In Situ Measurement of Density and Strength/Stiffness of HMA Mixtures

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Outline

- Objectives
- Scope
- Field Testing
- Laboratory Testing
- Discussion of Results
- Conclusions

Objectives

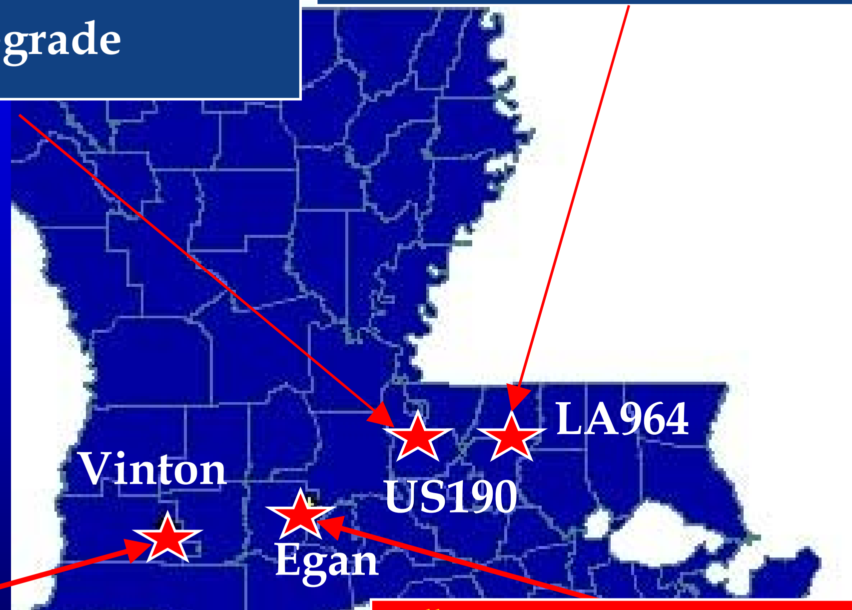
- Evaluate the variability of Air Voids of Plant Produced Mixtures
- Compare different methods of air void measurements
- Characterize SGC samples and field cores
- Assess the in-situ test measurements

Scope

- Four rehabilitation Projects
  - I-10 Egan
    - » 25.0 mm Superpave Binder Course
    - » 12.5 mm Superpave Wearing Course
  - I-10 Vinton
    - » SMA mixture
  - US190
    - » 25.0 mm Superpave Base Course
    - » 25.0 mm Superpave Binder Course
  - LA964
    - » 19 mm Type 8 Wearing Course

2″ 12.5mm-Superpave
4″ 25mm-Superpave
4″ 25mm-Superpave
10″ Fluorite Subbase
12″ lime-treated Subbase
Subgrade

1.5″ 19mm Type 8 Mix
4.5″ 25mm Type 8 Mix
9″ Soil-cement Base
12″ lime-treated Subbase
Subgrade



2″ SMA (12.5mm)
7″ 25mm-Superpave
10″ Rubblized PCC
Silty Clay Subgrade
(AASHTO A-6)

2″ 12.5mm-Superpave
7.5″ 25mm-Superpave
10″ Rubblized PCC
Silty Clay Subgrade
(AASHTO A-6)

Experimental Design

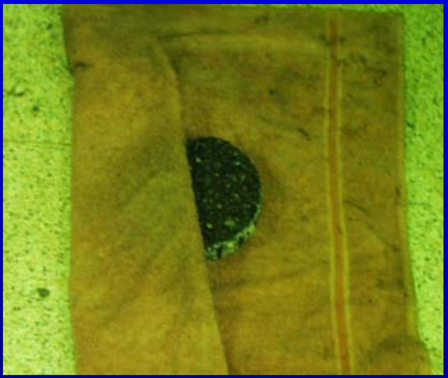
- Field Evaluation
  - In-situ Density
    - PQI Model 301
  - FWD
  - LFWD
  - PSPA
- Laboratory Evaluation
  - Density
    - Conventional, Vacuum Sealing
  - Mechanistic Properties
    - Indirect tensile strength
    - Indirect tensile resilient modulus
    - Frequency sweep at constant height

Mobile Laboratory

- **Test section**
  - Collect sufficient loose mixtures from the paver
  - Mixture composition analysis
  - Compacted Samples
    - » Air voids
    - » Mechanistic tests

Laboratory Density Measurement

- Cores and SGC samples
- Conventional (Saturated Surface Dry) Method
  - AASHTO T166

- Vacuum Sealing Method
  - CoreLok
  - ASTM D 6752



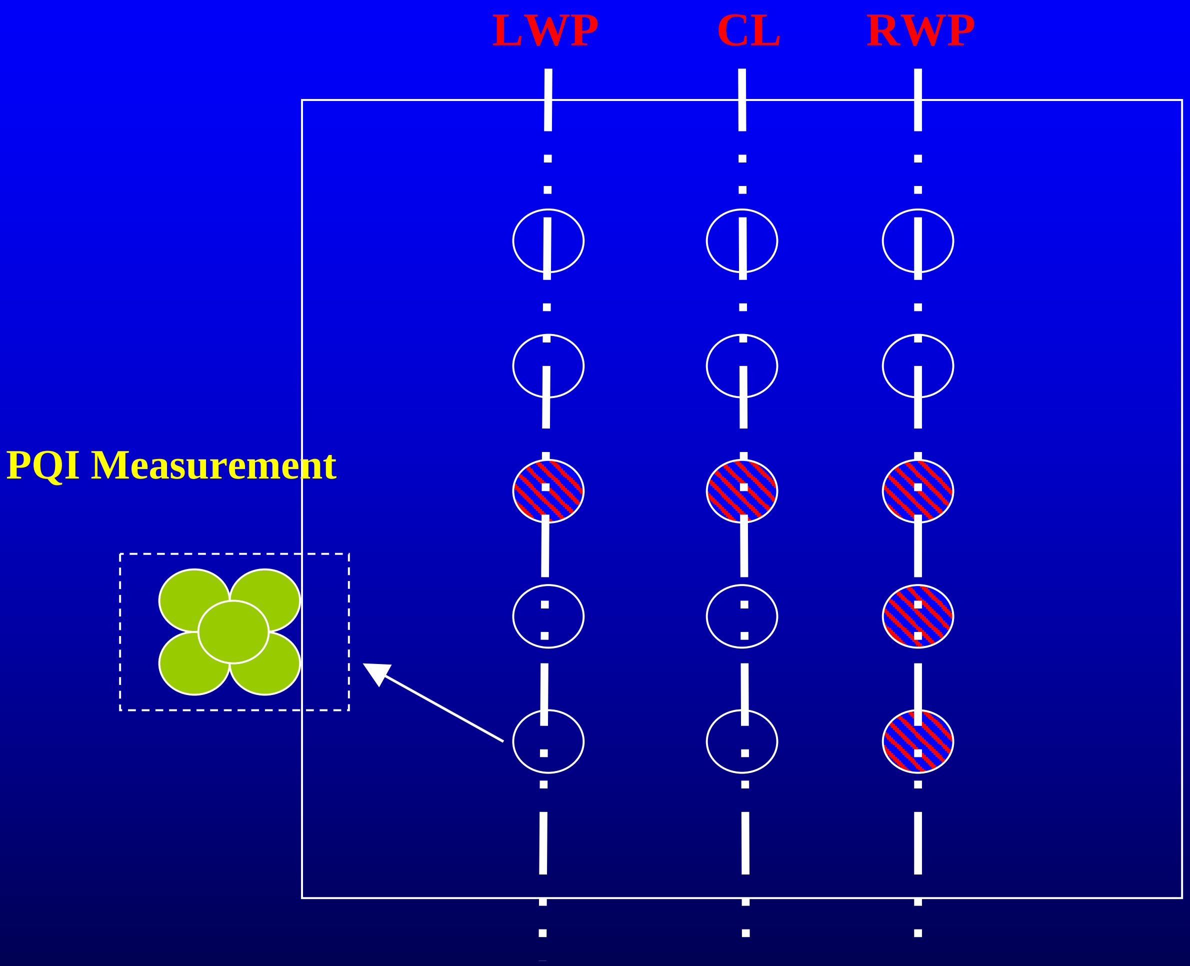
Laboratory Mechanistic Tests

- Indirect Tensile Strength Test
  - 25°C
  - Each test section:
    - » One Core and SGC sample
  - Analysis: ITS
- Indirect Tensile Resilient Modulus Test
  - 5 °C, 25°C, and 40°C
  - Each test section:
    - » One Core and SGC sample
  - Analysis: ITMr
- FSCH
  - AASHTO TP 7
  - 48°C and 60°C
  - Each test section:
    - » One Core and SGC sample
  - Analysis: G* and δ

Field Test Section Layout

- Density
  - 5 tests per point
  - 15 point
  - 75 test results

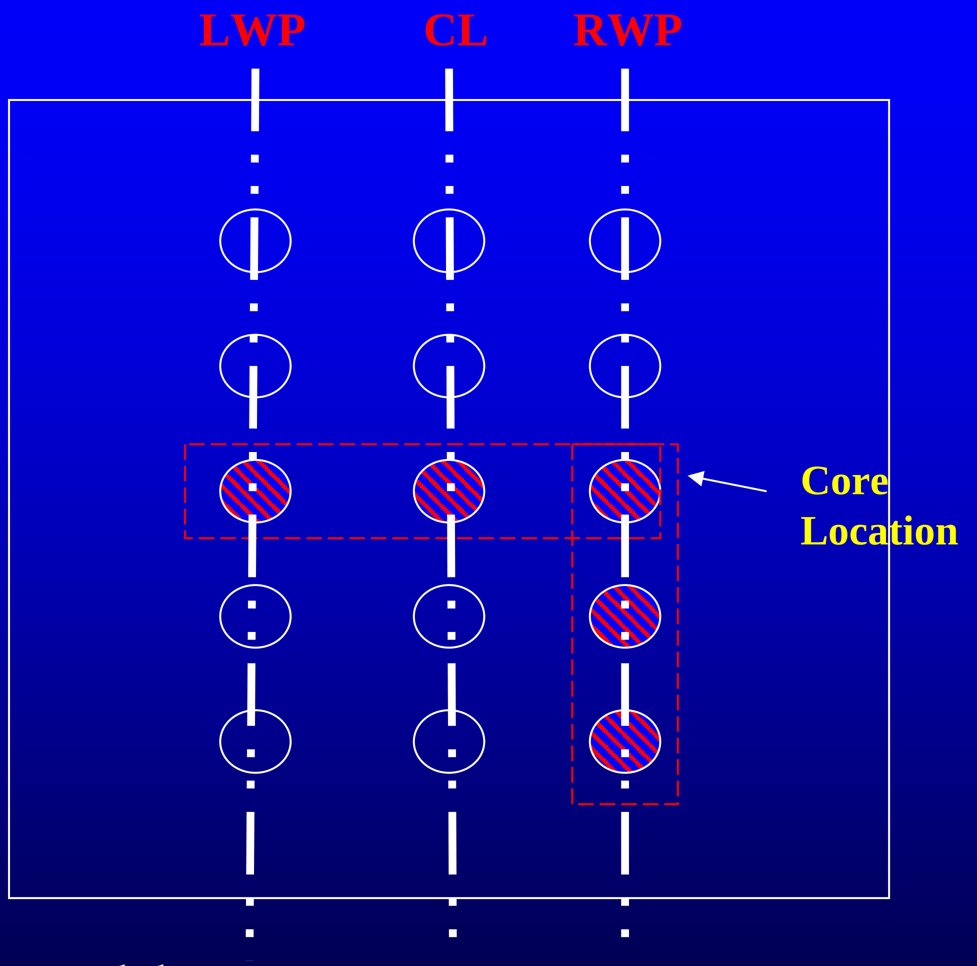
PQI model 301
TransTech System, Inc.



Field Test Section Layout (contd..)

- FWD & LFWD
  - 15 points

FWD
Dynatest 800 model



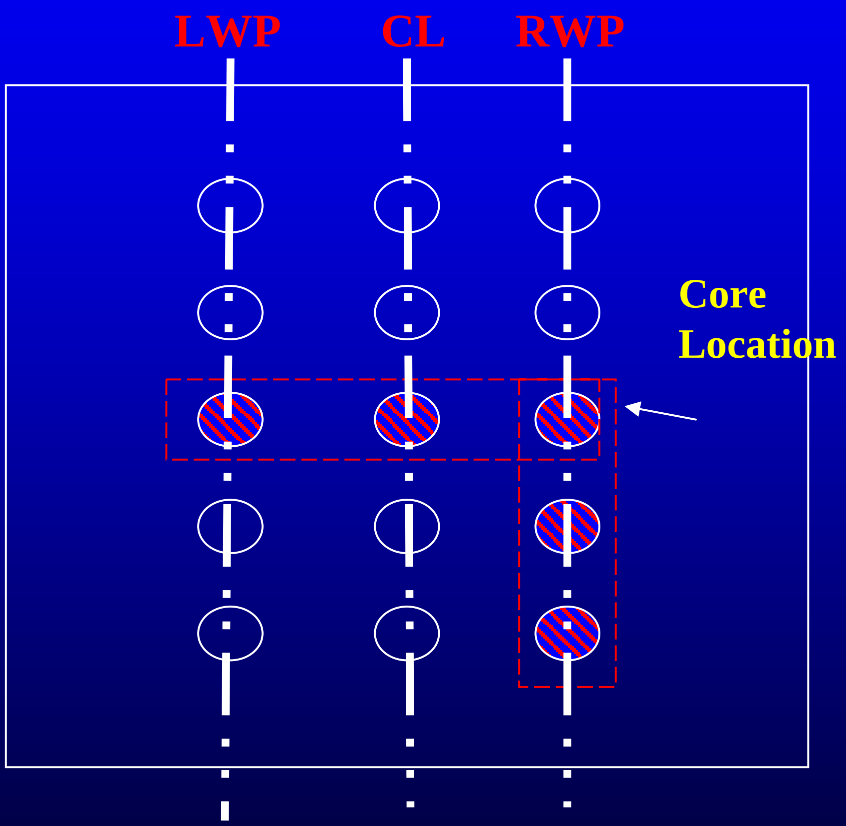
LFWD – PRIMA 100 model
Carl Bro Company, Denmark

Field Test Section Layout (contd..)

Portable Seismic Pavement Analyzer (PSPA)

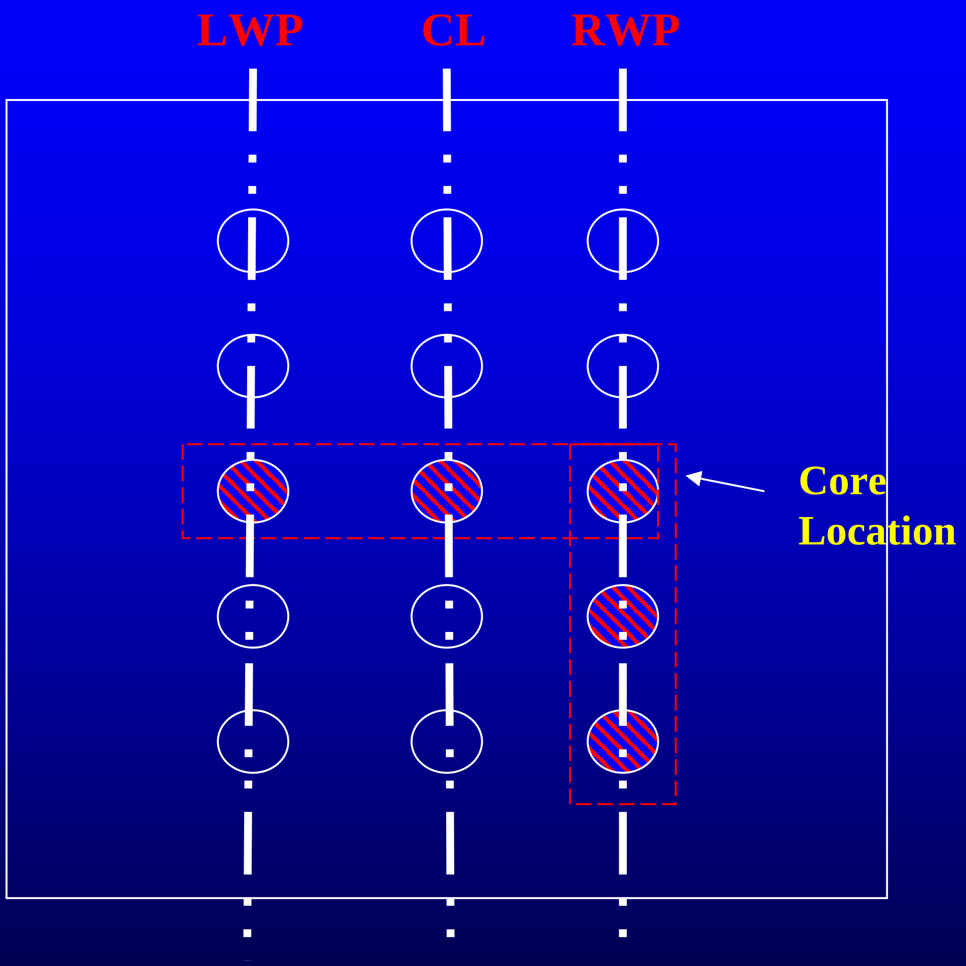
- **PSPA**
  - 15 points

PSPA-D
Geomedia Research & Development Inc.



Field Test Section Layout (contd..)

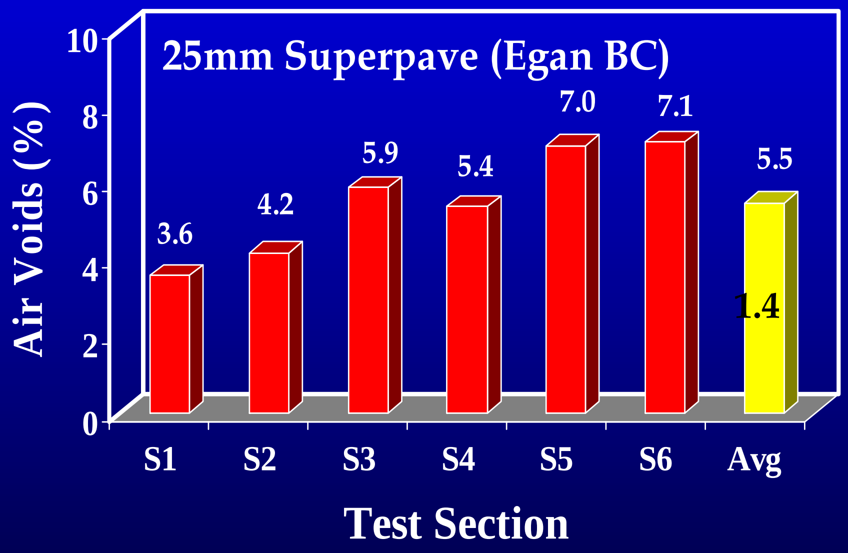
- Cores
  - 3: 6″ diameter
  - 2: 4″ diameter

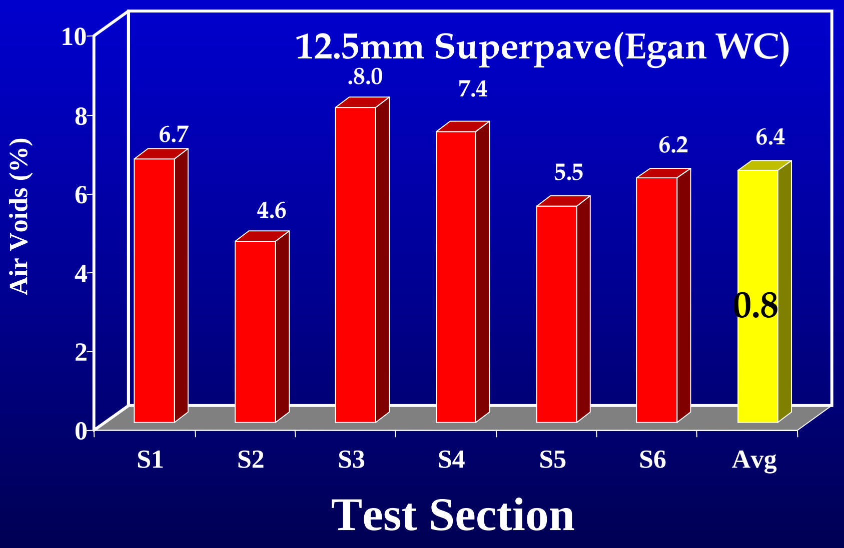


Results of Methods of Air Voids Measurements

Typical Variation of Air Voids Measurement

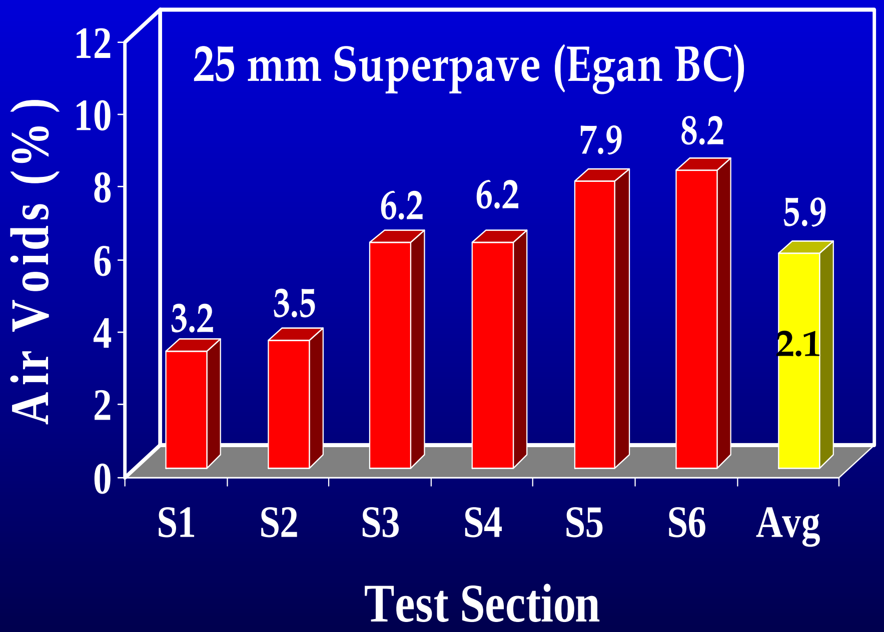
I. Conventional Method (AASHTO T-166)

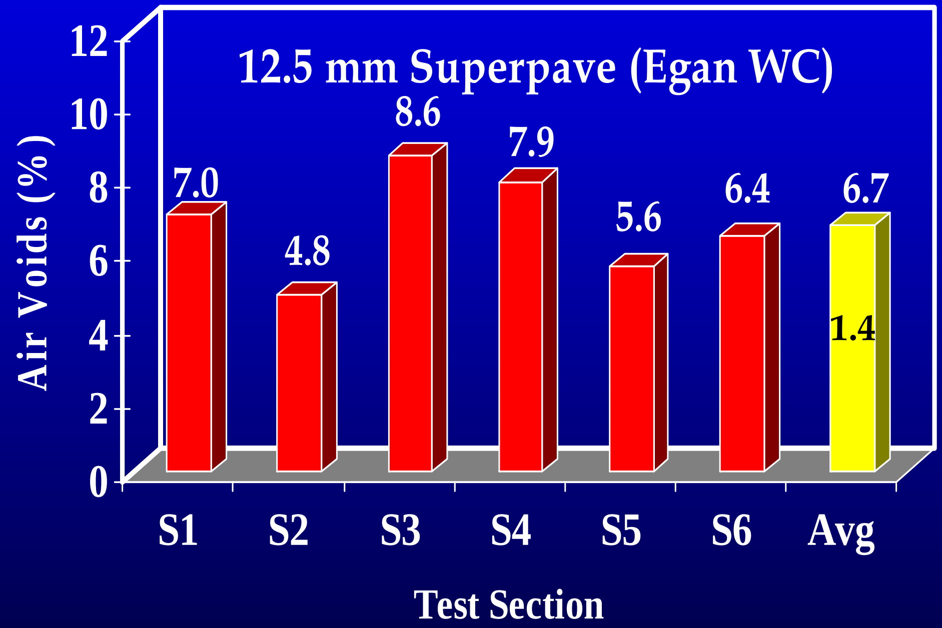




Typical Variation of Air Voids Measurement (Contd..)

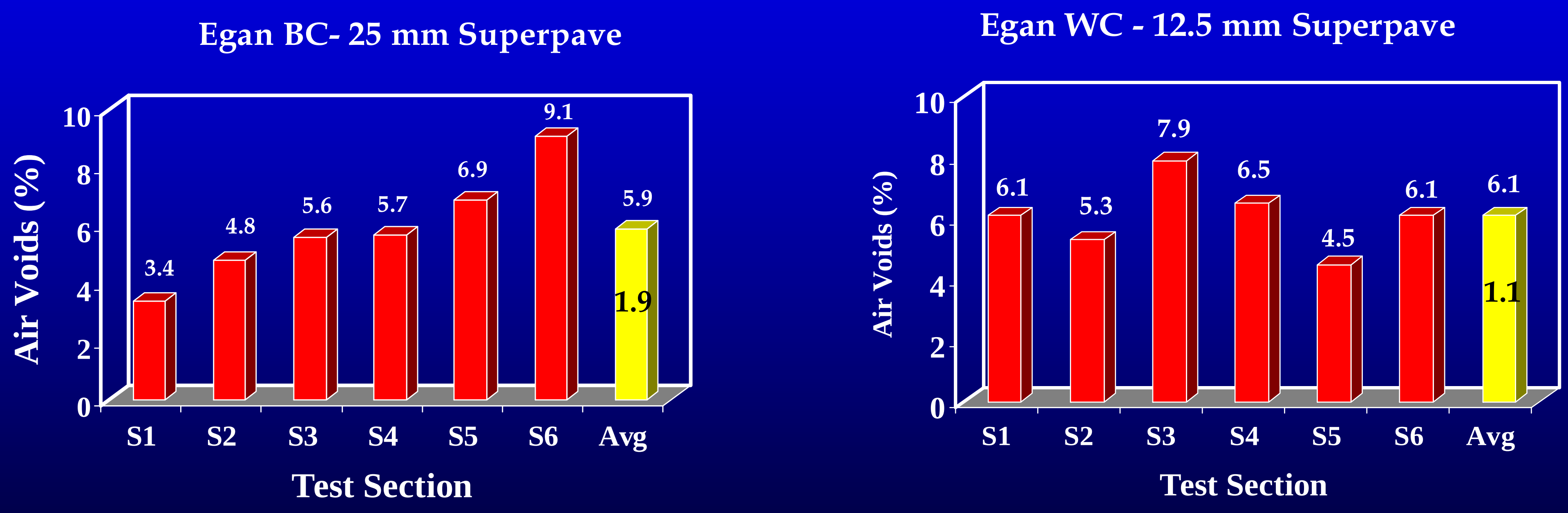
II. Vacuum Sealing Method (CoreLok)



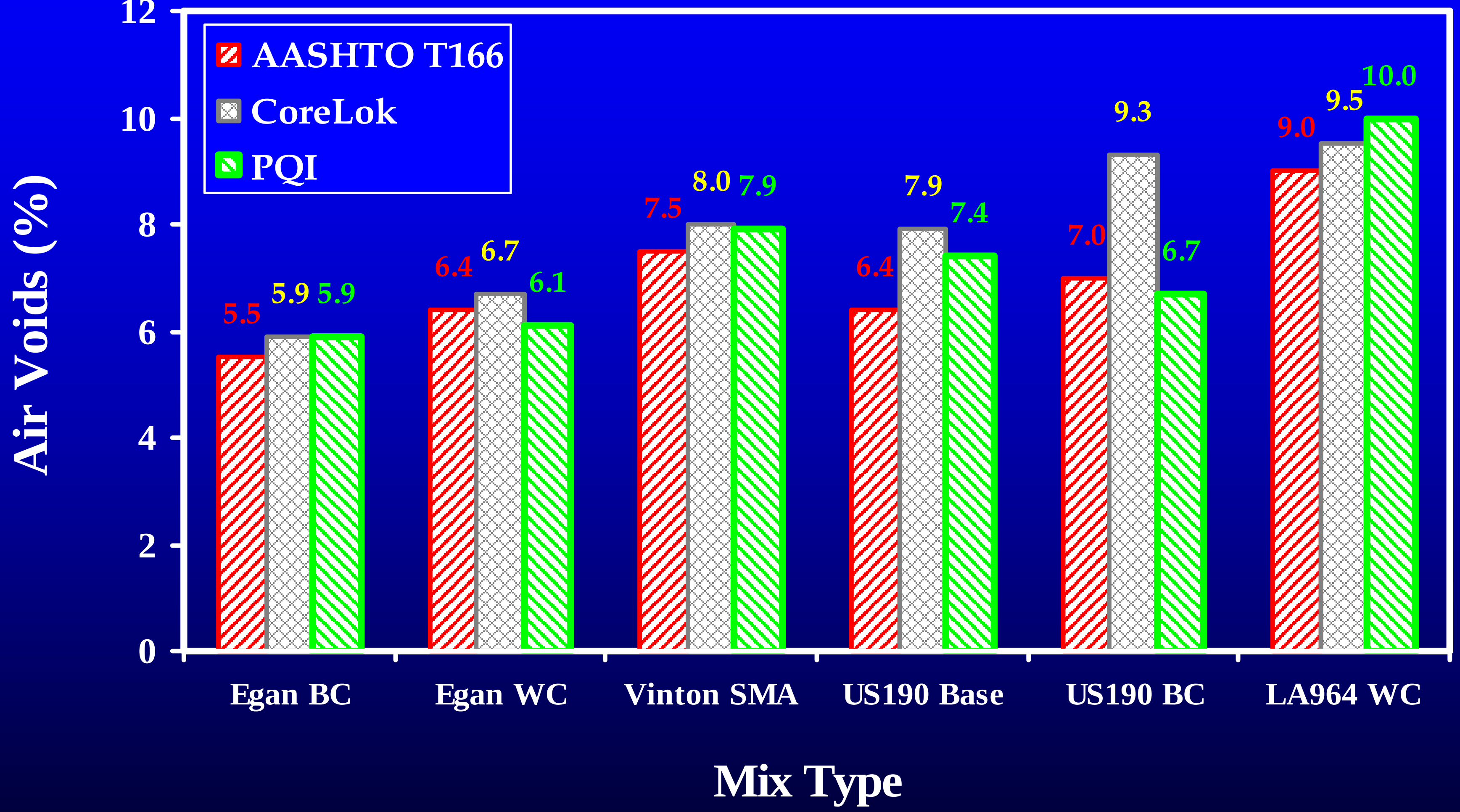


Typical Variation of Air Voids Measurement (Contd..)

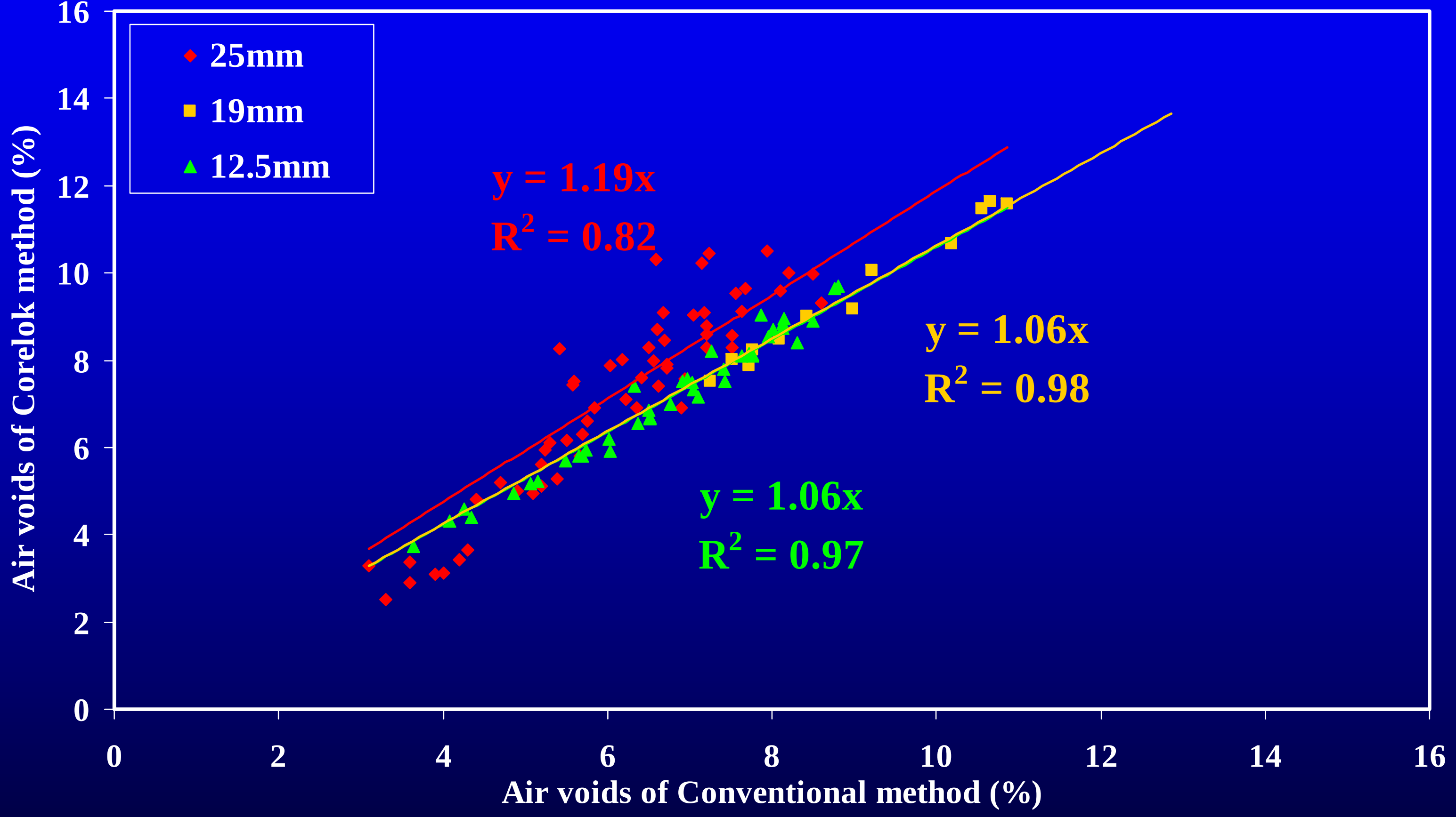
III. Pavement Quality Indicator (PQI)



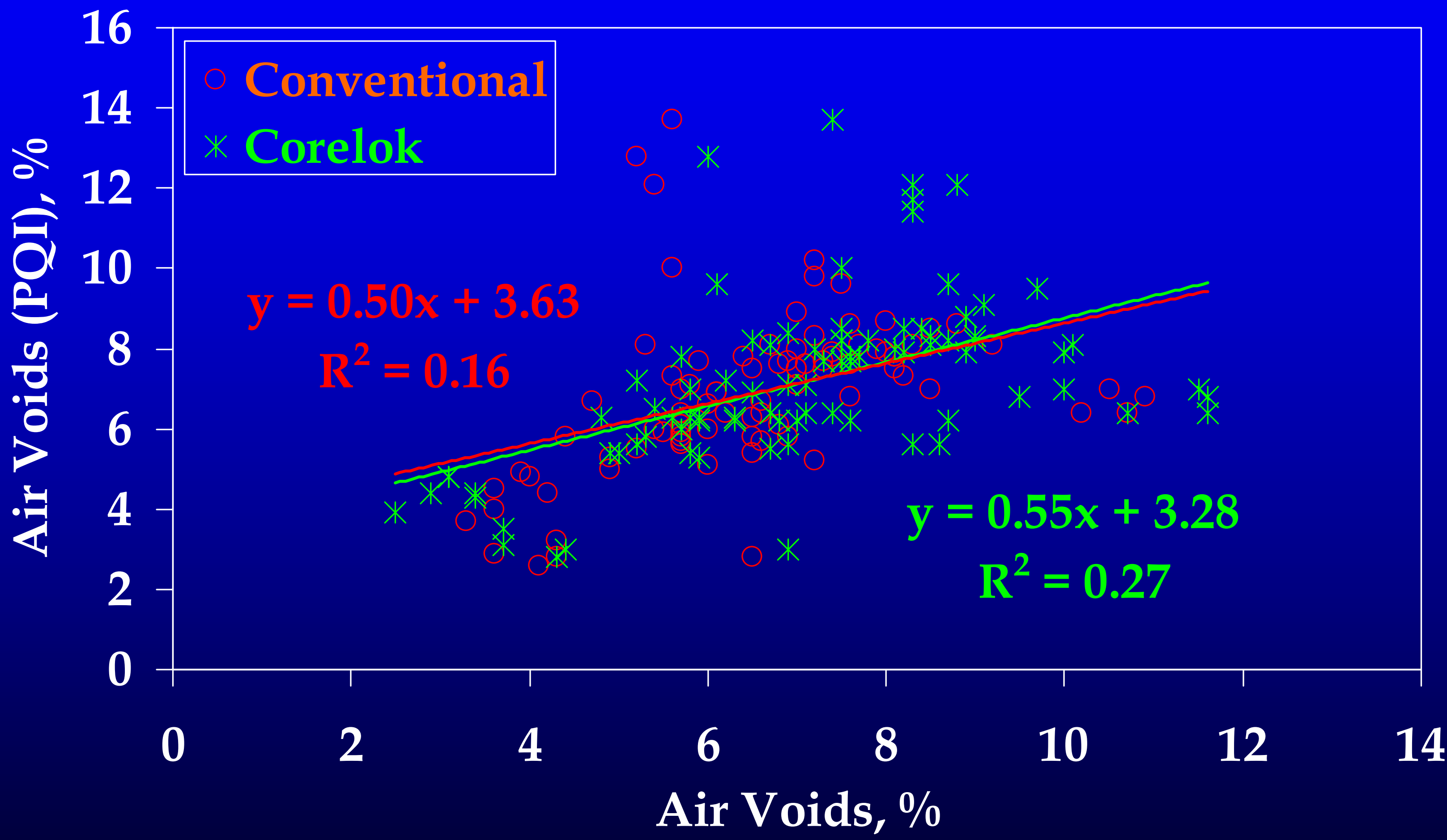
Comparison of Average Air Voids



Relationship of Air Voids Test Methods
(Conventional vs CoreLok)



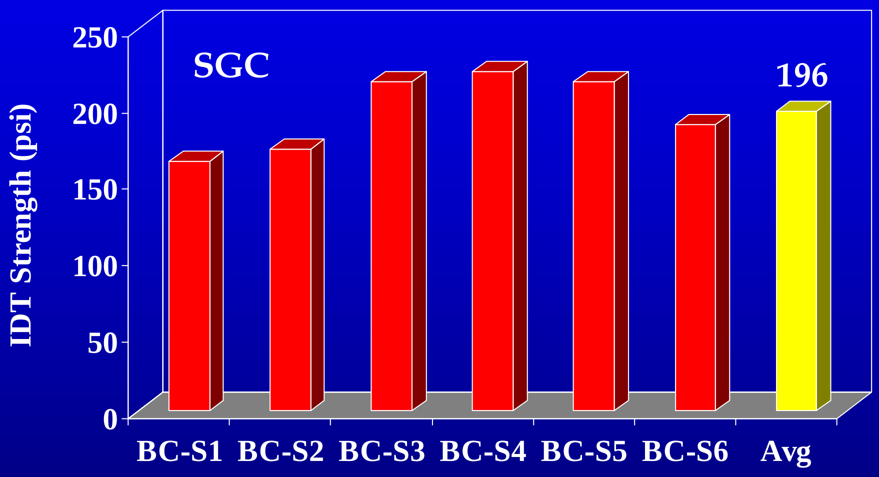
Relationship of Air Voids Test Methods
(PQI vs. Conventional / CoreLok)

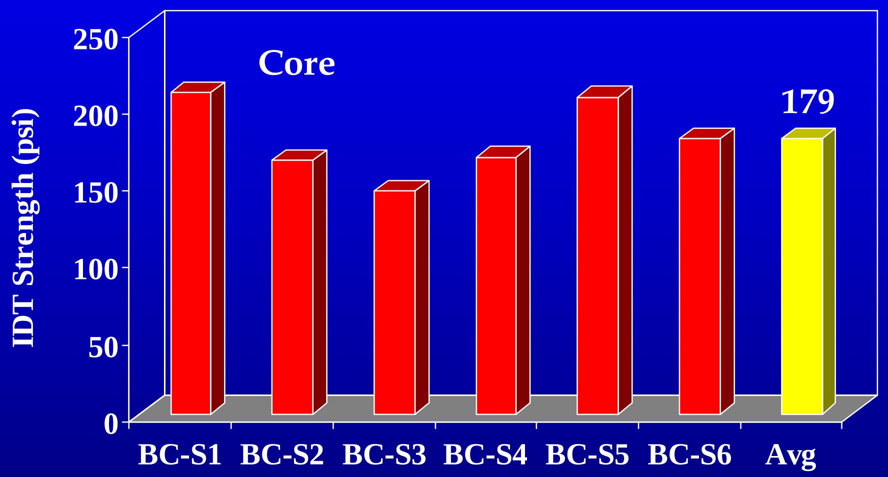


*Variation of ITS , ITMr, and G**

Typical Variation of ITS

I 10 Egan Binder Course (25 mm Superpave)



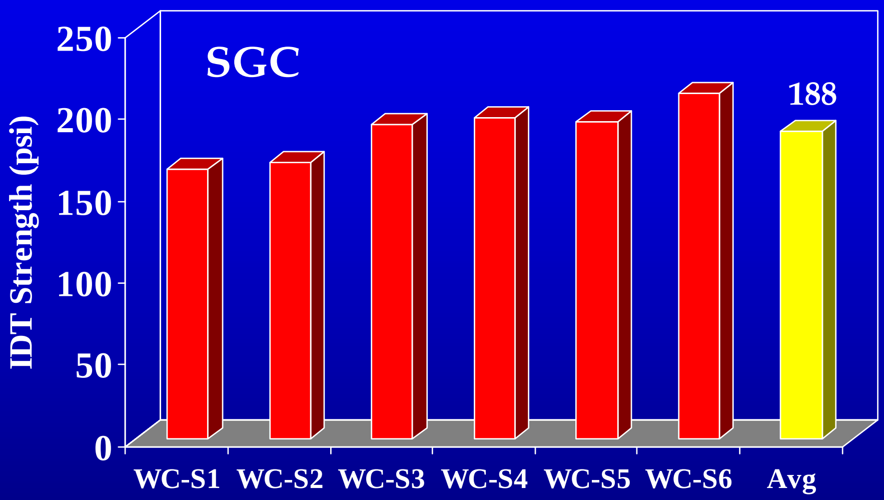


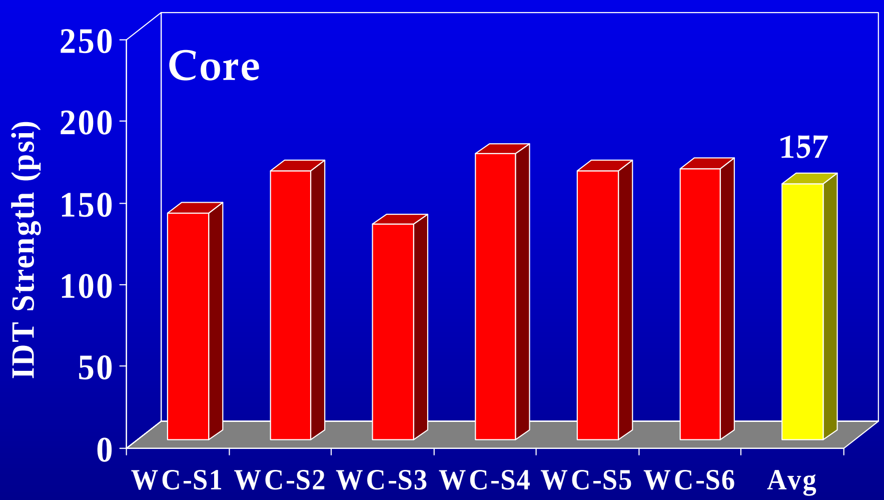
- SGC
  - Mean = 196psi
  - STD = 25psi
  - CV = 13%

- Core
  - Mean = 179psi
  - STD = 25psi
  - CV = 14%

Typical Variation of ITS (Contd..)

I 10 Egan Wearing Course (12.5mm Superpave)

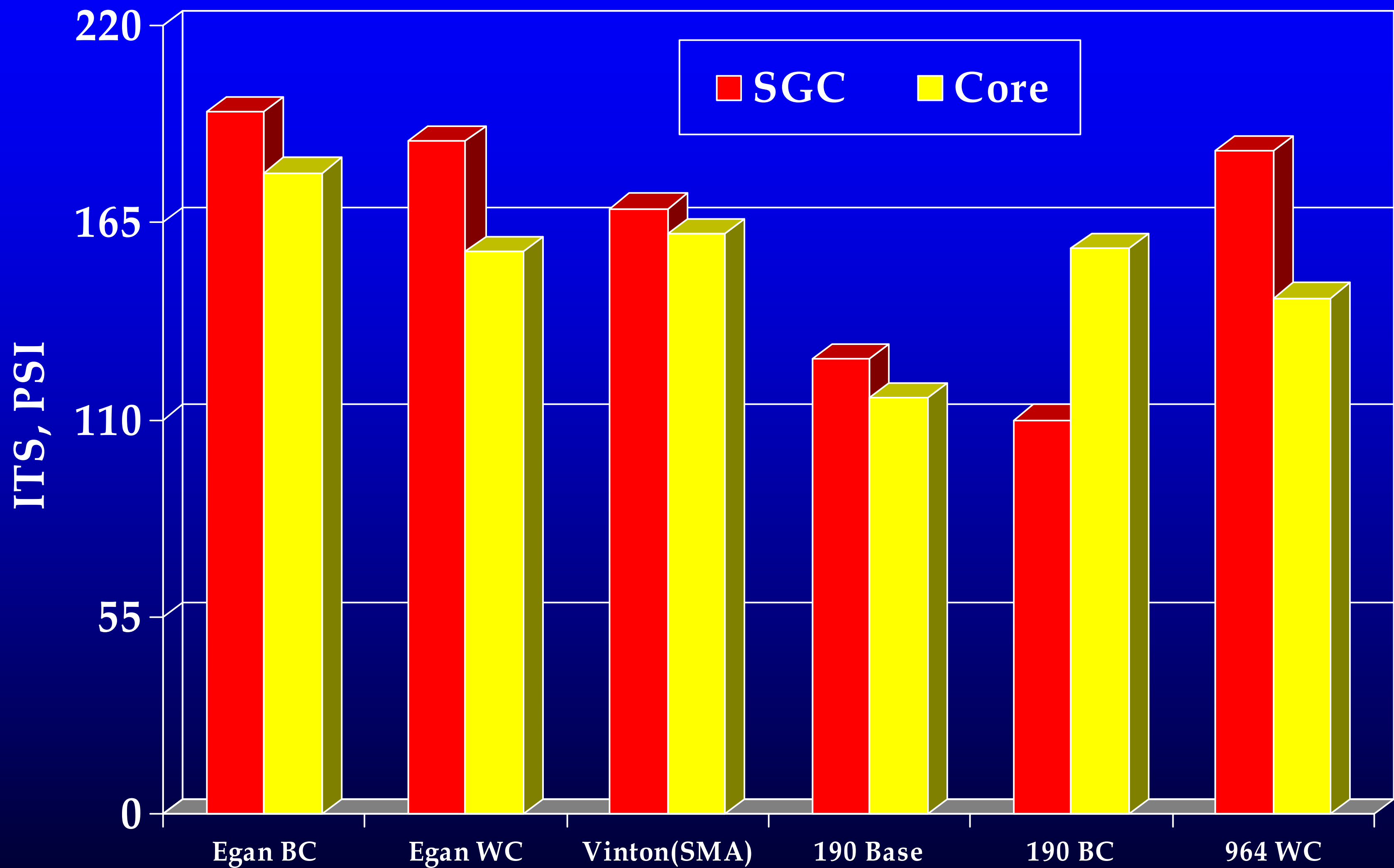




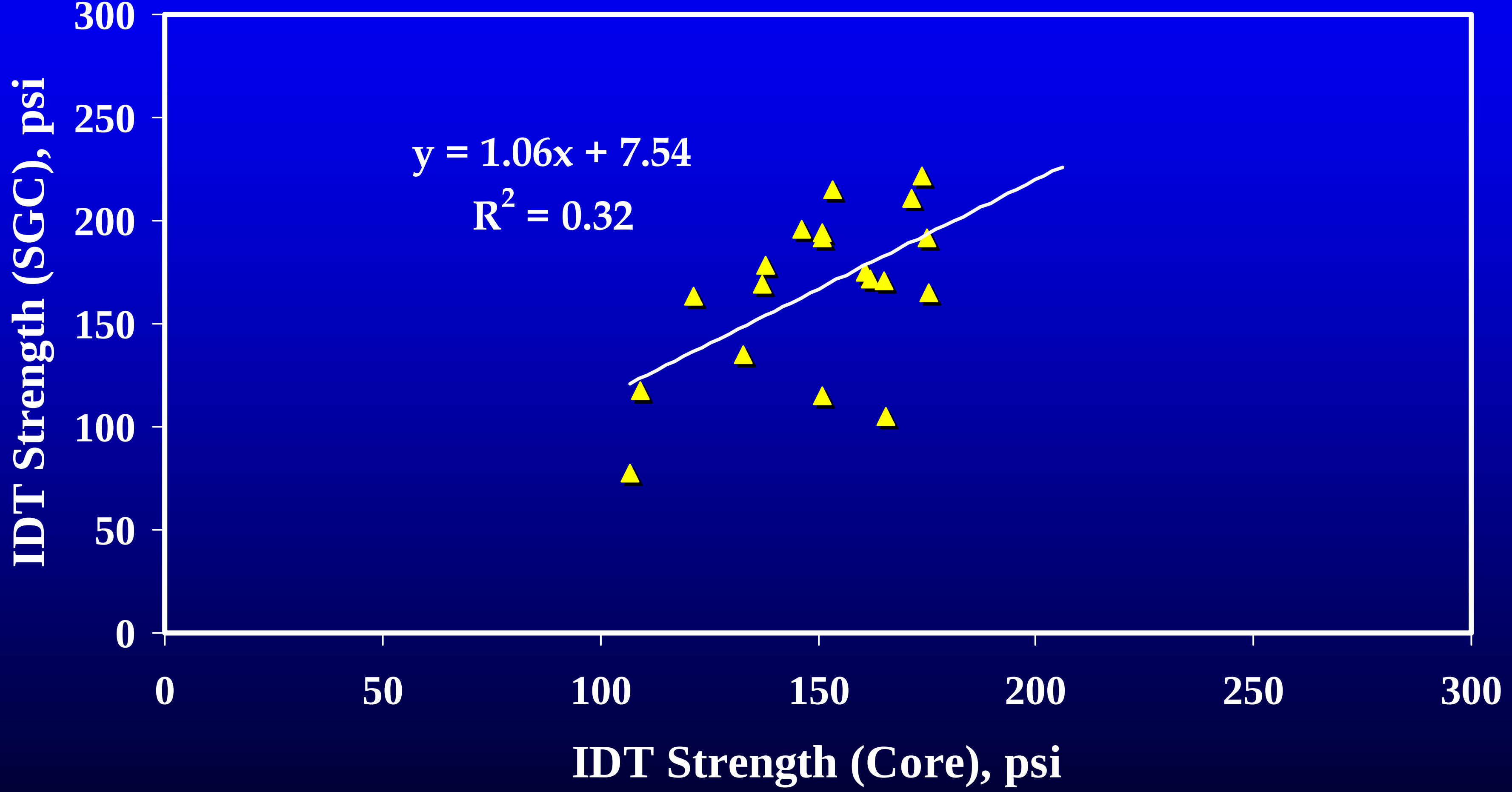
- SGC
  - Mean = 188psi
  - STD = 18psi
  - CV = 9%

- Core
  - Mean = 157psi
  - STD = 17psi
  - CV = 11%

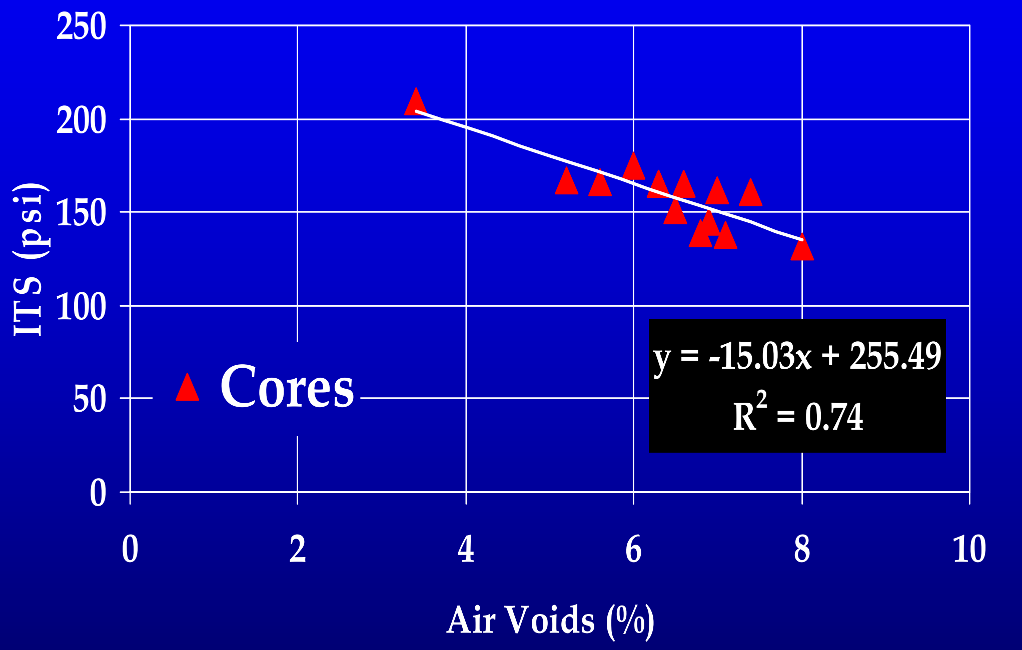
Average ITS Results (25 ºC)

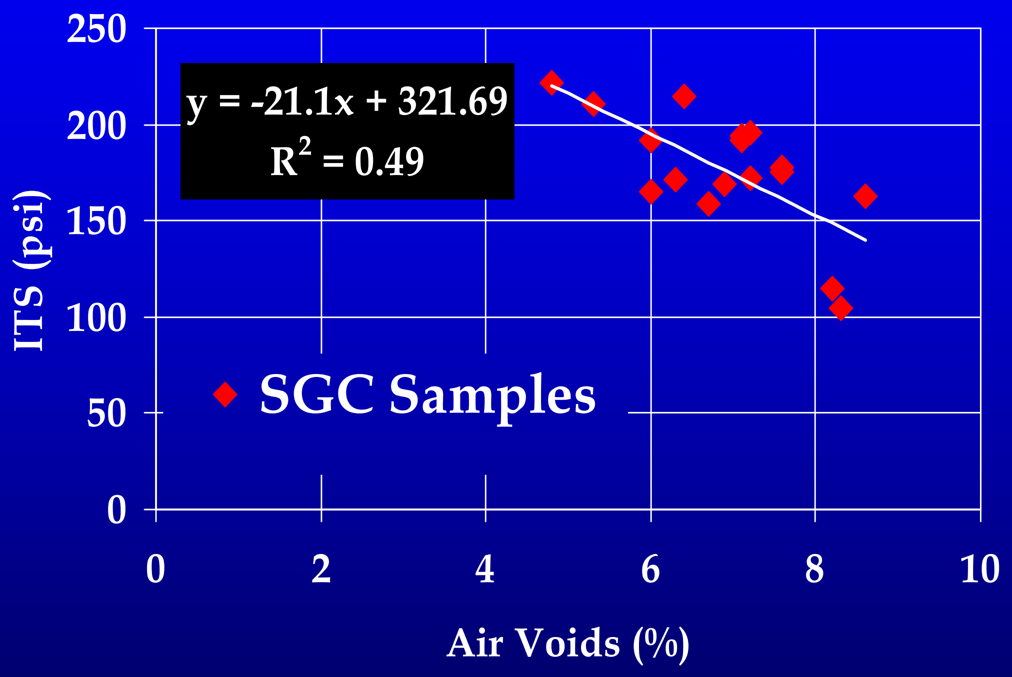


ITS(SGC) vs ITS (Core)

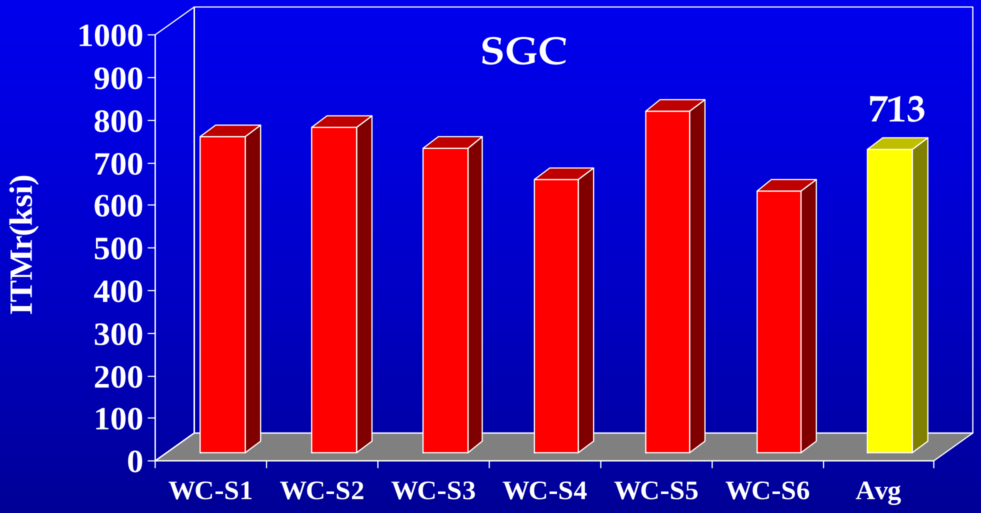


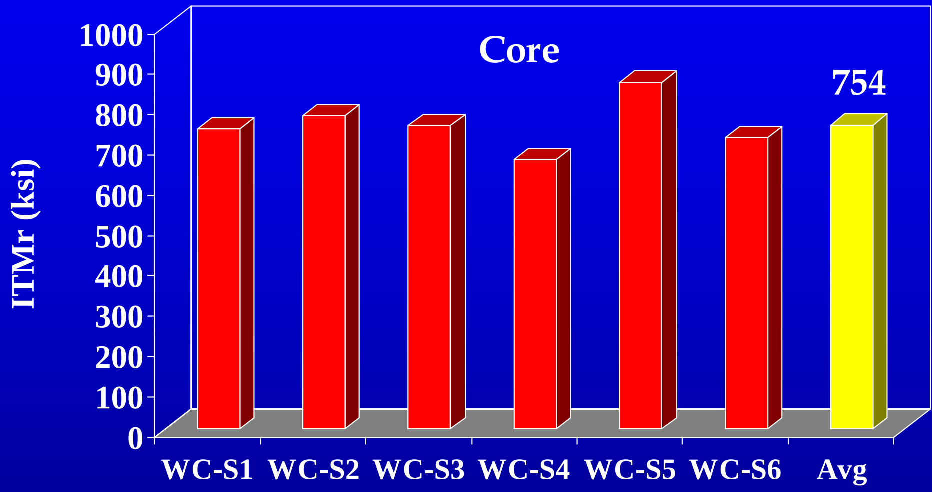
ITS vs Air Voids





Variation of ITMr – I 10 Egan 12.5 mm Mixture – 5°C

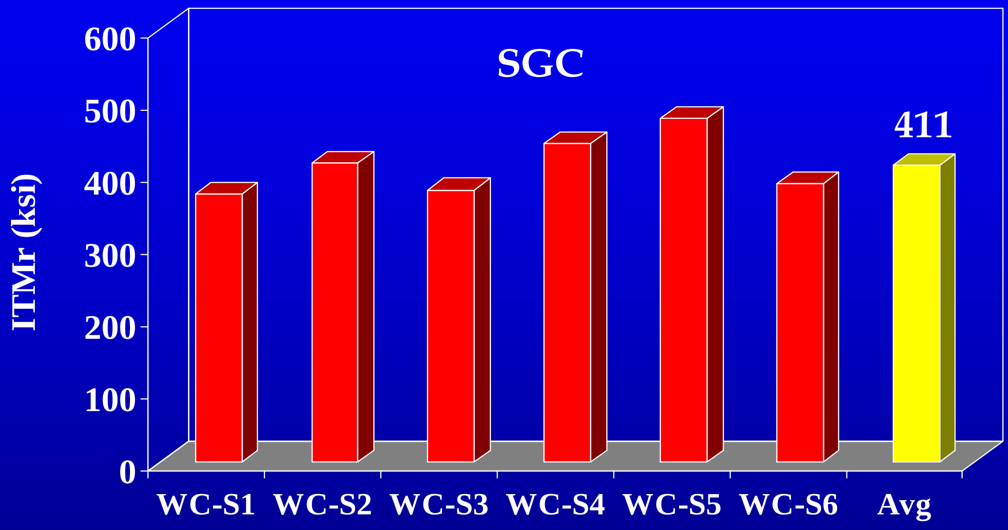


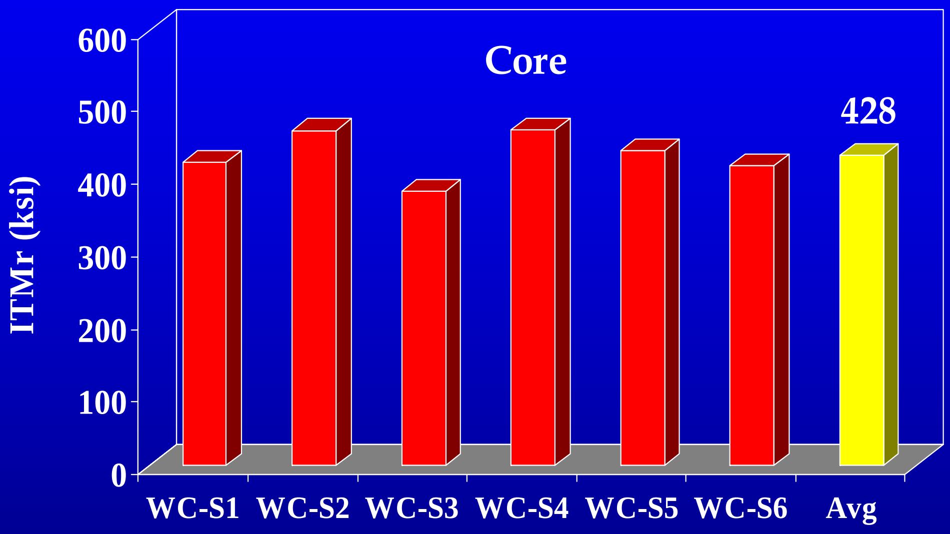


- **SGC**
  - Mean = 713ksi
  - STD = 72ksi
  - CV = 10%

- **Core**
  - Mean = 754ksi
  - STD = 63ksi
  - CV = 8%

Variation of ITMr – I 10 Egan 12.5 mm Mixture – 25°C

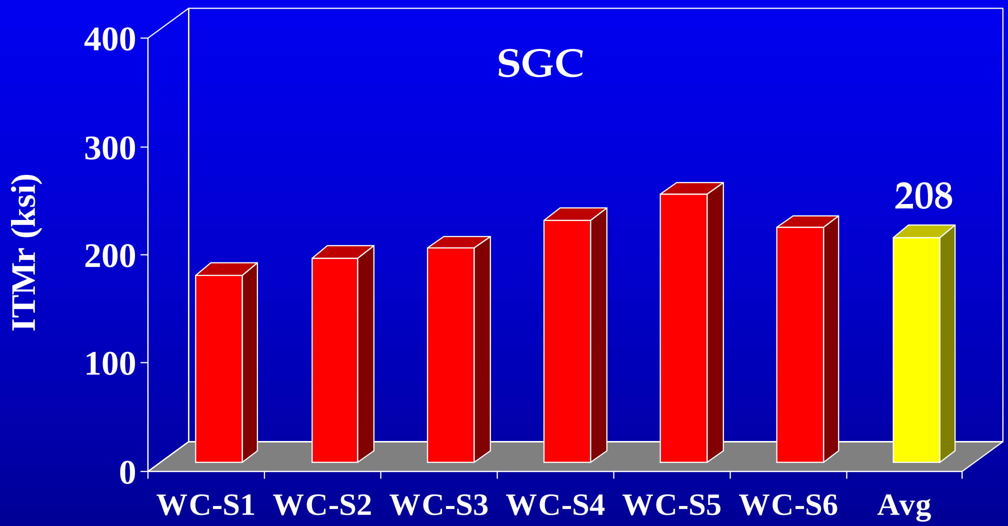


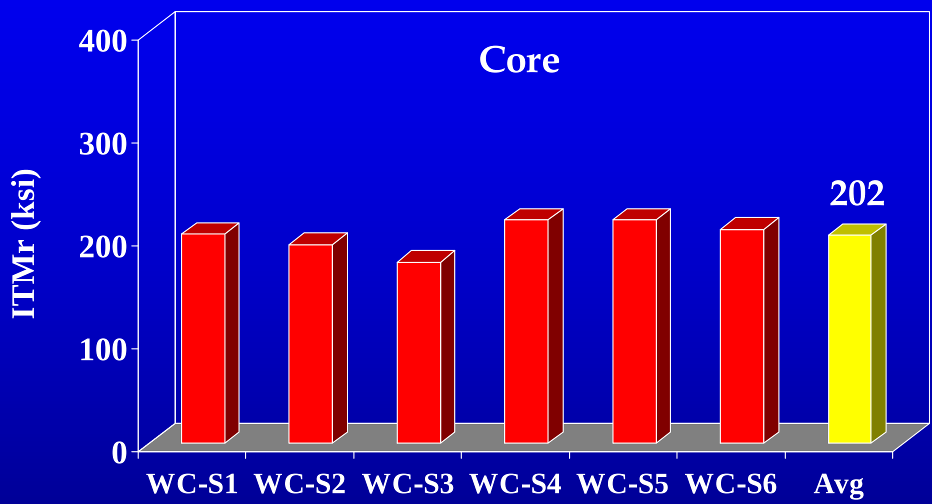


- SGC
  - Mean = 411ksi
  - STD = 41ksi
  - CV = 10%

- Core
  - Mean = 428ksi
  - STD = 32ksi
  - CV = 8%

Variation of ITMr – I 10 Egan 12.5 mm Mixture – 40°C

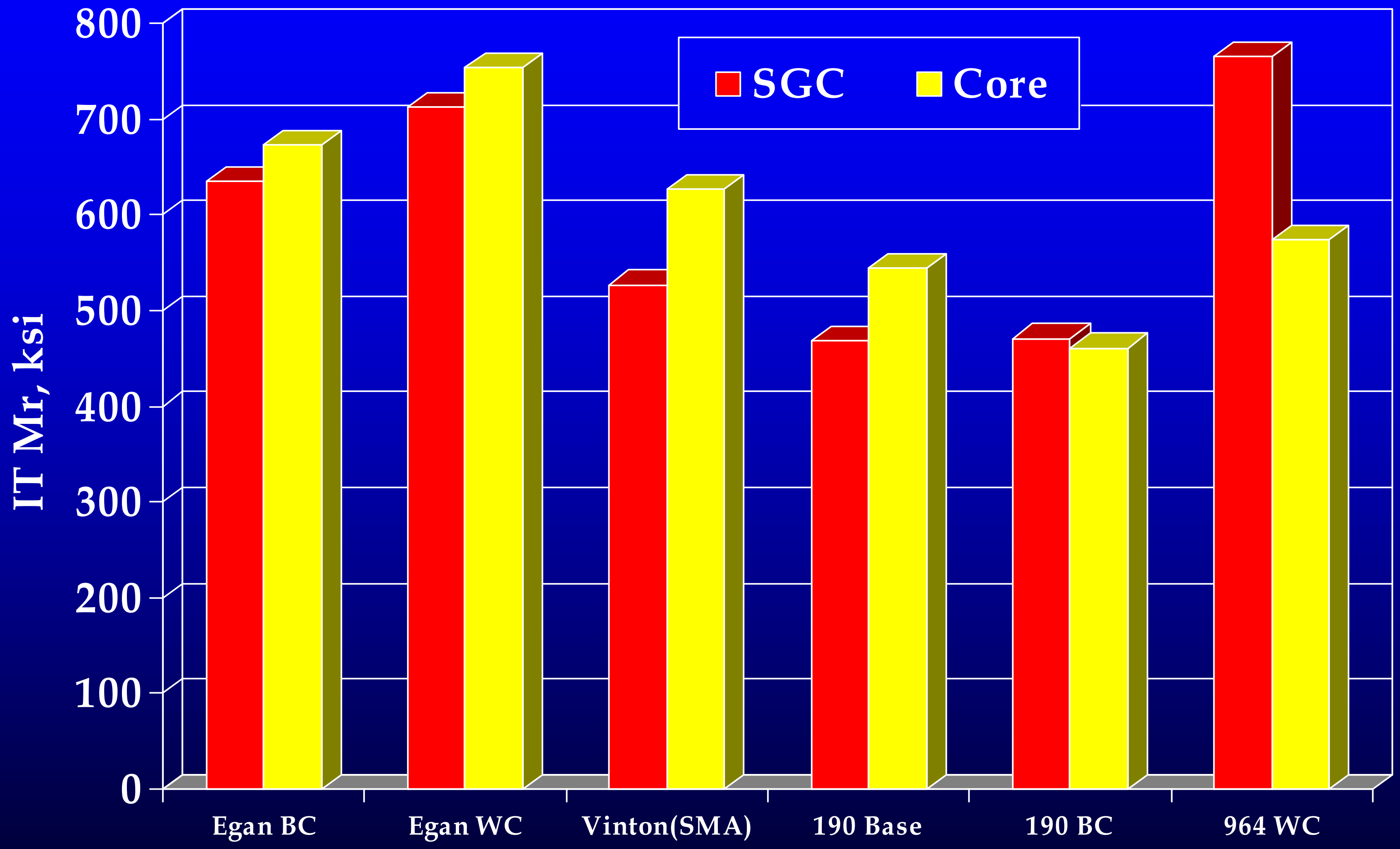




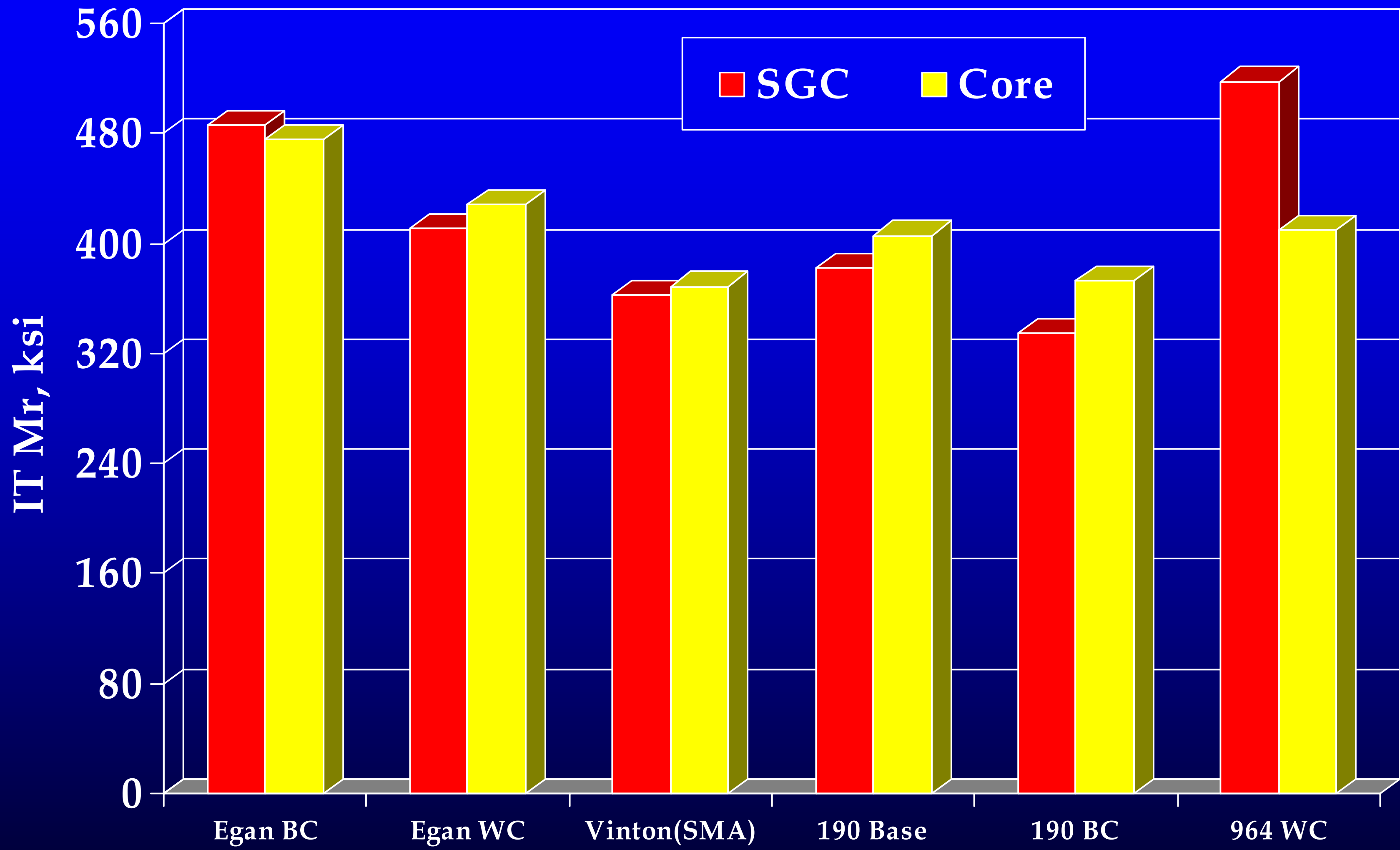
- **SGC**
  - Mean = 208ksi
  - STD = 27ksi
  - CV = 13%

- **Core**
  - Mean = 202ksi
  - STD = 16ksi
  - CV = 8%

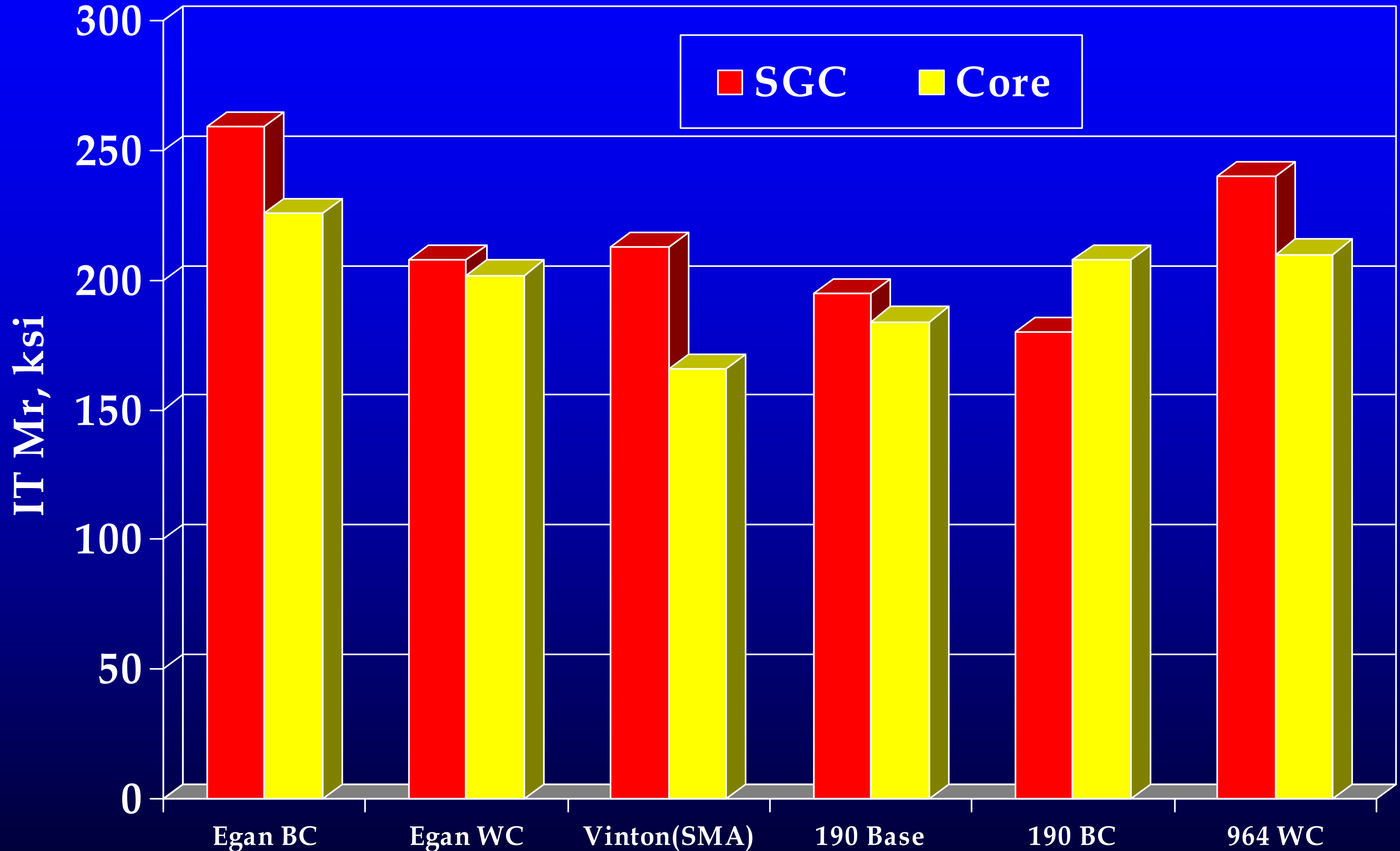
Average IT Mr Results (5 ºC)



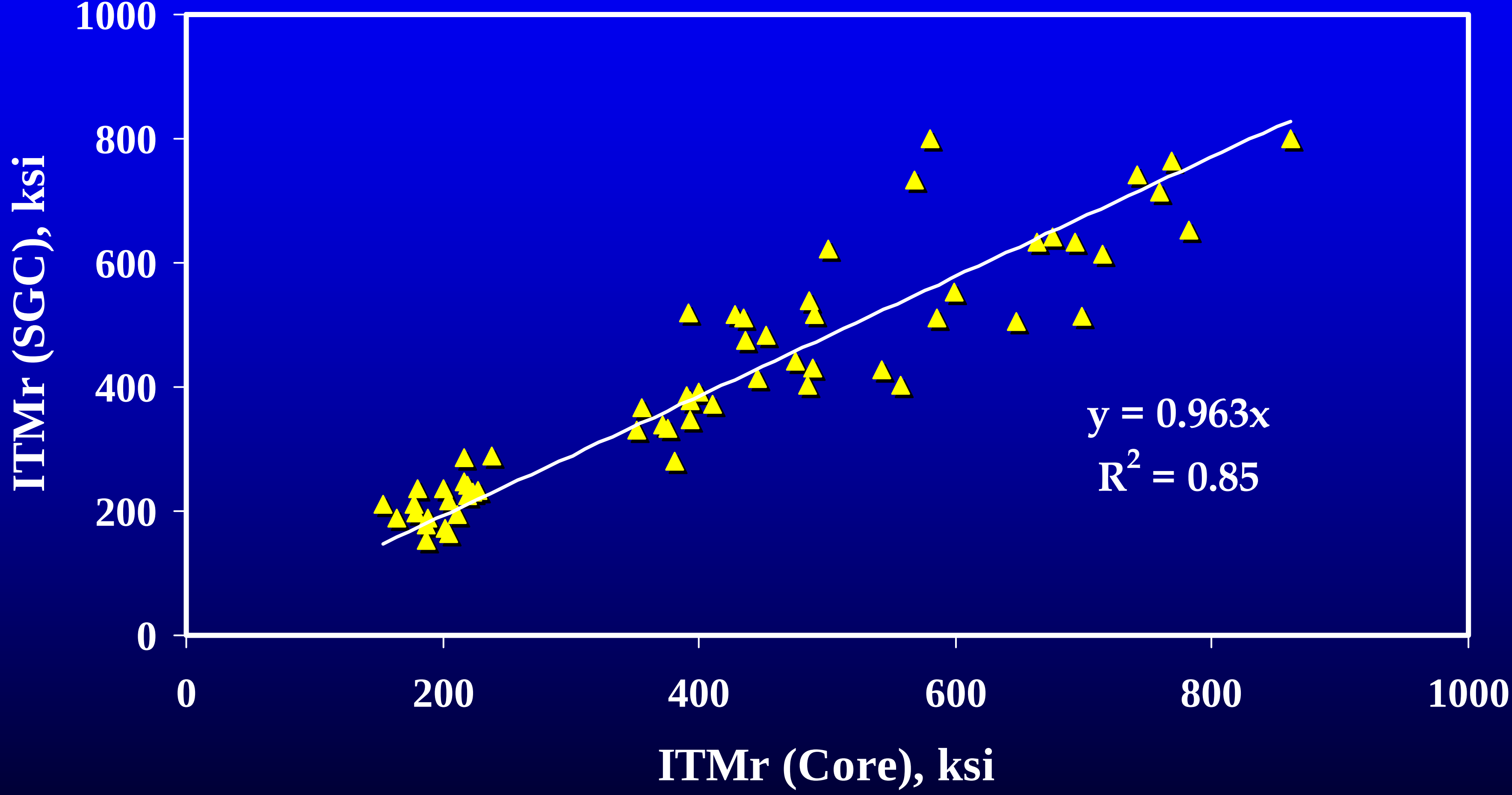
Average IT Mr Results (25 ºC)



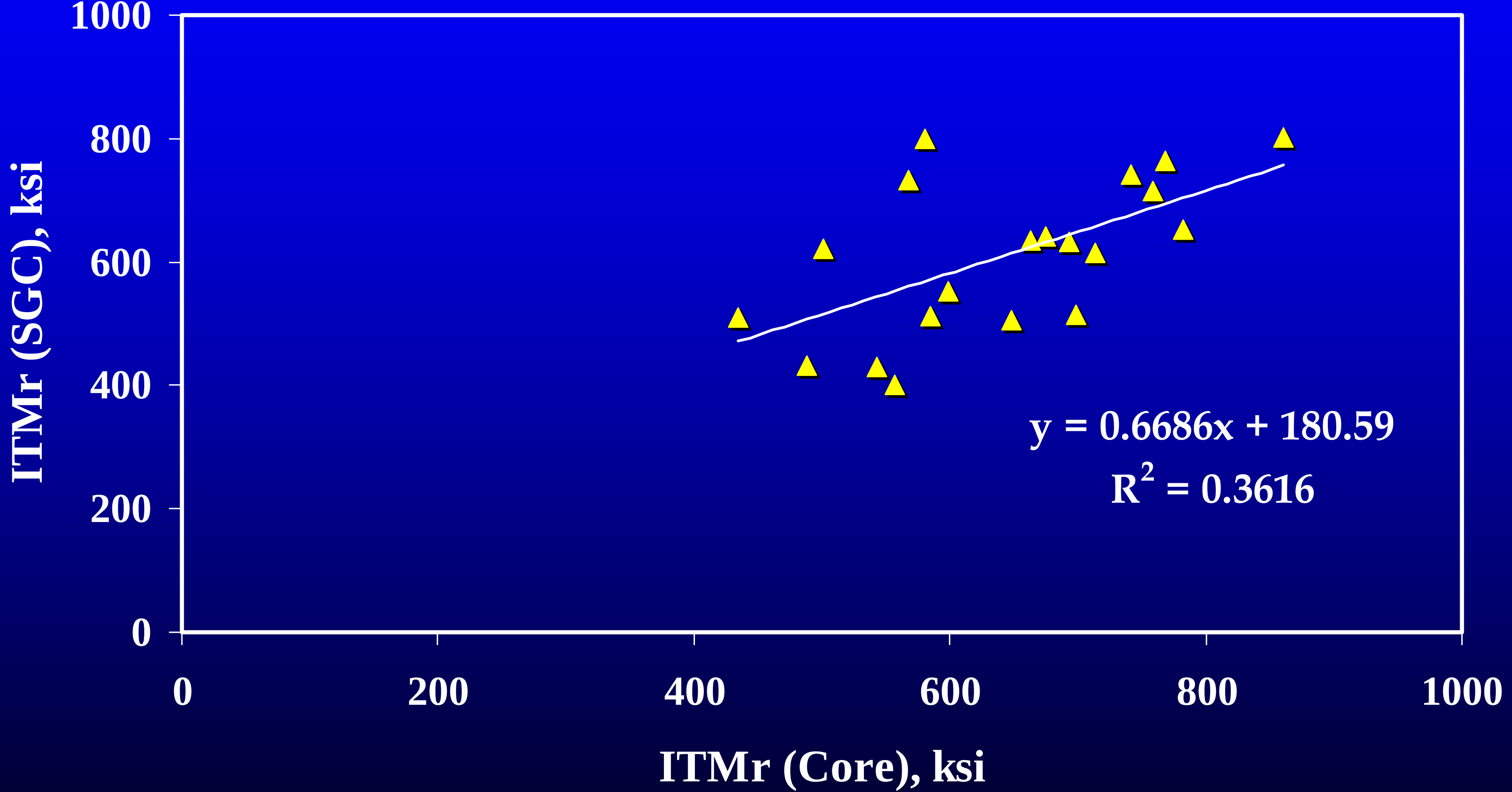
Average IT Mr Results (40 ºC)



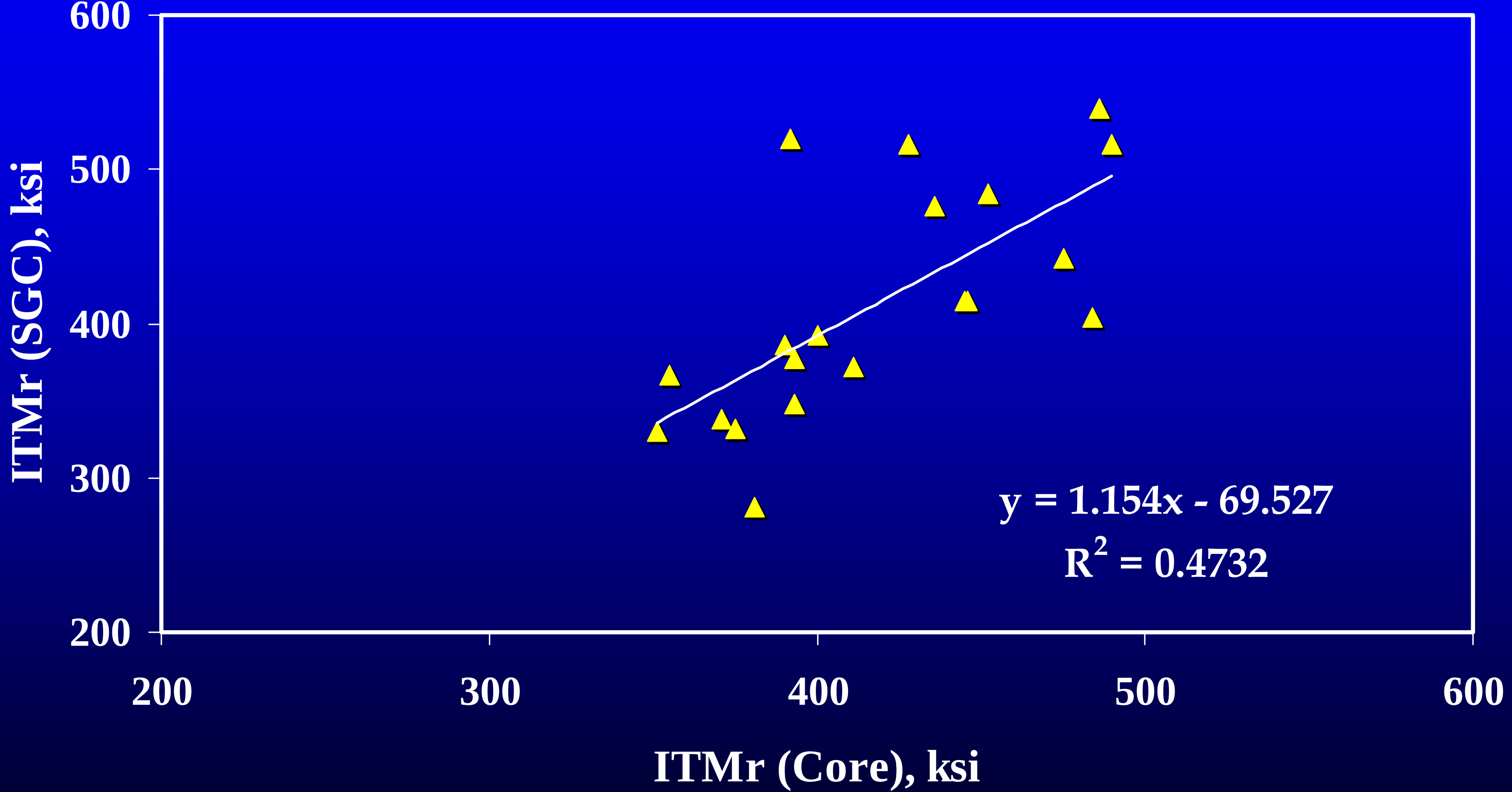
ITMr of All Mixtures (5°C, 25°C,and 40°C) (SGC vs. Core)



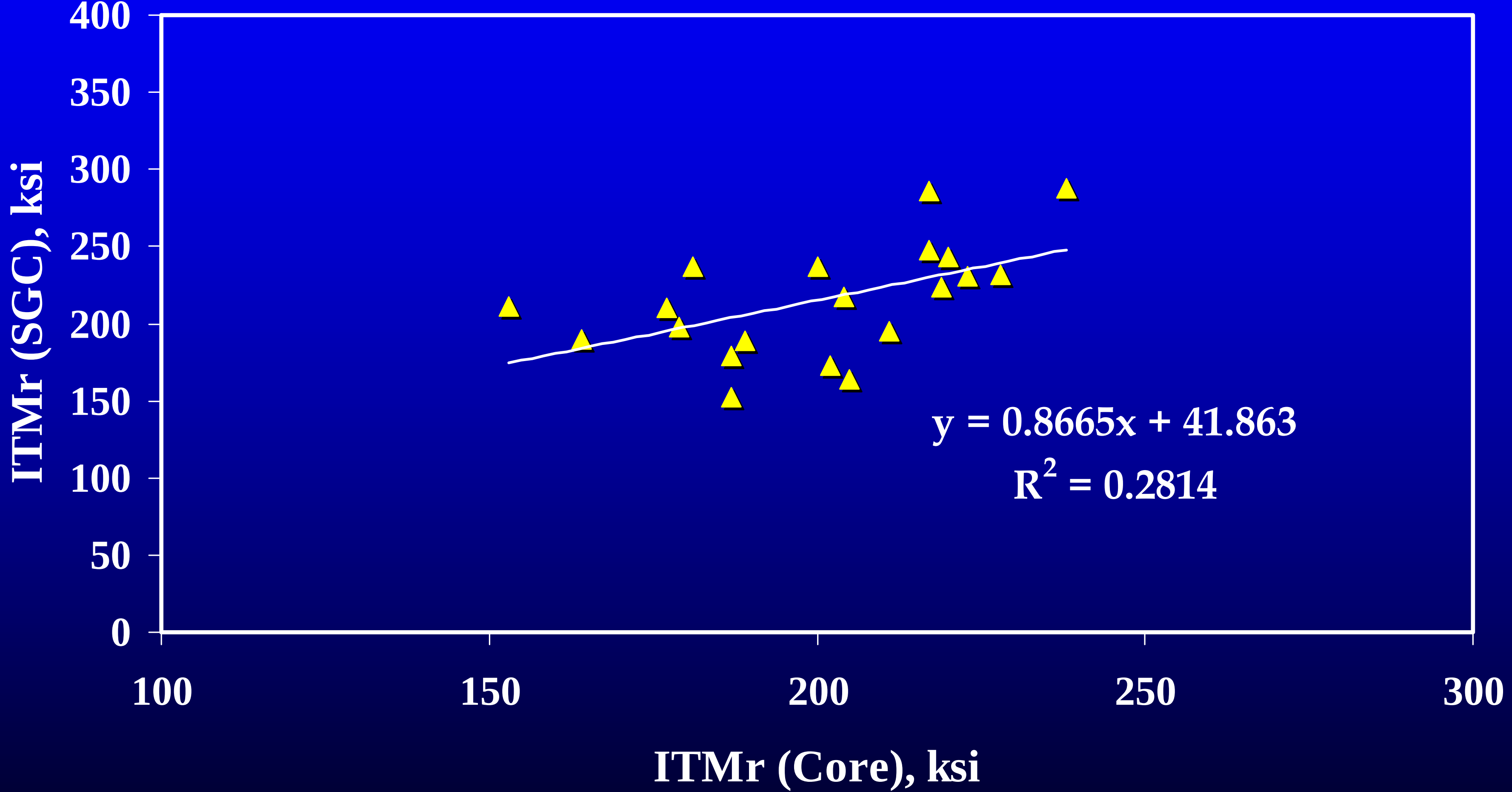
ITMr of All Mixtures (5°C)
(SGC vs. Core)



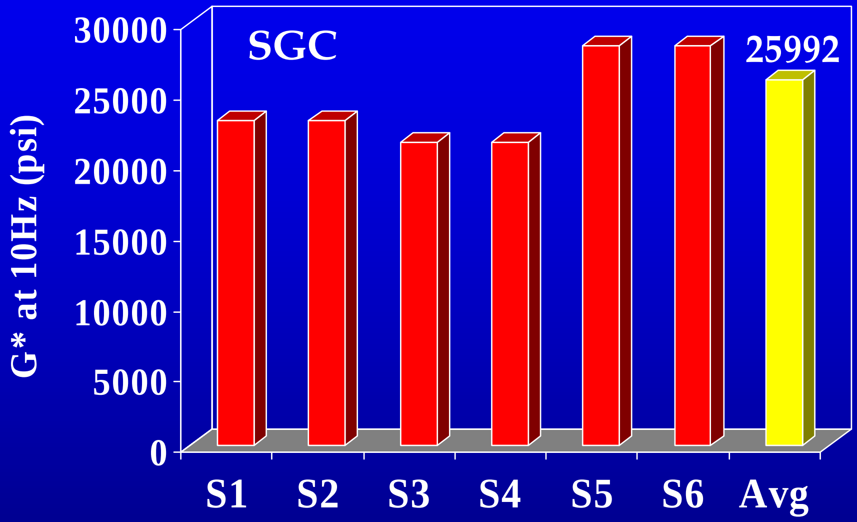
ITMr of All Mixtures (25°C)
(SGC vs. Core)

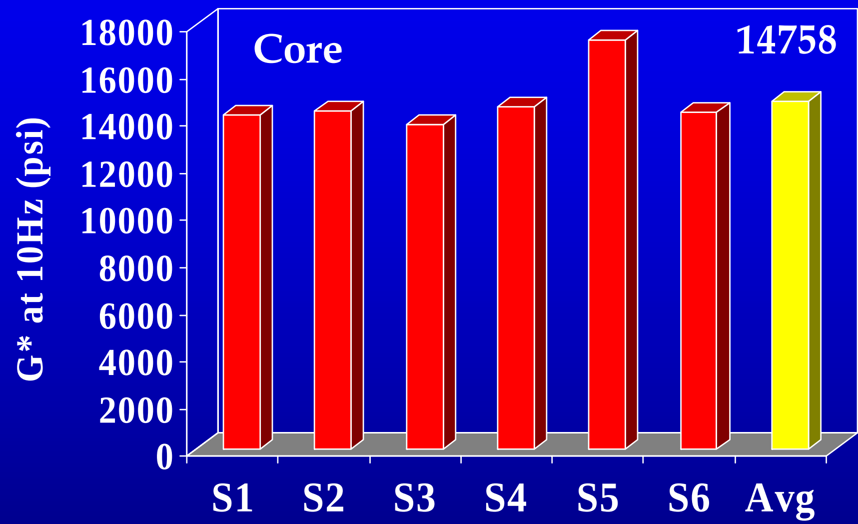


ITMr of All Mixtures (40°C)
(SGC vs. Core)



*Typical Variation of G**
I 10 Egan 12.5 mm Mixture – 48 C

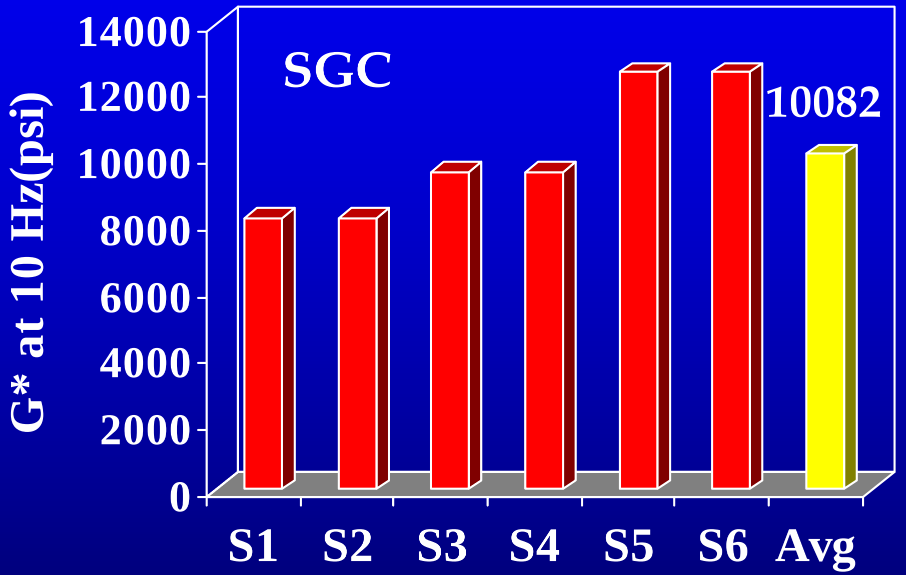


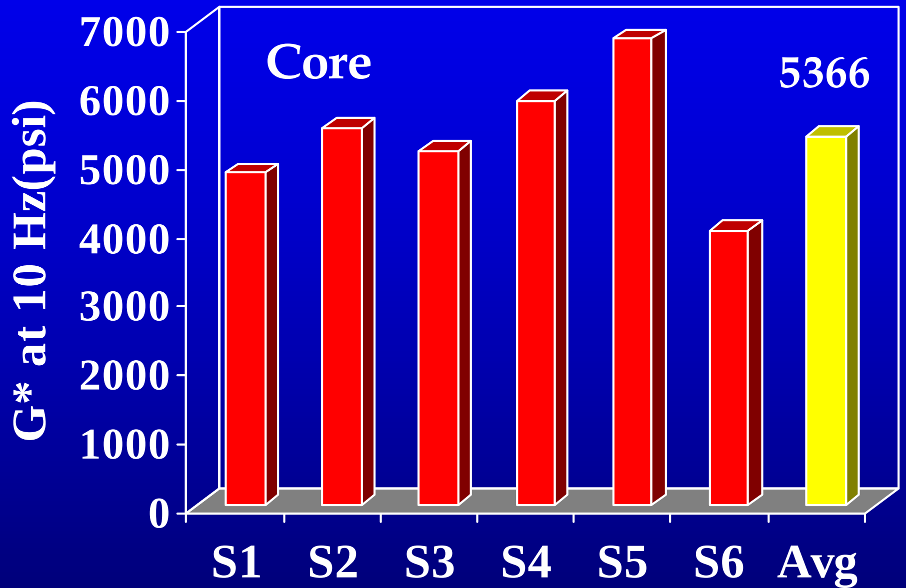


- **SGC**
  - **Mean = 25992 psi**
  - **SD = 3604 psi**
  - **CV = 14 %**

- **Core**
  - **Mean = 14758 psi**
  - **SD = 1310 psi**
  - **CV = 9 %**

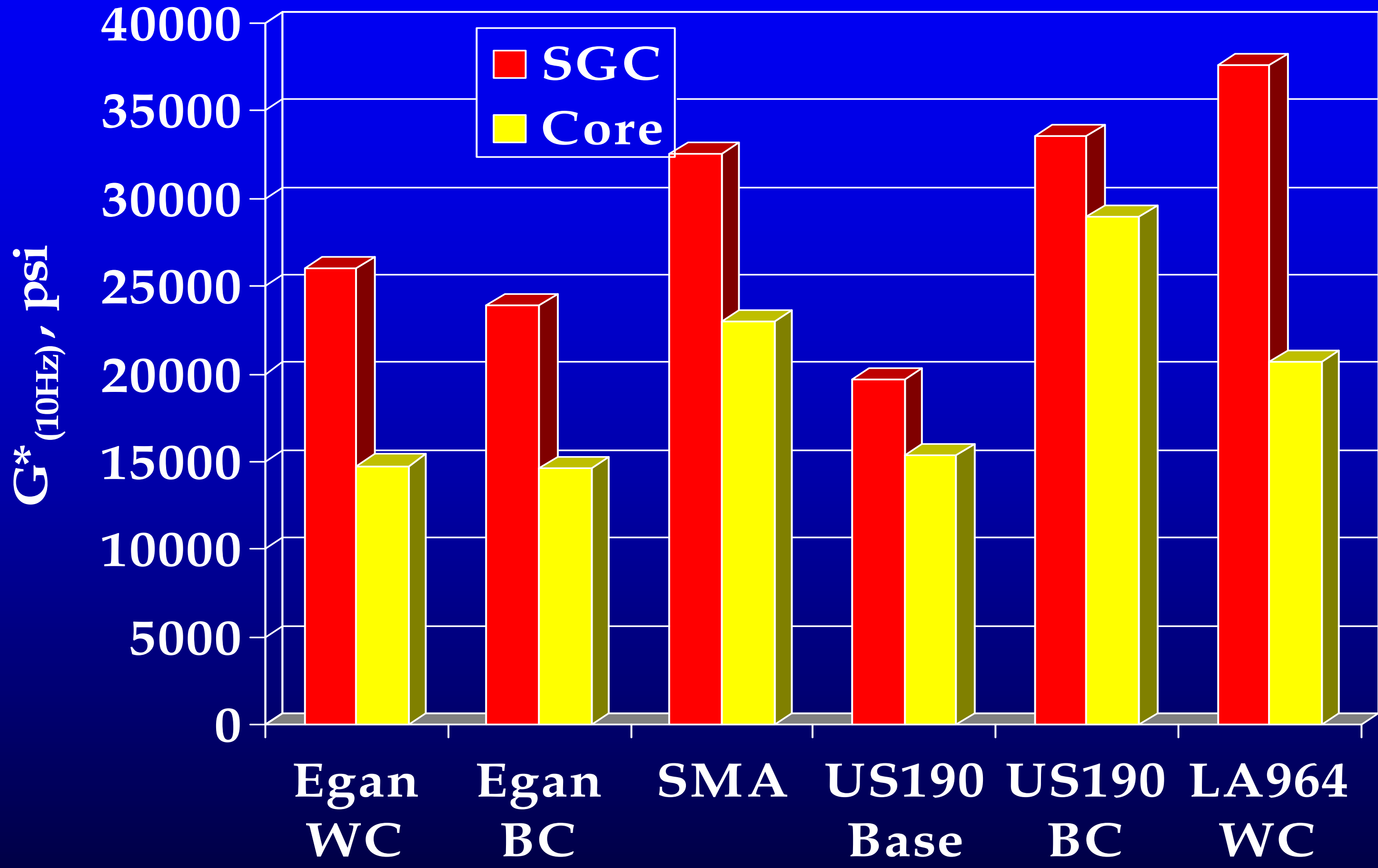
Typical Variation of G I 10 Egan 12.5 mm Mixture – 60 C*



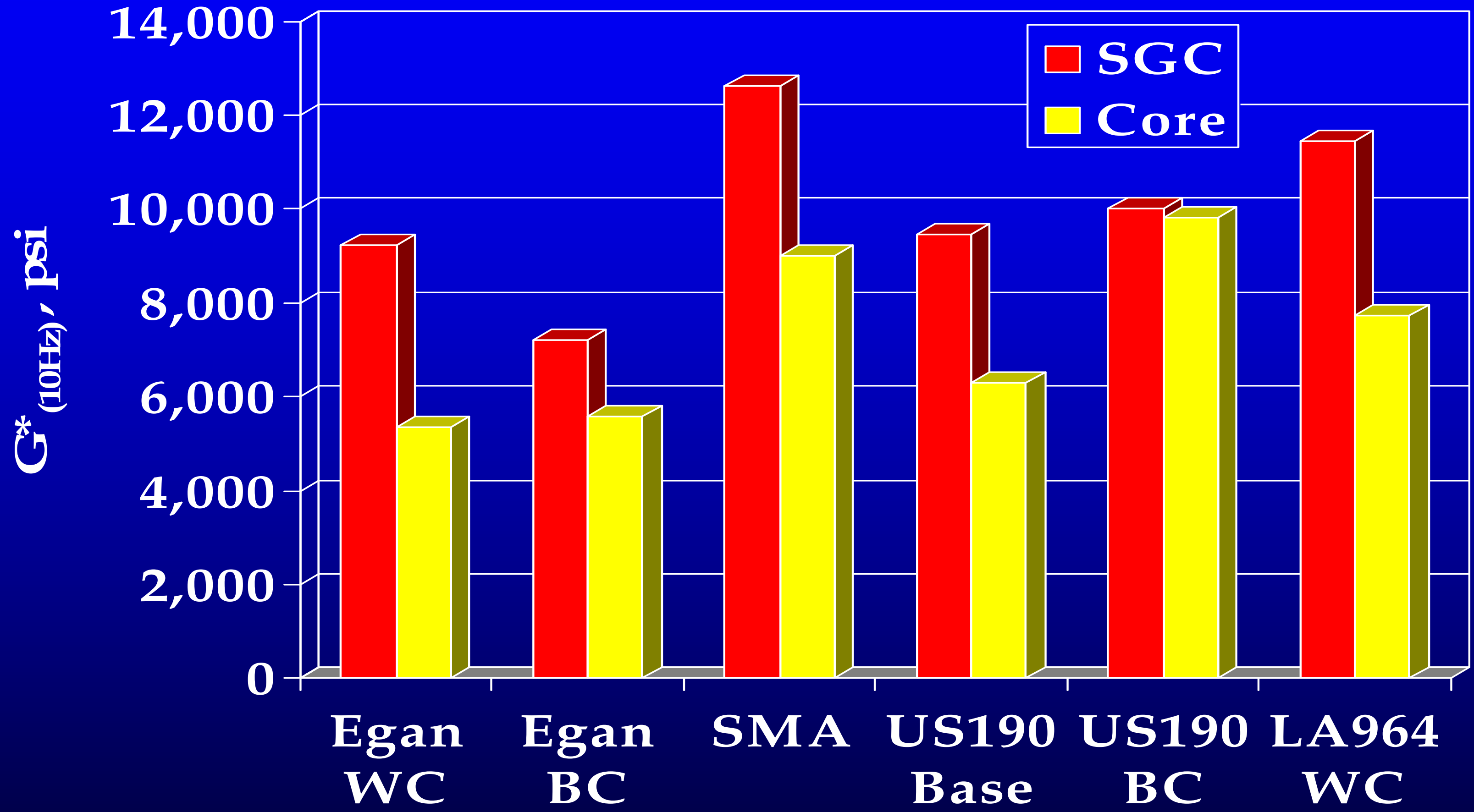


- SGC
  - Mean = 10082 psi
  - STD = 2243 psi
  - CV = 22 %
- Core
  - Mean = 5366 psi
  - STD = 949 psi
  - CV = 18 %

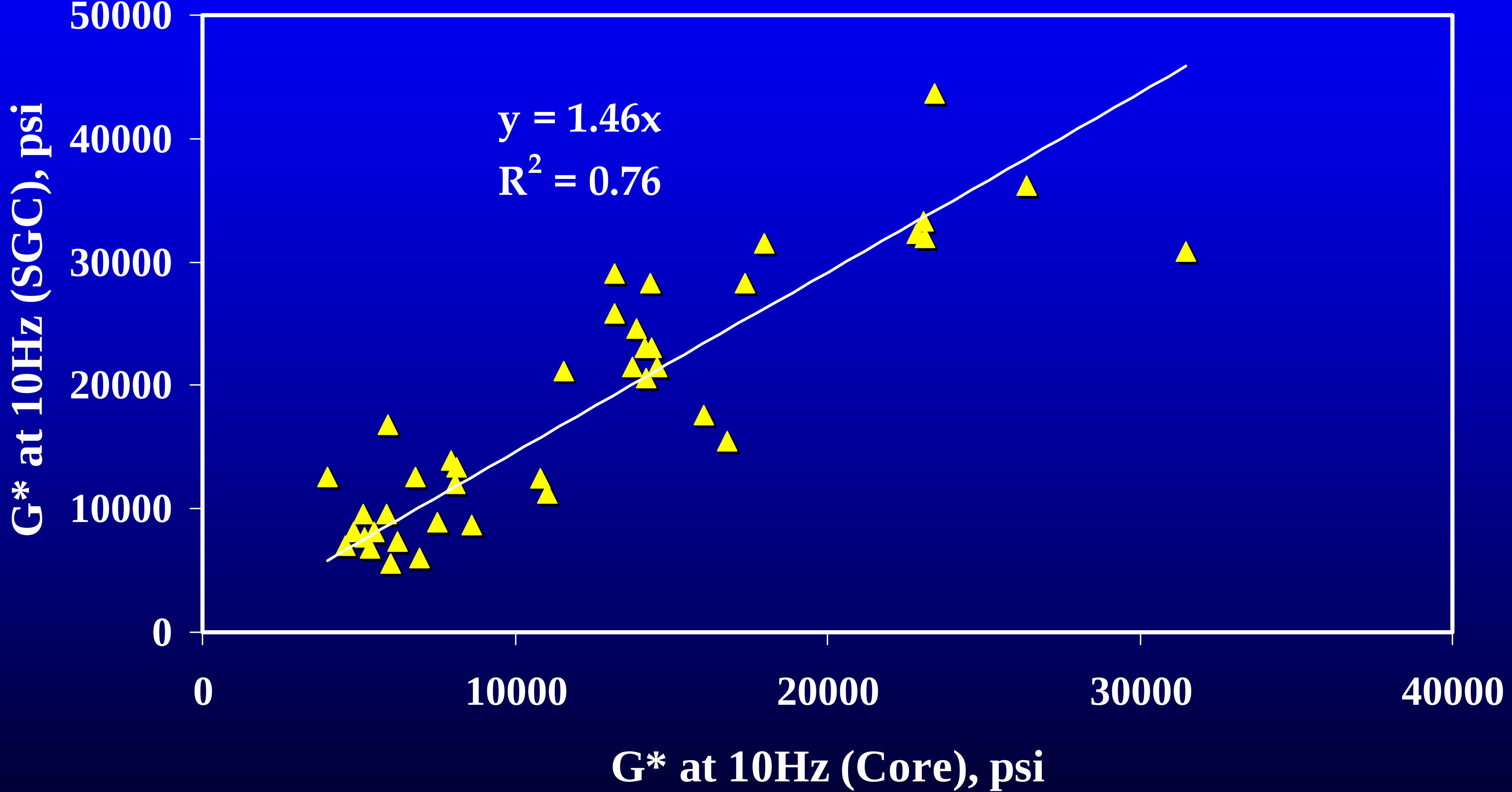
Average FSCH Test Results at 48 ºC



Average FSCH Test Results at 60 ºC



Complex Shear Modulus (G^*_{10Hz})
(SGC vs. Core)



Variation of Field Measurements

Light Falling Weight Deflectometer (LFWD)

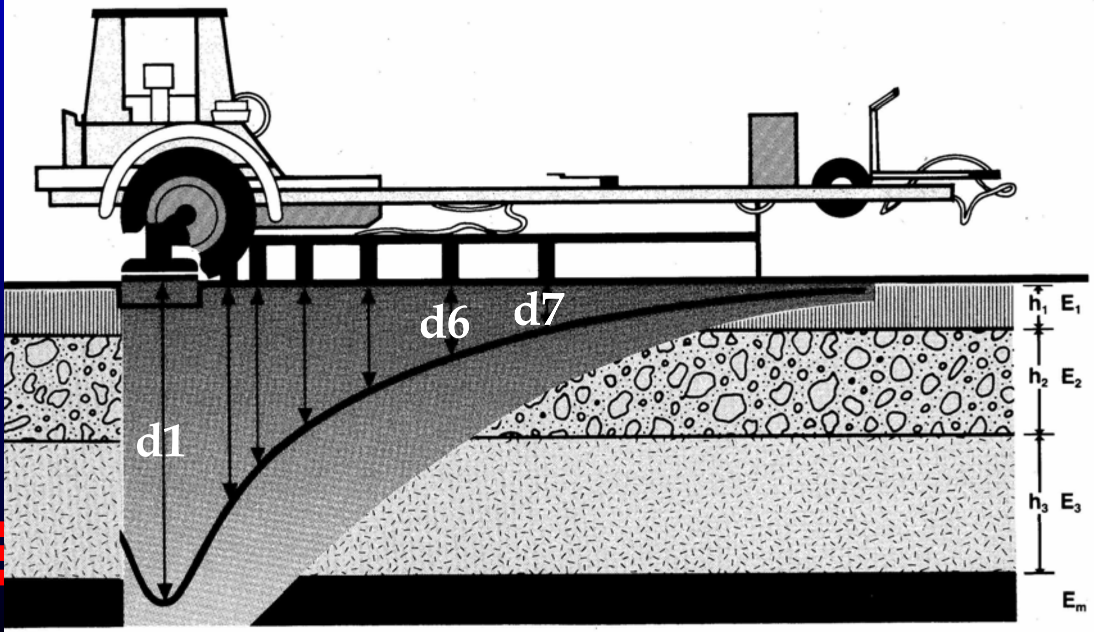
- **10-kg drop weight onto loading plate**
- **The center deflection (δ_c)**

$$E_{LFWD} = \frac{K.(1-\nu^2).P.r}{\delta_c}$$

Where: K = 2 for flexible plate and or $K = \pi/2$ for rigid.
P is the applied load, r is the plate radius.

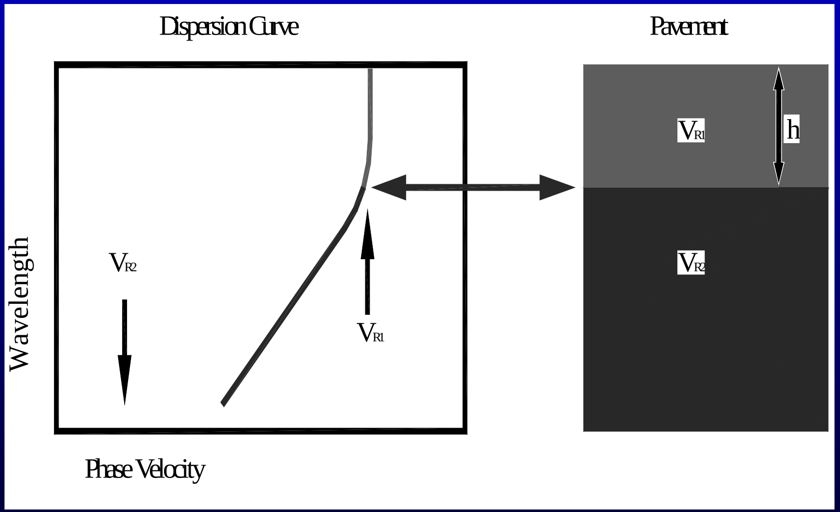
FWD

- Dynatest Model 800
- 7 Sensors
- Three indicators
  - d1
  - d1-d6
  - d7

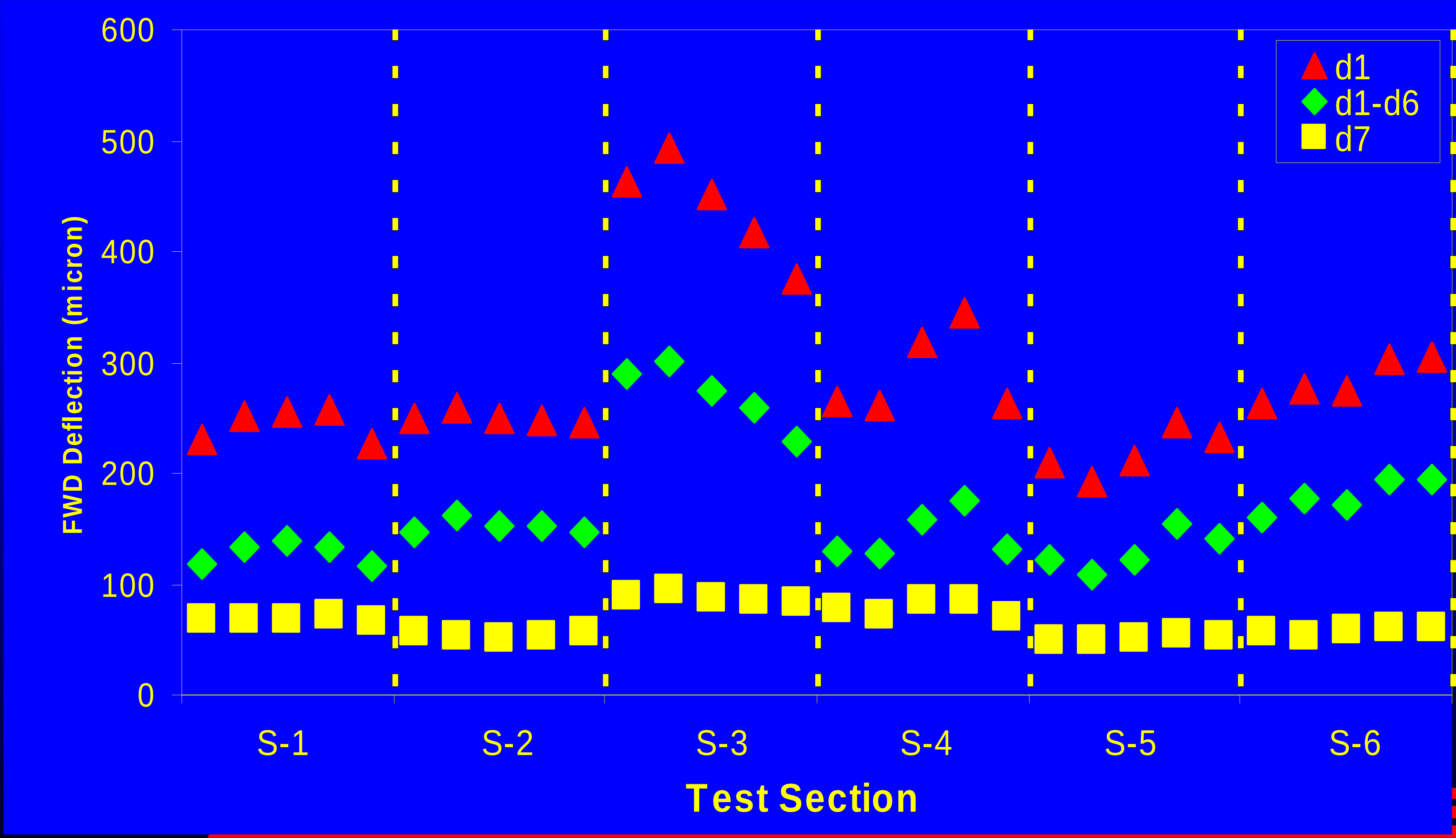


Portable Seismic Pavement Analyzer (PSPA)

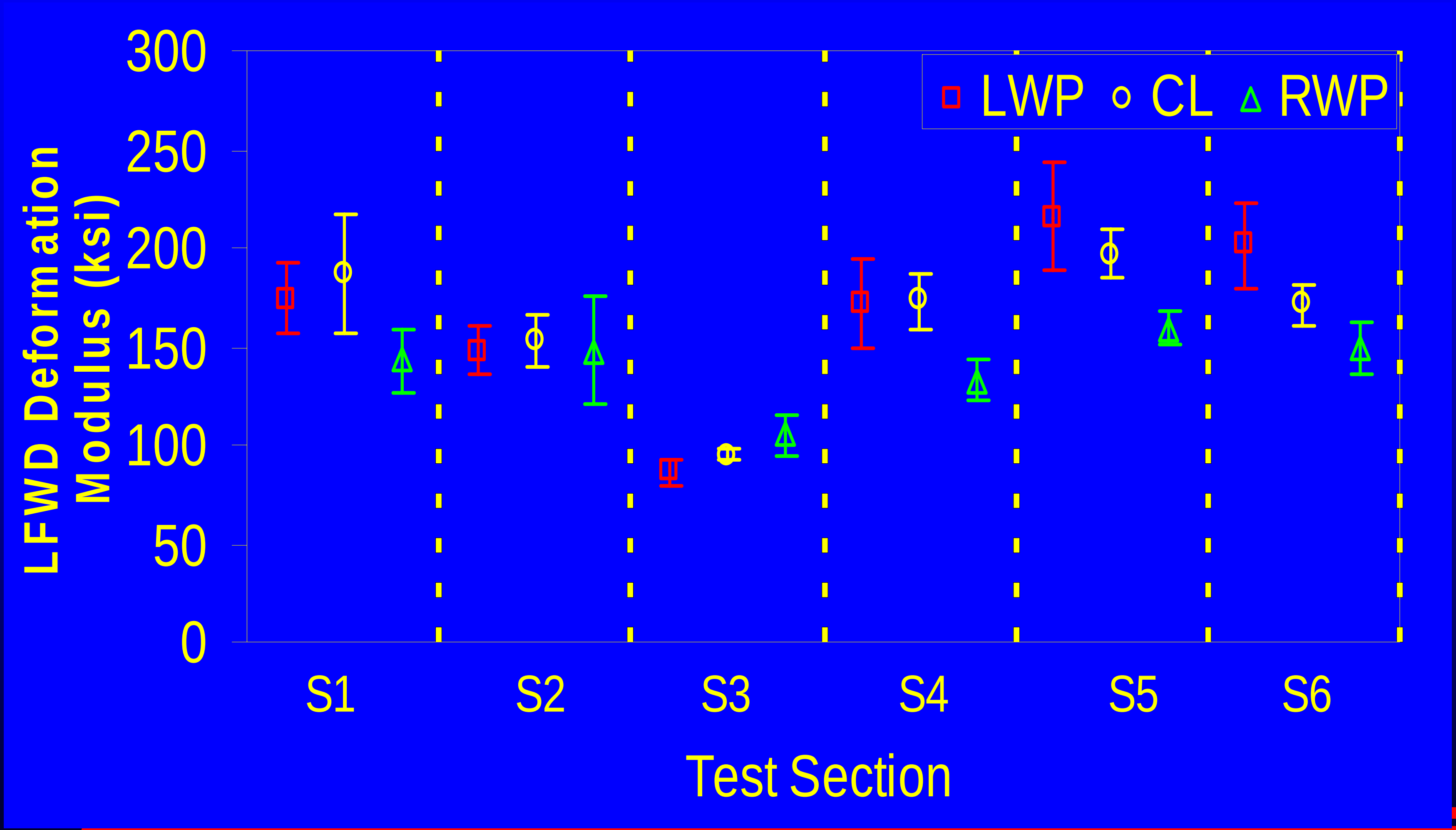
- **Ultrasonic Surface Wave method to determine the surface layer modulus**
  - **One source producing surface wave**
  - **Two sensors measuring wave propagation time/velocity**



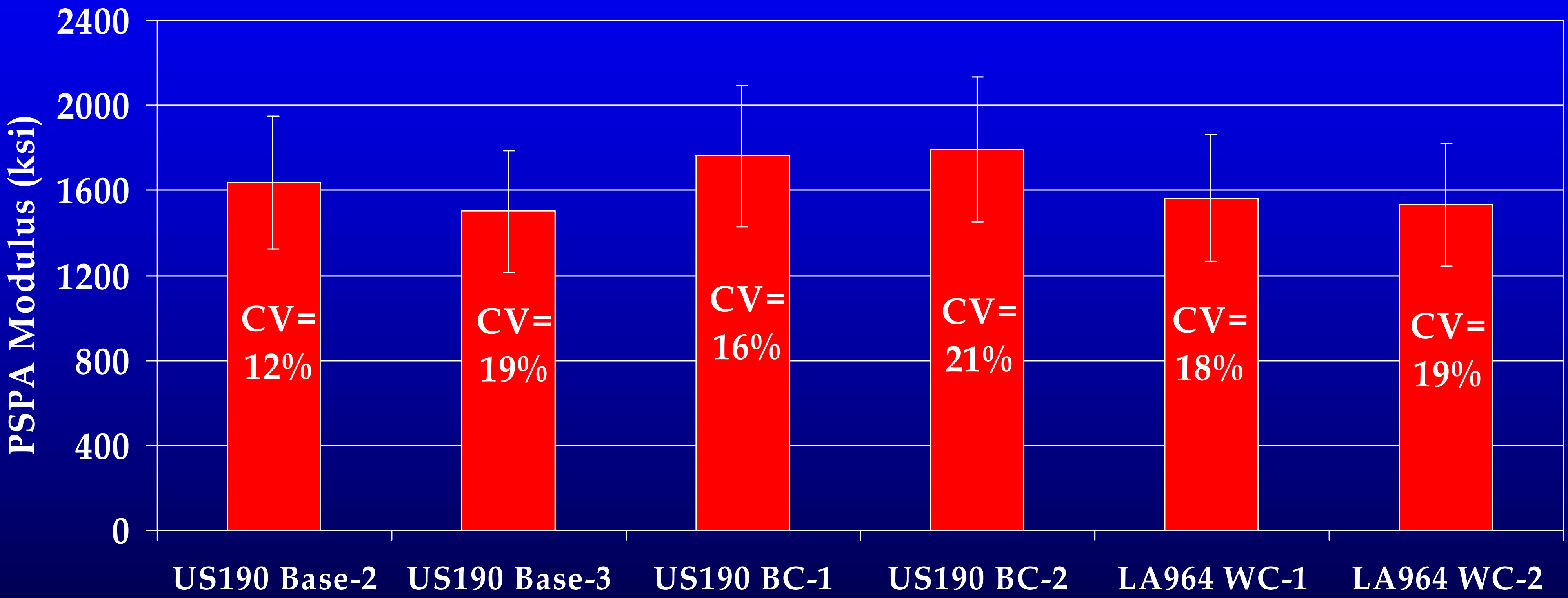
Typical Variation of FWD Results
I 10 Egan 25 mm Binder Course



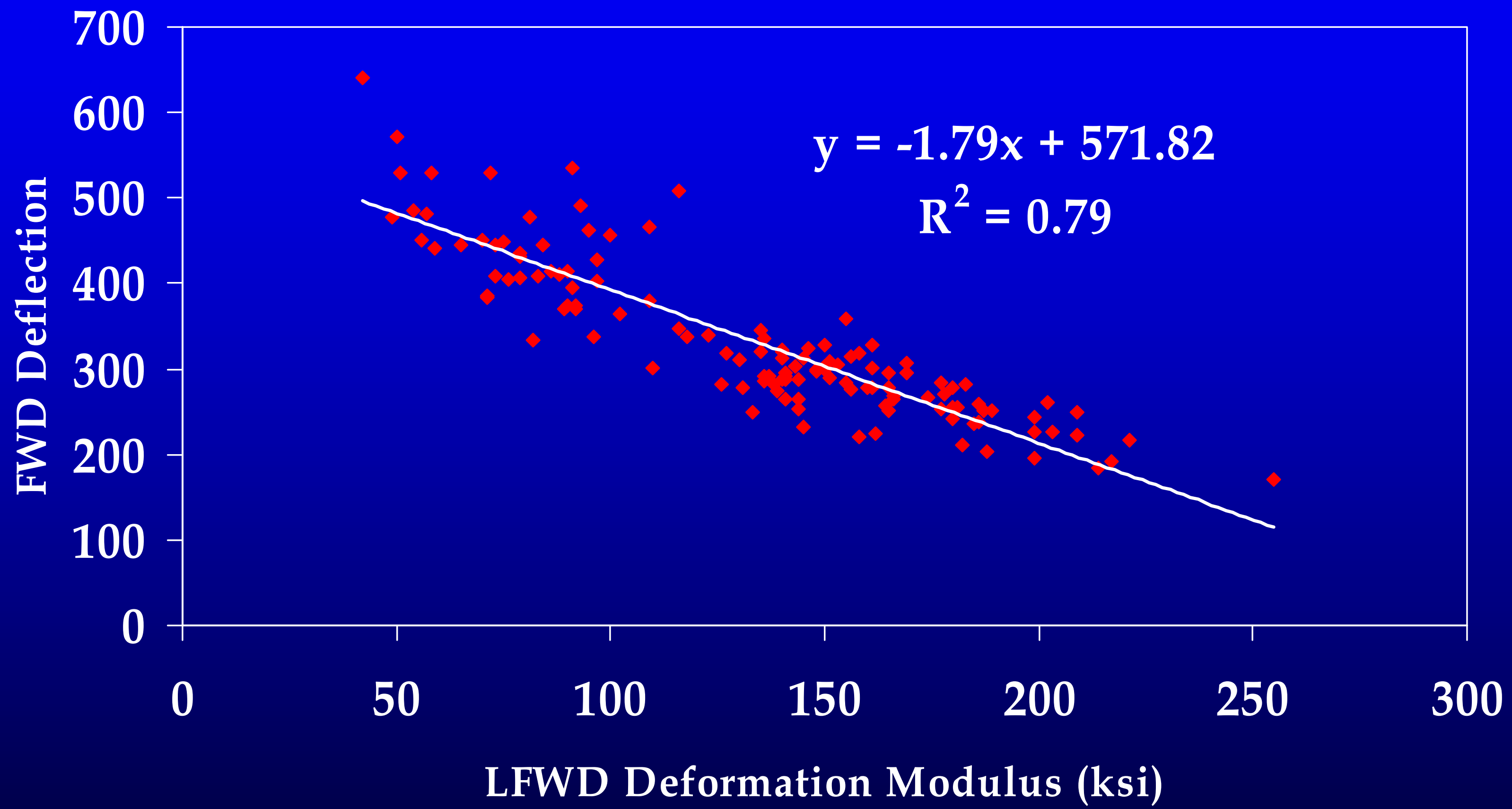
Variation of LFWD Results – I 10 Egan 25 mm Mixture



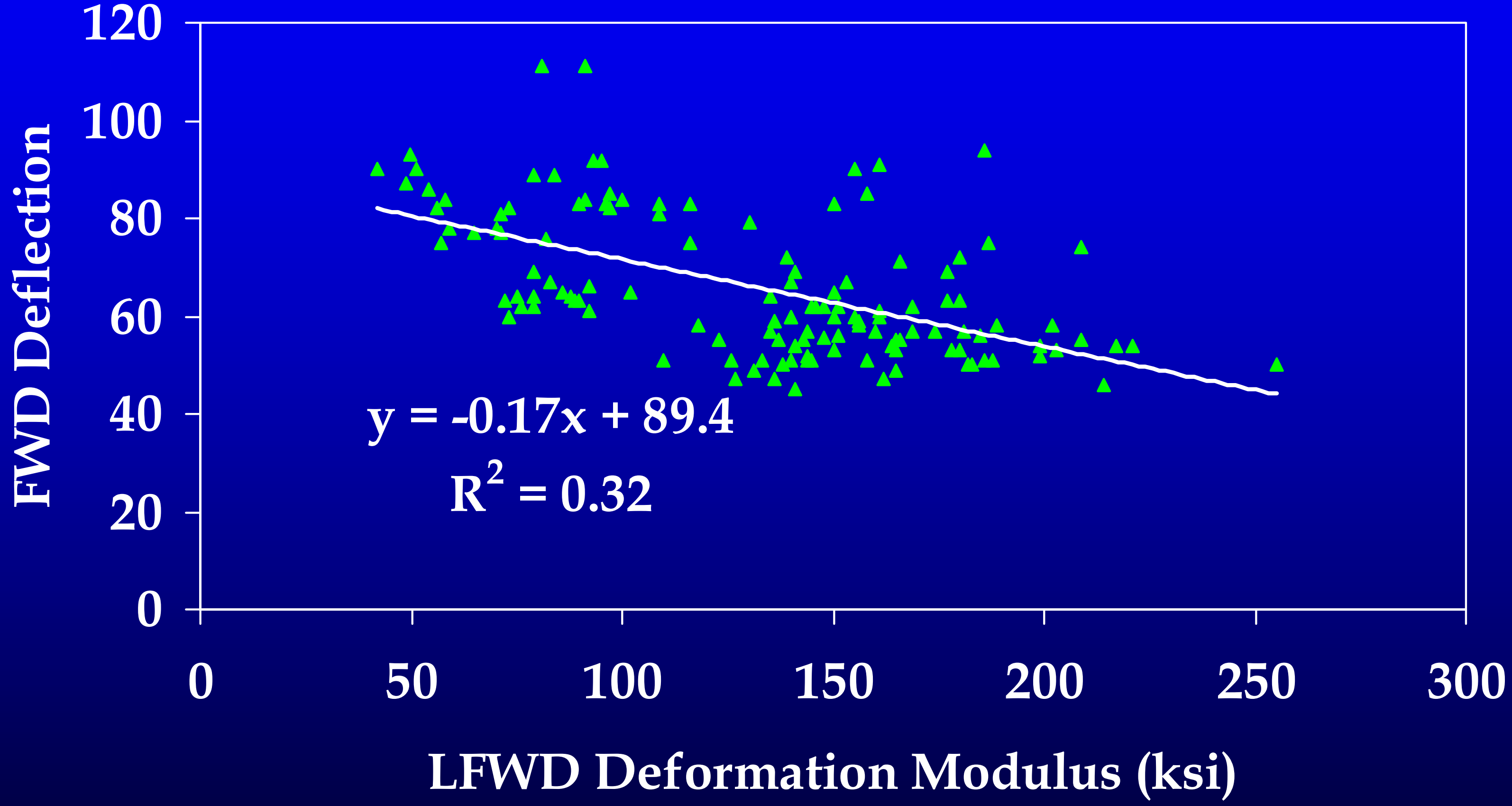
Variation of PSPA Modulus



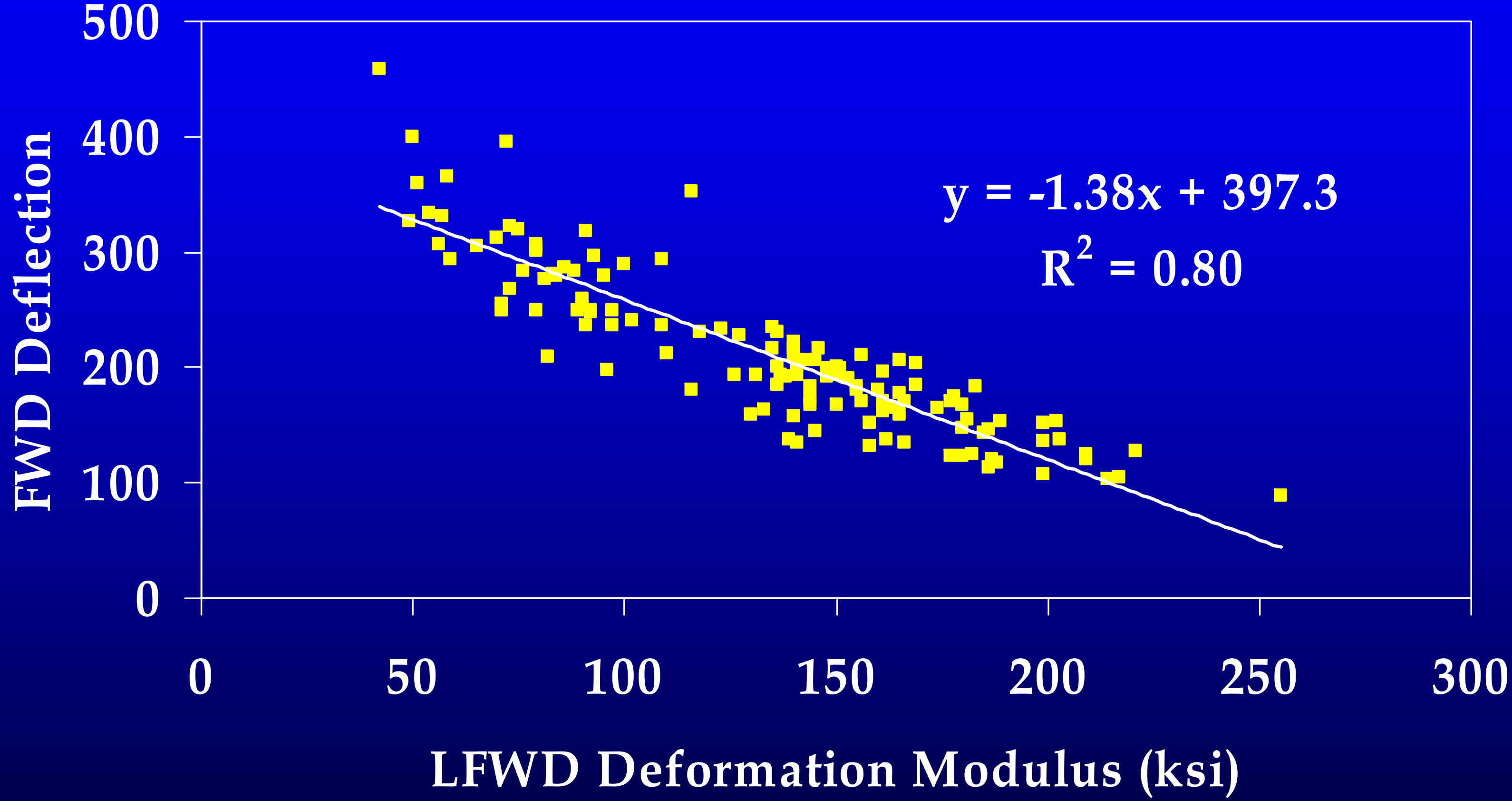
Relationship Between FWD and LFWD – d1 (200 mm loading plate)



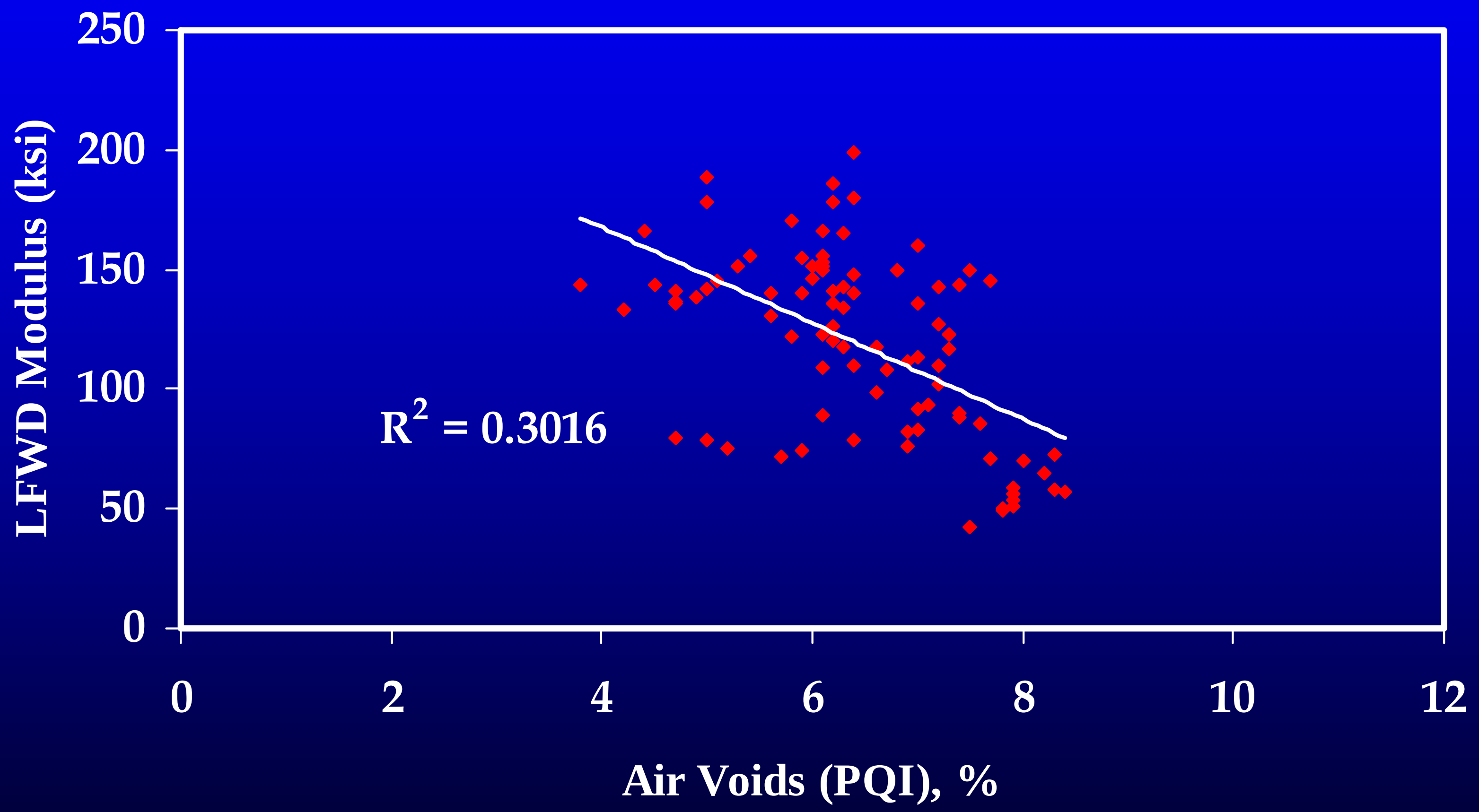
Relationship Between FWD and LFWD – d7 (200 mm loading plate)



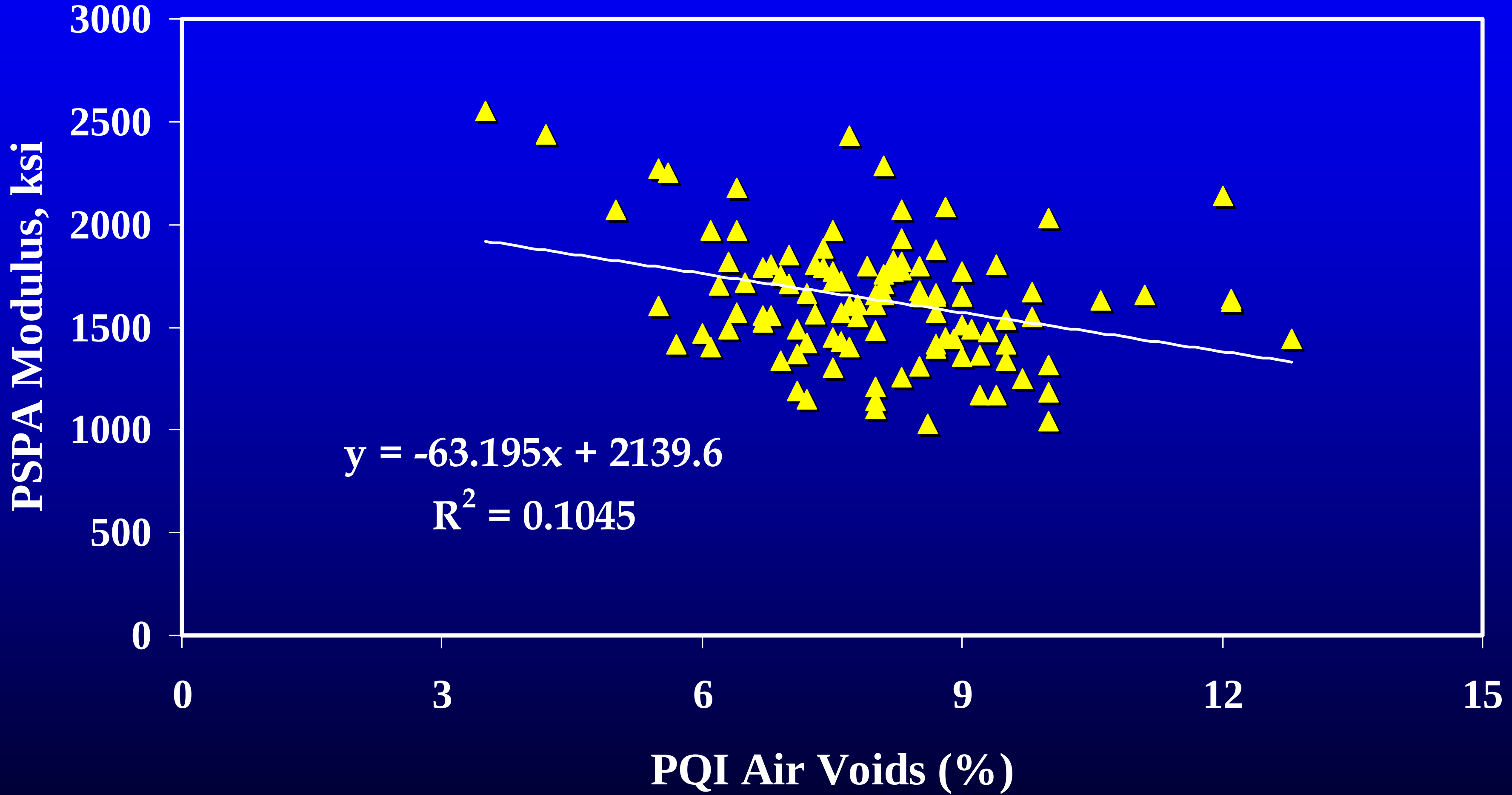
Relationship Between FWD and LFWD – d1-d6 (200 mm loading plate)



Variation of $E_{(LFWD)}$ with PQI Air voids



PSPA Modulus vs PQI Air Voids



Conclusions Air Voids

- Binder course mixtures had the highest air voids variation as measured by all three methods, followed by the wearing course and SMA mixtures
- CoreLok air voids variation were slightly higher than the conventional methods
- Strong correlation between air voids measured using Conventional and CoreLok methods
- Correlations between PQI measured air voids and other two methods (CoreLok and AASHTO T-166) are fair

Conclusions
Mechanistic Tests

- Binder course mixtures had the highest ITS & G* variations followed by the wearing course and SMA mixtures
- Cores showed better correlations to air voids than SGC samples
- Cores and SGC samples showed Similar variations
  - ITS, G*
- The ITS and G* of SGC samples were higher than cores
- Good correlation was observed between the G* of the cores and SGC samples

Conclusions Mechanistic Tests

- Good correlations were observed between E_{LFWD} and FWD deflections d1 and d1-d6
- LFWD test may be used as an alternative to FWD testing in pavement structure evaluation


Thank You !

Project	Location	Modulus(25°C) (ksi)	CV(%)	Mid depth temp (°C)	STD
US190	base2	1637	12	28.6	196
	base3	1501	19	32.6	285
	BC1	1761	16	21.3	282
	BC2	1795	21	35.3	377
LA964	WC1	1563	18	27.6	281
	WC2	1533	19	29.1	291

PSPA Modulus vs LFWD Modulus