsy
SSEF 1.0 gsy
Envirokleen 0.25 gsy
Envirokleen 0.5 gsy

Soil Sement @ 0.5 gsy During First Hundred Passes



Renovation of the CBR Design Procedure

- REPORT 1
  - UNDERSTANDING, SCRUTINIZING AND REVAMPING THE CBR THICKNESS DESIGN METHODOLOGY
- REPORT 2
  - SOFTWARE, CRITERIA AND PROCEDURE DEVELOPMENT

$$t = \alpha \cdot \sqrt{\frac{ESWL}{8.1 \cdot CBR} - \frac{A}{\pi}}$$

The vertical stress under a single-wheel from the CBR stress distribution is:

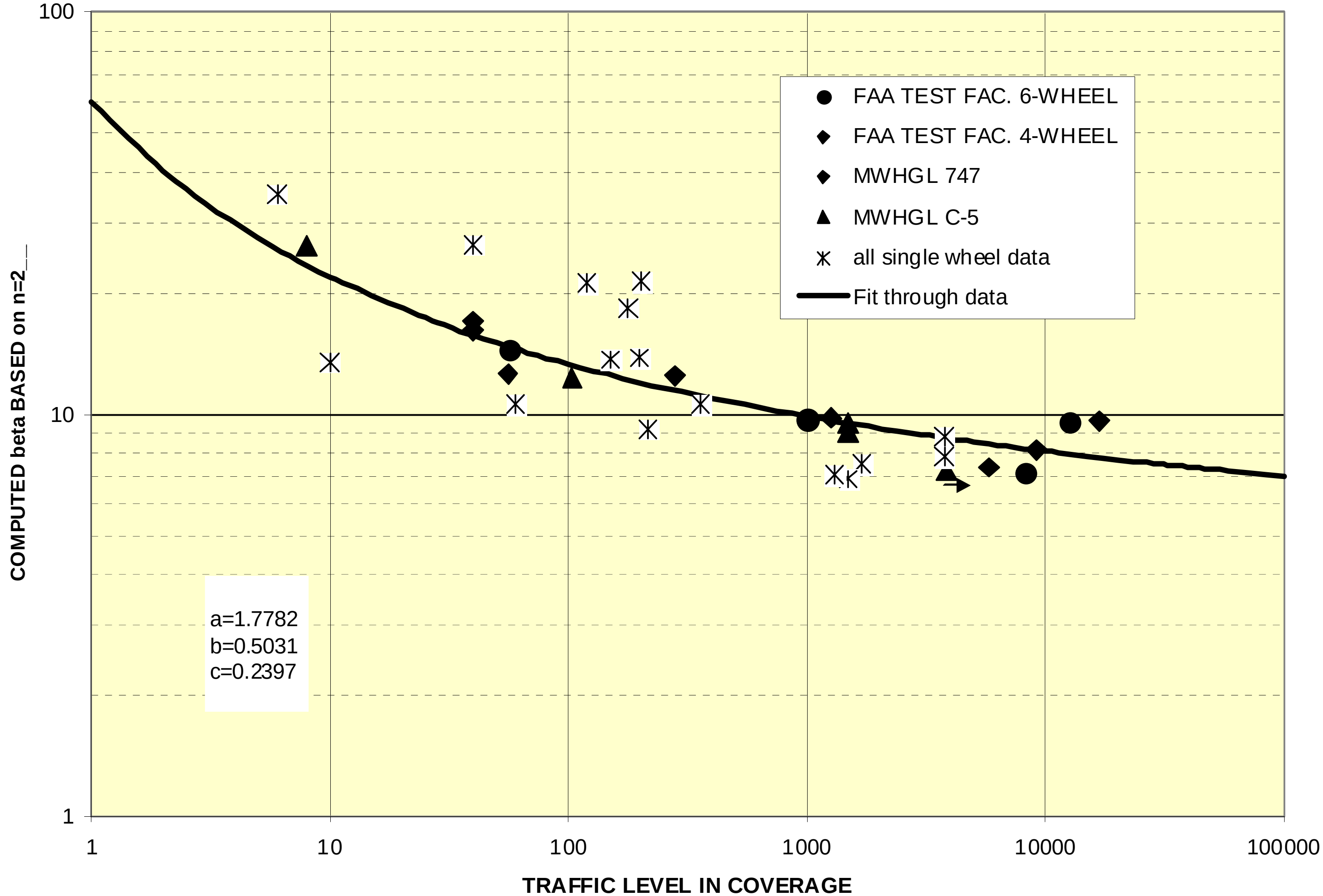
$$\sigma = \sigma_0 \cdot \left[1 - \frac{1}{1 + \left(\frac{r}{z} \right)^2} \right]$$

When ***t*=*z*** this stress is the failure stress.

$$\sigma_f = \left(\frac{\beta}{\pi} \right) \cdot CBR$$

$$\beta = \frac{\sigma_f \cdot \pi}{CBR}$$

Beta Criteria based on n = 2

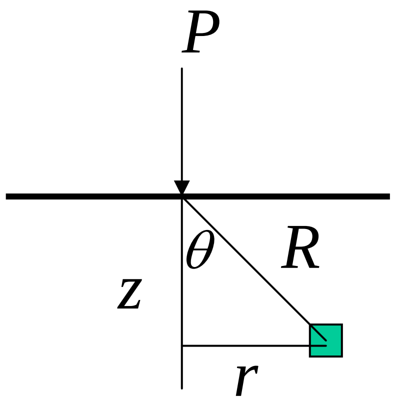


Stress Distribution for the Center Line Under Circular Load

$$\sigma_z = \sigma_0 \cdot \left[1 - \frac{1}{\left| \sqrt{1 + \left(\frac{a}{z} \right)^2} \right|^n} \right]$$

For n = 3: equation becomes the Boussinesq equation.

Multi-Wheel Gear



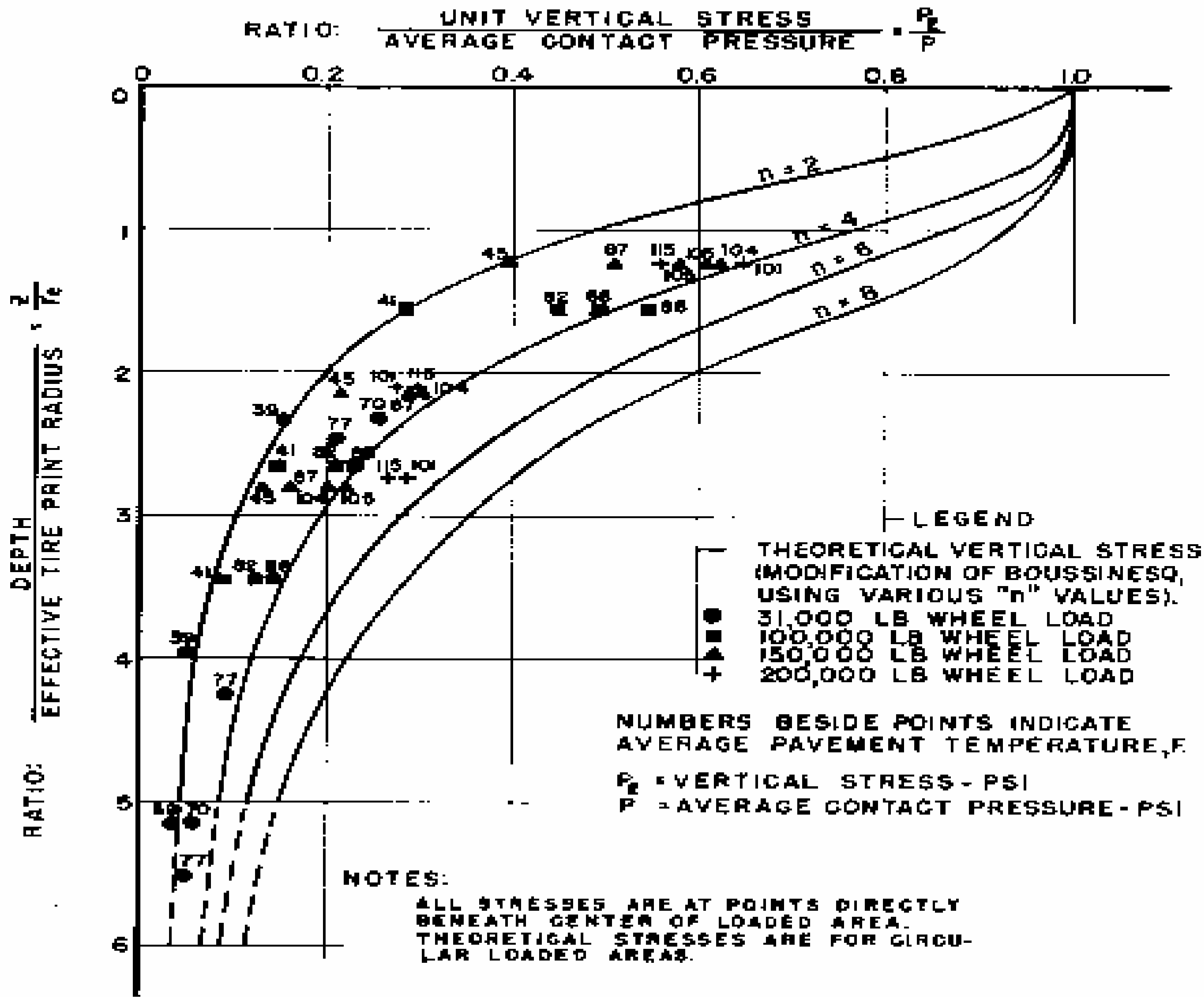
$$\sigma_z = \sum_{i=1}^{wheels} \frac{n \cdot P_i}{2 \cdot \pi \cdot R^2} \cdot \cos^n \theta$$

Where: n = the concentration factor

R = the distance from the load to the general point

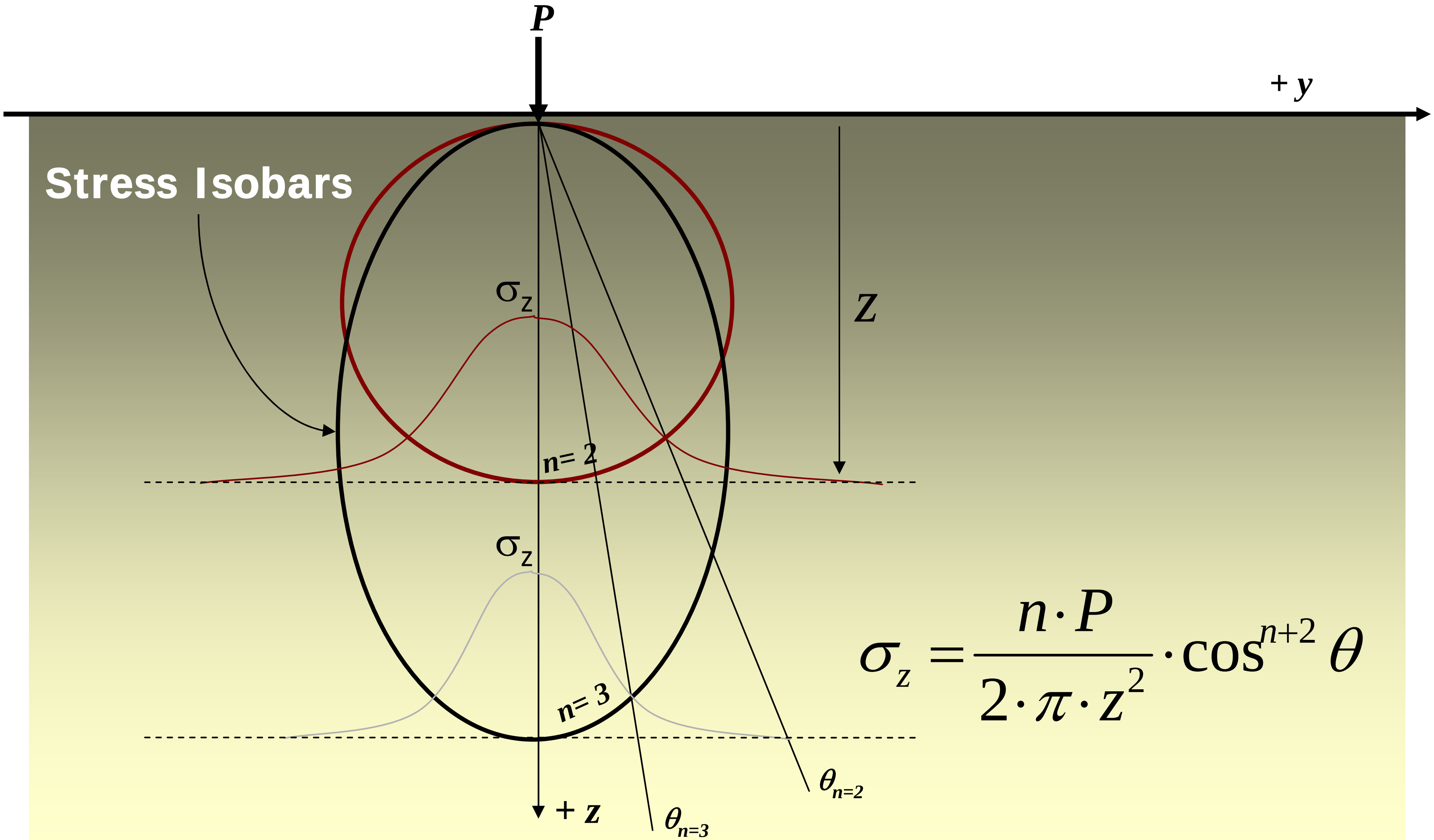
θ = the angle from the vertical to point

P = the applied point load



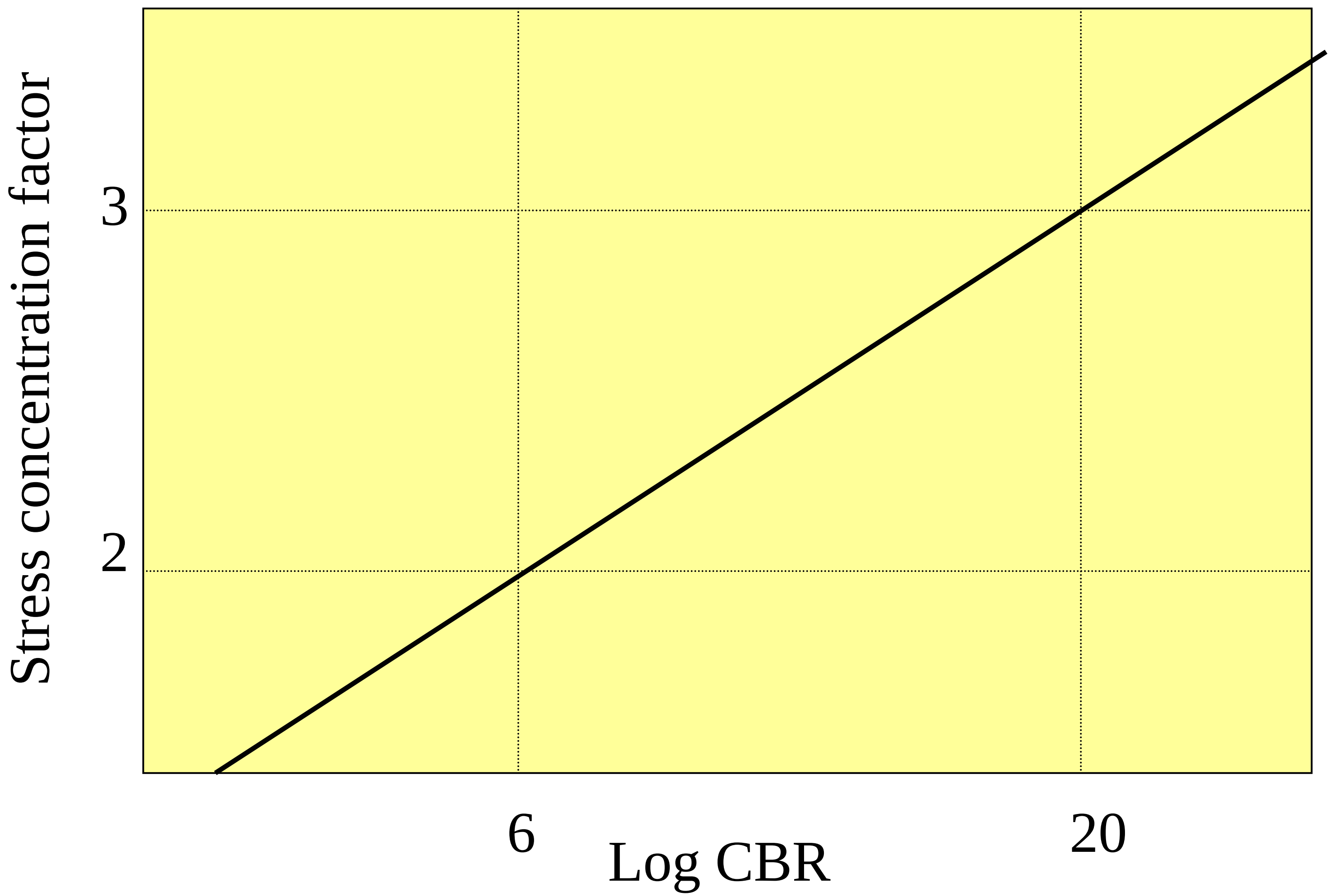
RATIO: UNIT VERTICAL STRESS / AVERAGE CONTACT PRESSURE = $\frac{P_z}{P}$
0
0.2
0.4
0.6
0.8
1.0
RATIO: DEPTH / EFFECTIVE TIRE PRINT RADIUS = $\frac{z}{r_e}$
n = 2
n = 4
n = 6
n = 8
LEGEND
THEORETICAL VERTICAL STRESS (MODIFICATION OF BOUSSINESQ, USING VARIOUS "n" VALUES).
31,000 LB WHEEL LOAD
100,000 LB WHEEL LOAD
150,000 LB WHEEL LOAD
200,000 LB WHEEL LOAD
NUMBERS BESIDE POINTS INDICATE AVERAGE PAVEMENT TEMPERATURE, F.
P_z = VERTICAL STRESS - PSI
P = AVERAGE CONTACT PRESSURE - PSI
NOTES:
ALL STRESSES ARE AT POINTS DIRECTLY BENEATH CENTER OF LOADED AREA.
THEORETICAL STRESSES ARE FOR CIRCULAR LOADED AREAS.

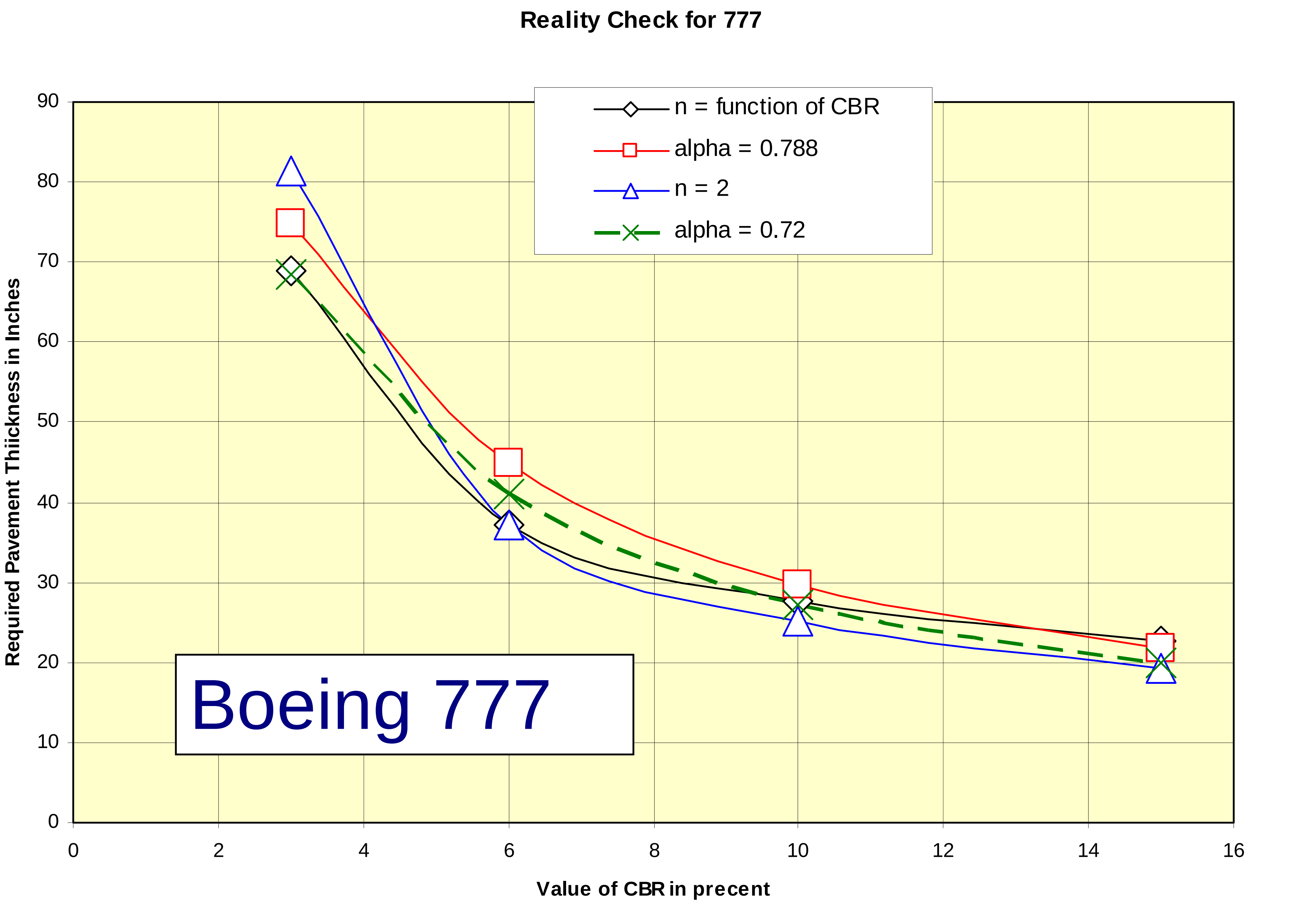
n-factor Changes the Stress Distribution

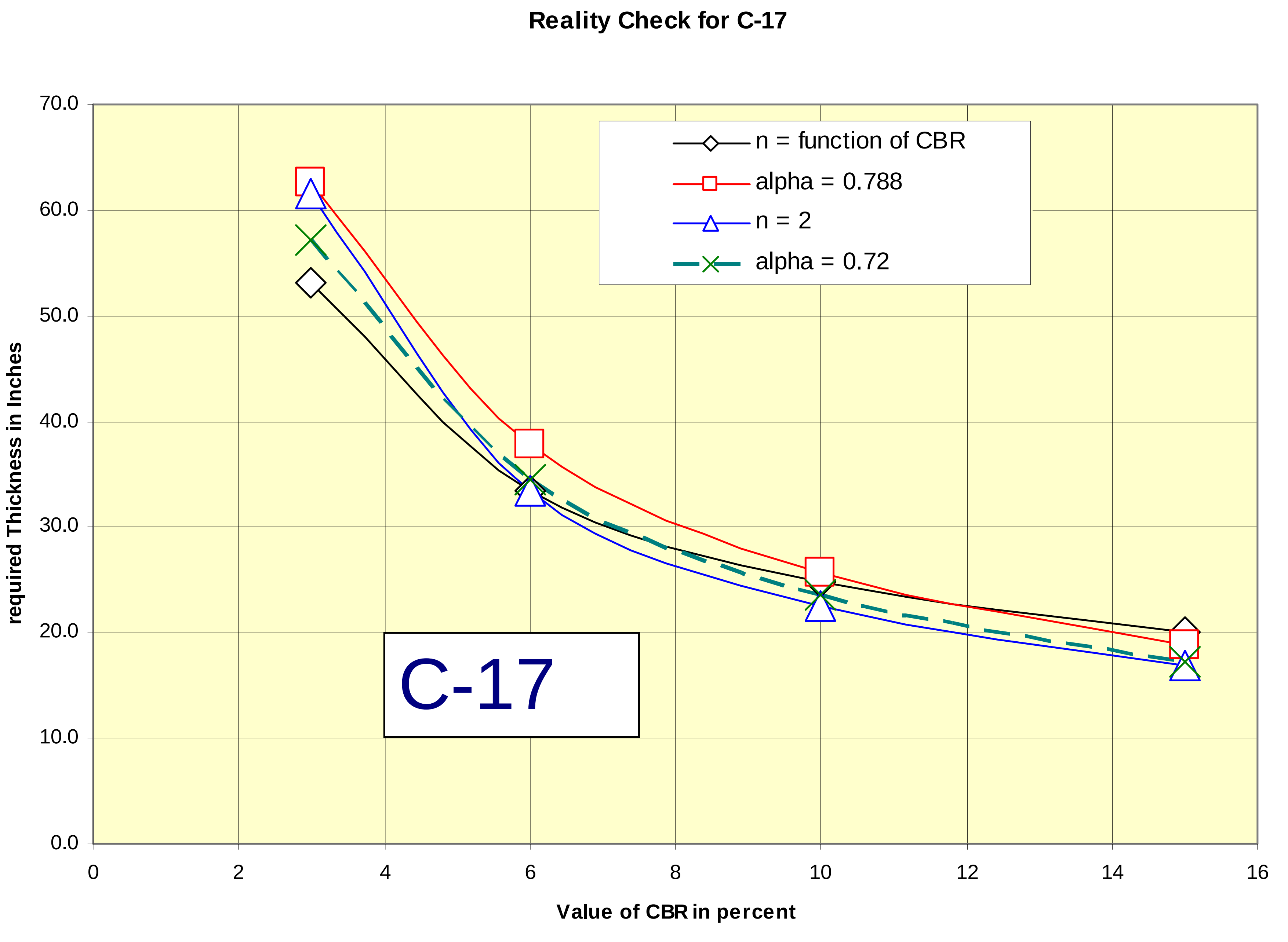


$$\sigma_z = \frac{n \cdot P}{2 \cdot \pi \cdot z^2} \cdot \cos^{n+2} \theta$$

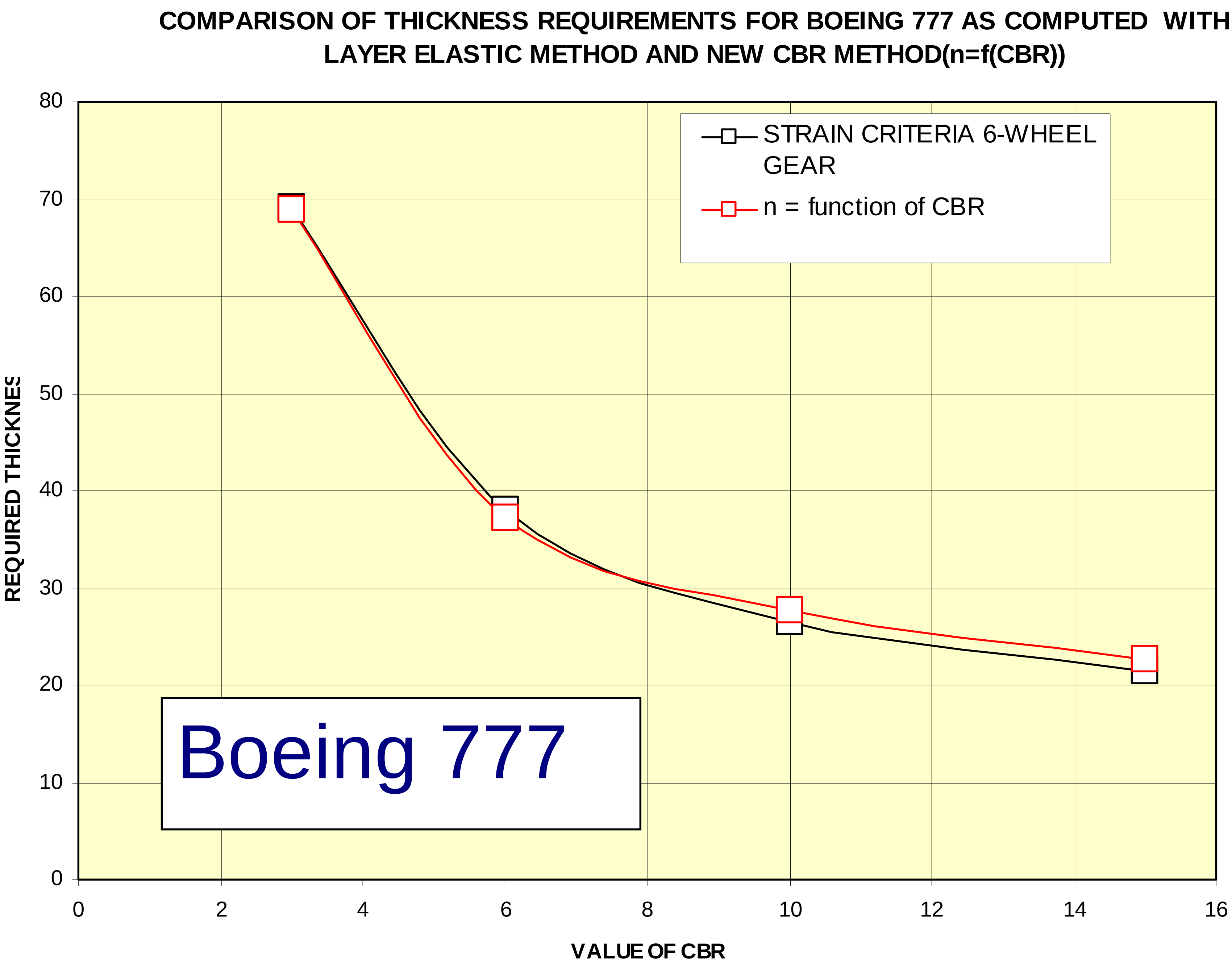
Relationship Between Concentration Factor and CBR



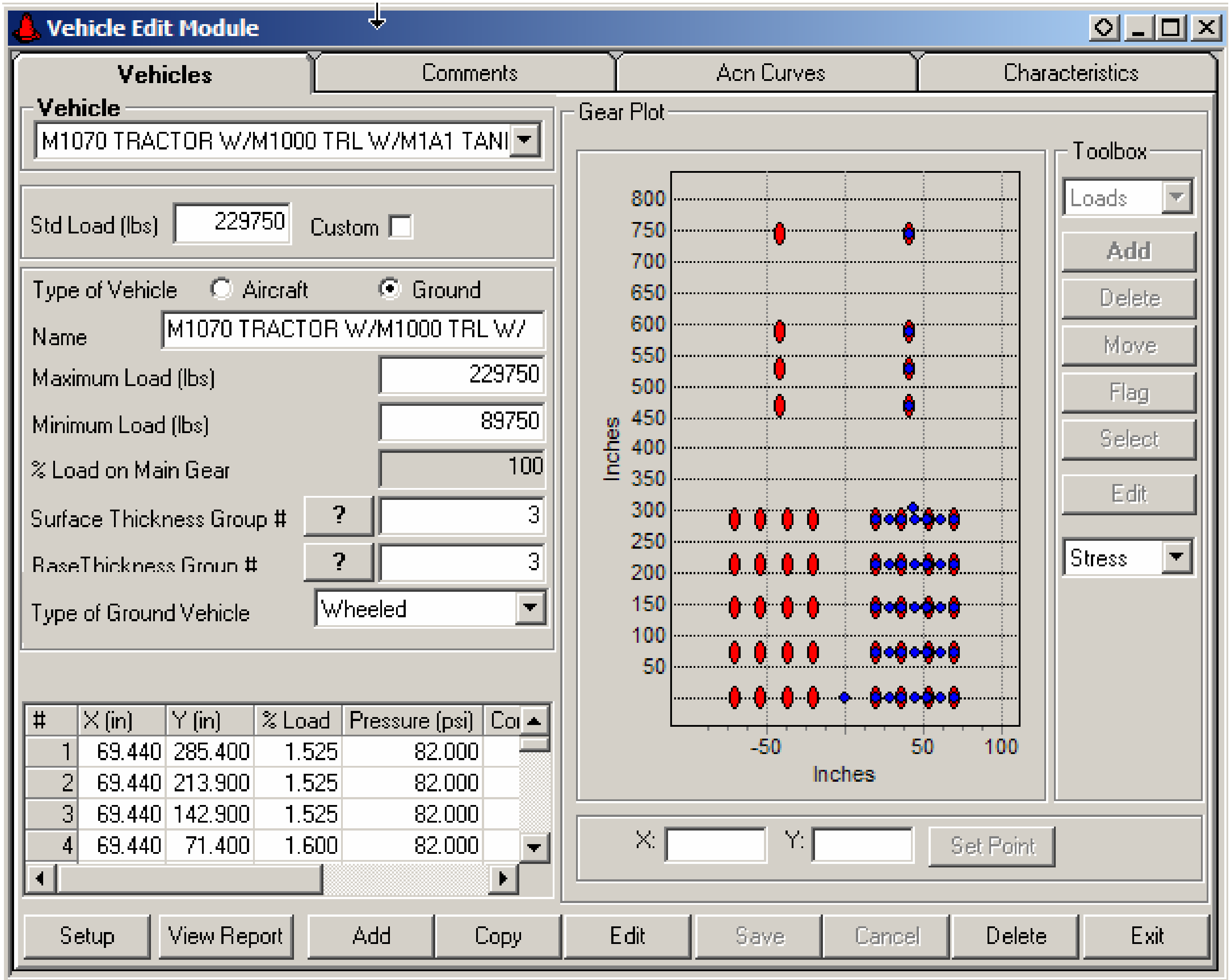

Reality Check for 777
n = function of CBR
alpha = 0.788
n = 2
alpha = 0.72
Boeing 777
Required Pavement Thiickness in Inches
Value of CBR in precent
0
10
20
30
40
50
60
70
80
90
0
2
4
6
8
10
12
14
16



Reality Check for C-17
n = function of CBR
alpha = 0.788
n = 2
alpha = 0.72
C-17
required Thickness in Inches
Value of CBR in percent
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
0
2
4
6
8
10
12
14
16


COMPARISON OF THICKNESS REQUIREMENTS FOR BOEING 777 AS COMPUTED WITH LAYER ELASTIC METHOD AND NEW CBR METHOD(n=f(CBR))
STRAIN CRITERIA 6-WHEEL GEAR
n = function of CBR
Boeing 777
REQUIRED THICKNES
VALUE OF CBR
0
10
20
30
40
50
60
70
80
0
2
4
6
8
10
12
14
16

Military Trailer With M1A1



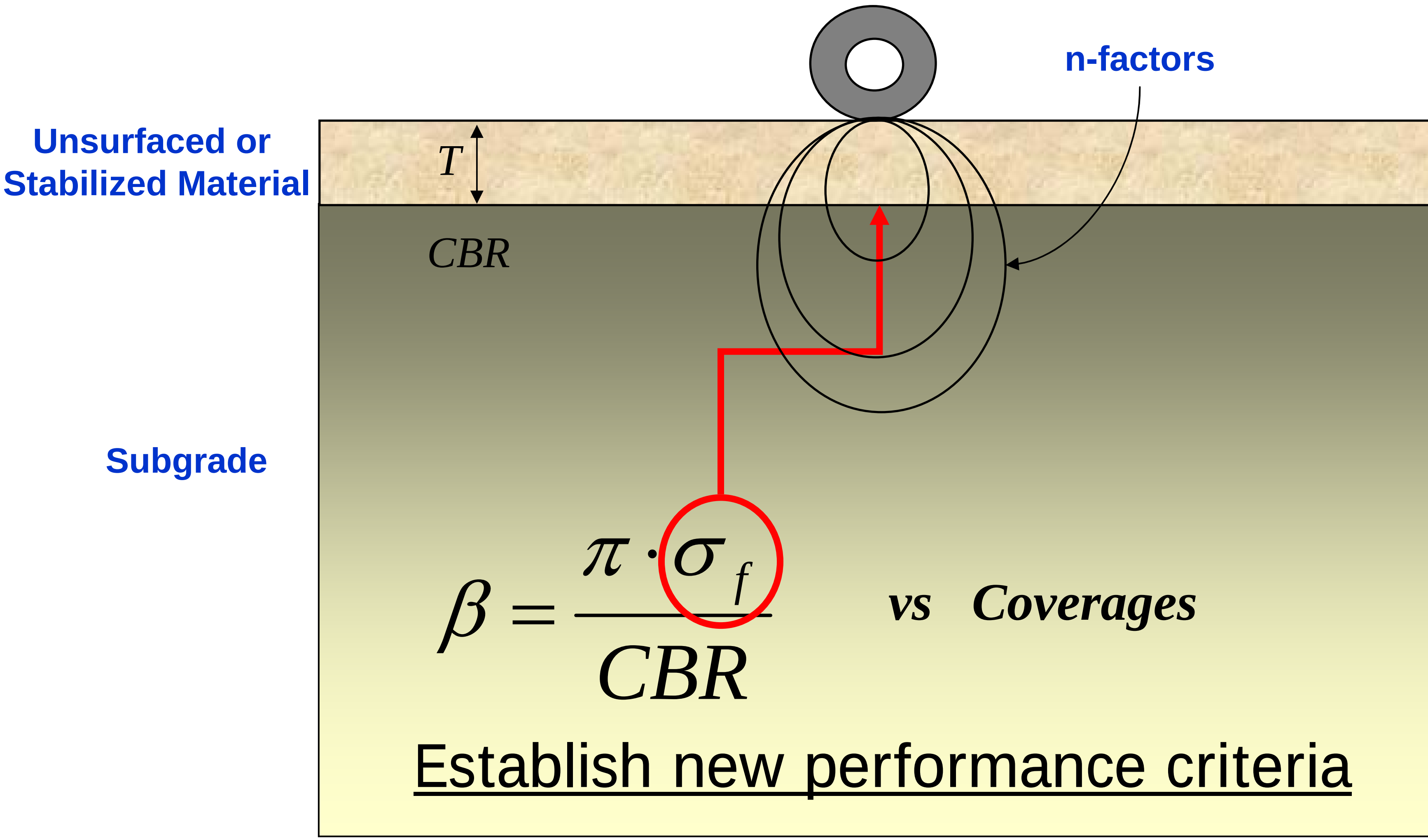
In the Final Form

- Design Criteria will be in terms of Beta
- Beta will be computed for each aircraft based on a concentration factor
- Concentration factor will be a function of Design CBR
- Traffic volume in terms of coverages will be a function of aircraft operations, number of tires, gear arrangement, and depth

What will be gained?

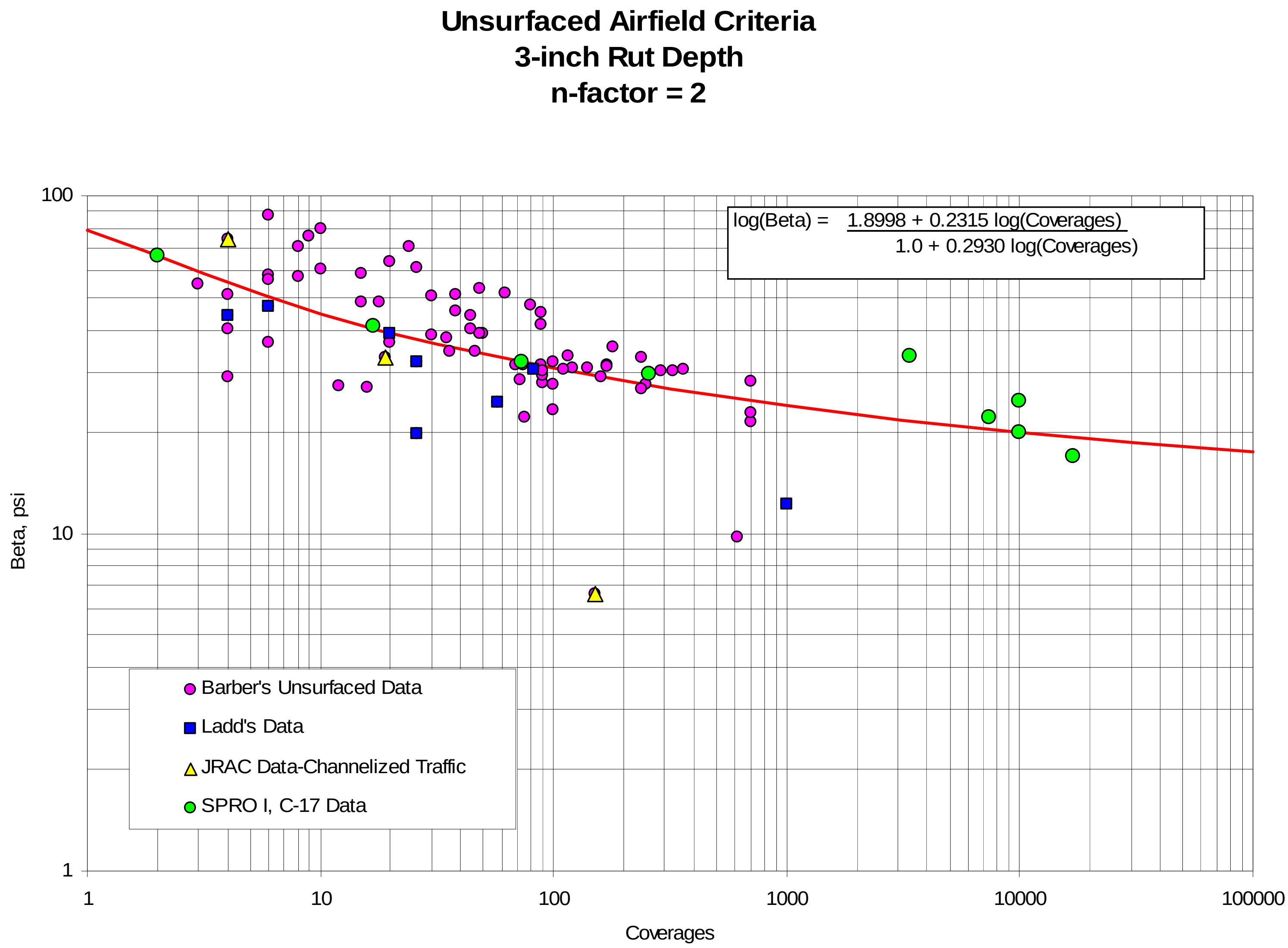
- The CBR method will be retained
- The design criteria becomes visible
- The procedure becomes more mechanistic
- A direct procedure for handling multi-wheel tire groups without the ESWL
- Will eliminate the need for α

Extend to Other Pavement Types

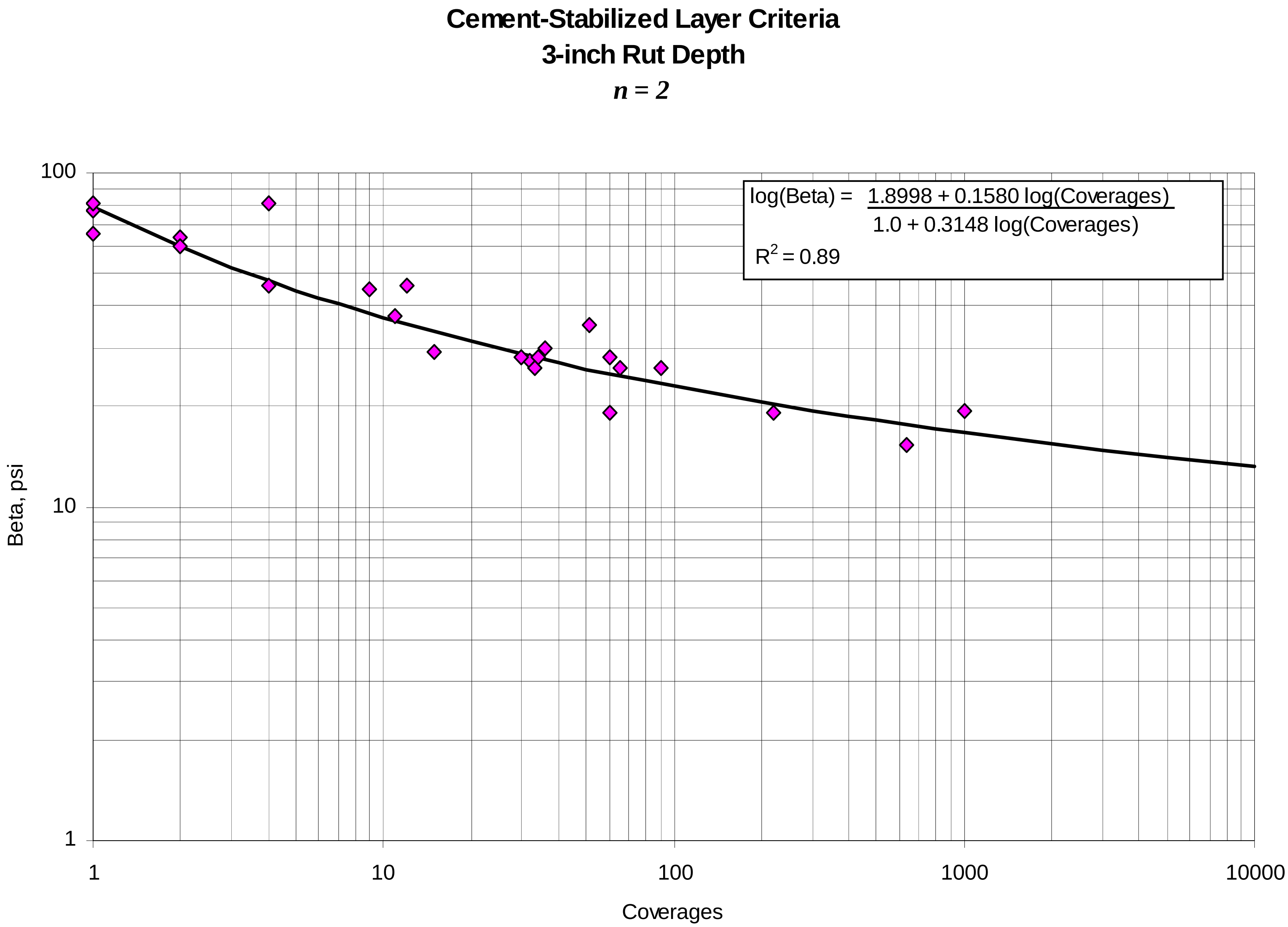


$$\beta = \frac{\pi \cdot \sigma_f}{CBR} \quad \text{vs Coverages}$$

Established Performance Criteria

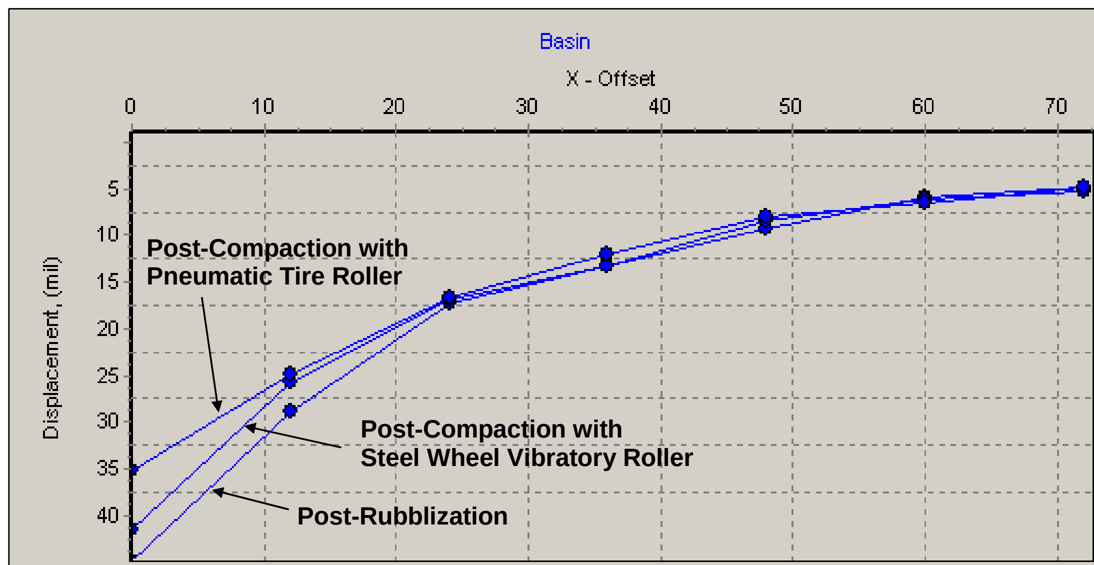


Established Performance Criteria



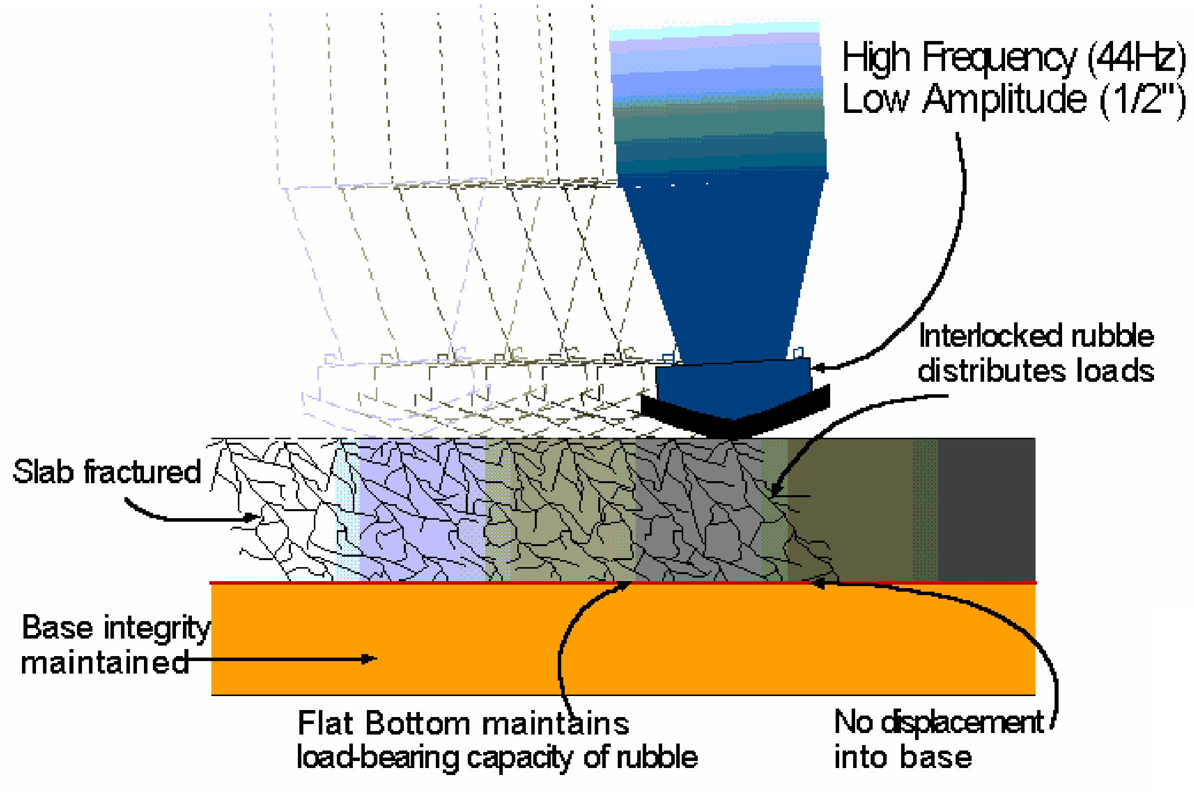
Rubblization

- ***Objective:***
  - Develop a design procedure and criteria for rubblized PCC pavements.
- ***Rubblization…***
  - …is a relatively "new" rigid pavement rehabilitation technique.
  - …eliminates existing slab action by breaking the PCC pavement into small particles



Ongoing Work – Analytical Studies

- ***How do we model this "new pavement structure" and be able to predict performance so we can establish a design criteria?***

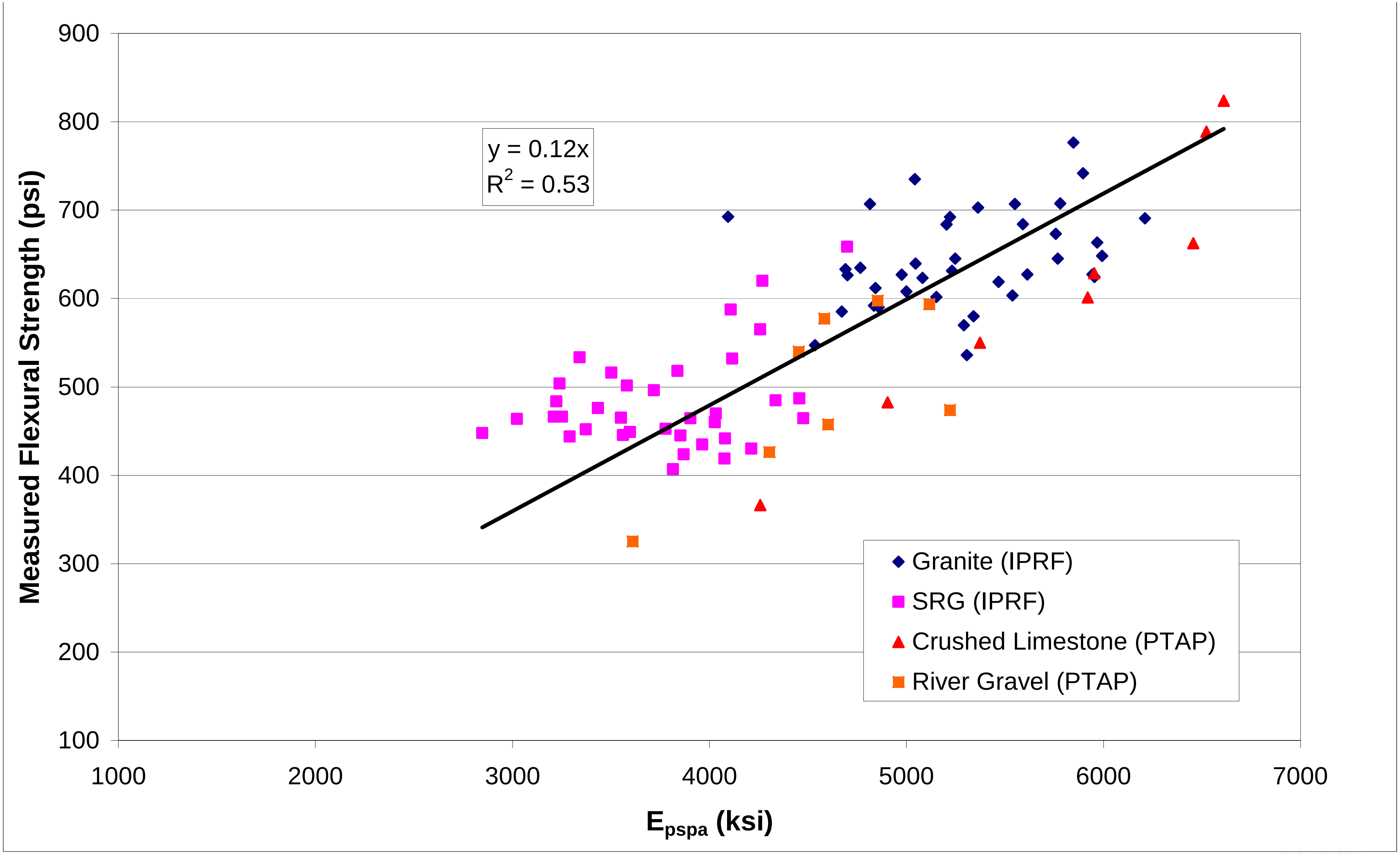


Research Work to be Done

- **Monitor FAA Pavement Test Facility, New Jersey**
  - Load/Rolling tests
    - HVS
    - Aircraft loading
- **Monitor Long-term Rubblization Projects**
  - Existing condition evaluations
  - Non destructive testing:
    - HWD/FWD
  - Traffic responses
    - 5 (+) year term
    - HVS-A
      - Full-Scale Accelerated Pavement Testing
- **Small-Scale/Laboratory Tests**
  - Test Box
    - 5ft x 5 ft x 6-in slab
    - Instrumented-Measure Stress/Deflections
    - Test intact, then rubblized and test again
    - Select a model that better represents actual behavior

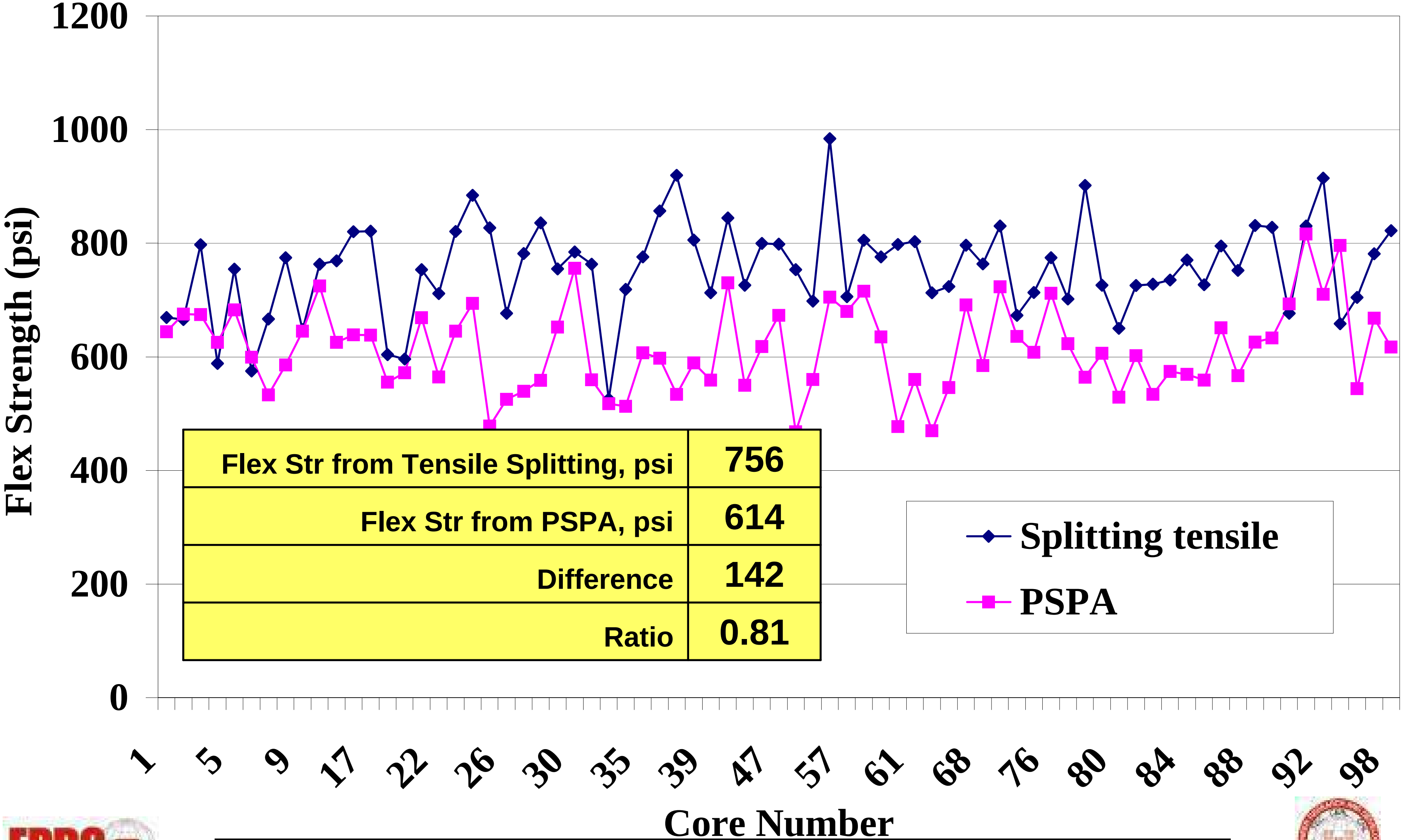
Portable Seismic Pavement Analyzer (PSPA)

Results from Recent Laboratory Studies



$$flexural\ \ strength = 0.12 * E_{PSPA}$$

PSPA vs. Tensile Splitting (Airfield Pavement)



Flex Str from Tensile Splitting, psi	756
Flex Str from PSPA, psi	614
Difference	142
Ratio	0.81

Hangar 4 – 15 Year Old PCC

Hangar 4 – Beams

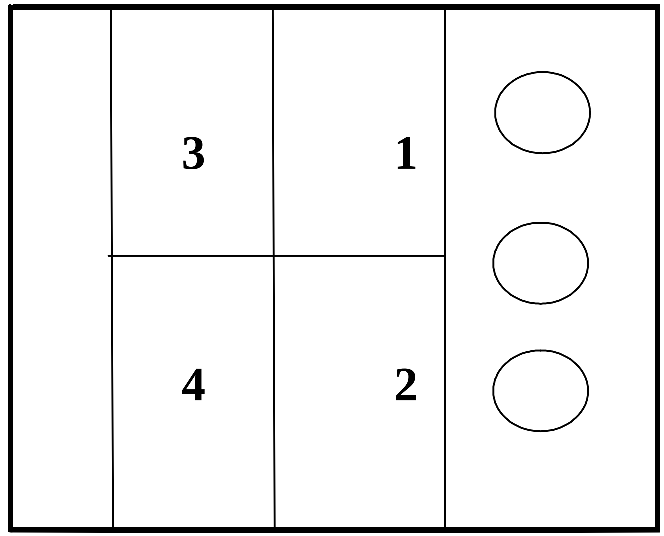
18” PCC Slab – Vicksburg (15 years old)

Core	FS (psi)
1	775
2	859
3	731
Avg Flex Str from Tensile Splitting=>	788

Avg Flex Str from PSPA (psi) =>	653

Ratio	0.83

Avg Modulus from PSPA (ksi)	5,441



Beam	FS (psi)
TOP 1	530
TOP 2	523
TOP 3	513
TOP 4	611
BOT 1	615
BOT 2	664
BOT 3	503
BOT 4	417
Avg =>	547

Questions??