

Air-Void Analyzer (AVA) Air-Void Parameters in Fresh Concrete

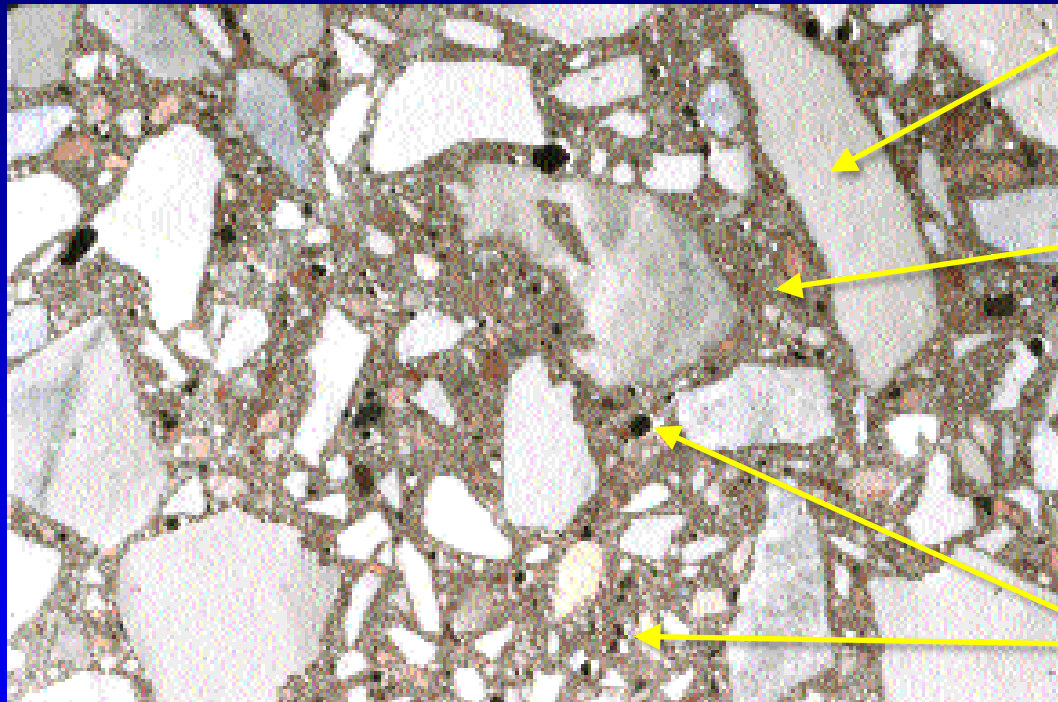
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Outline

- Benefits of entrained air
- How entrained air protects concrete during freezing
- Air-void parameters
- Principle of the AVA
- Kansas DOT movie
- Conclusion

Concrete



Coarse aggregate

Mortar

- Binder
- Water
- Fine aggregate

Air

- Entrapped or
- Entrained

Entrapped vs. Entrained Air

Entrapped Air	Entrained Air
Irregular shape; large size	Spherical shape; small size
Introduced during mixing	Introduced during mixing with air entraining agent
No practical benefit	Improves properties of fresh concrete; enhances resistance to freezing and thawing cycles; enhances resistance to other forms of chemical attack

Freezing of Saturated Concrete

- Water expands in volume by 9 % when it freezes
- This expansion introduces tensile stresses that are sufficient to crack the concrete
- Cycles of freezing and thawing will turn concrete to rubble

Outdoor Exposure to Freezing and Thawing 40 years

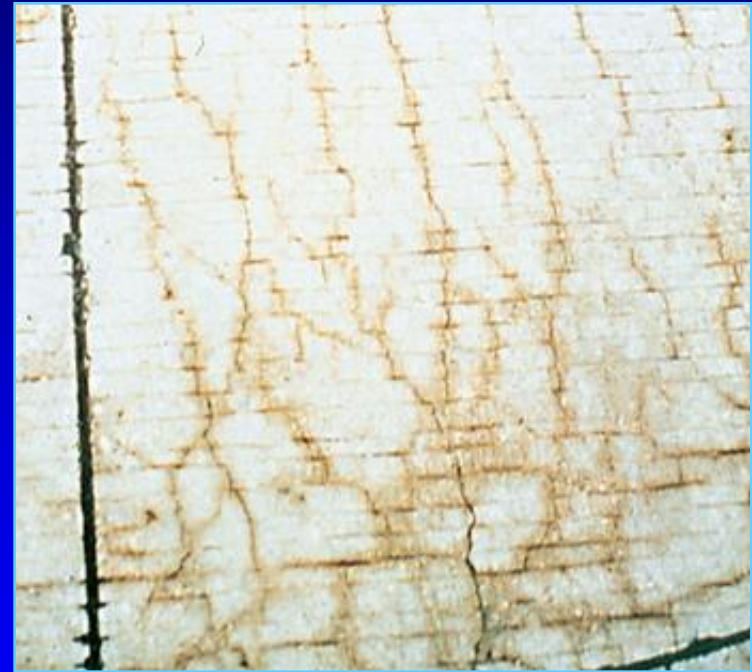
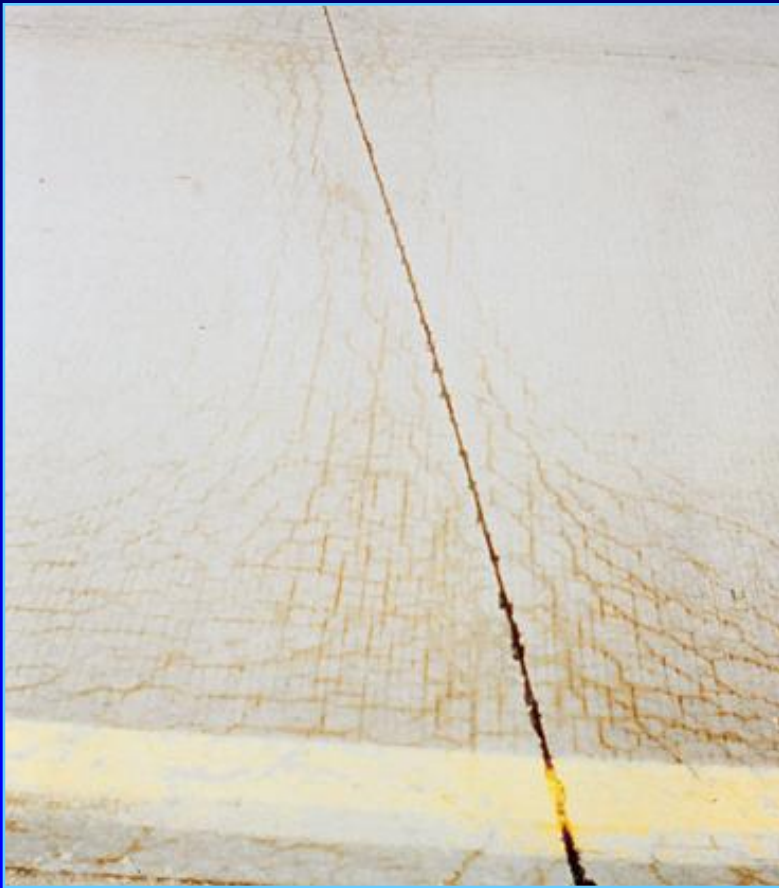


Air-entrained concrete

From: PCA

Test smart – Build right

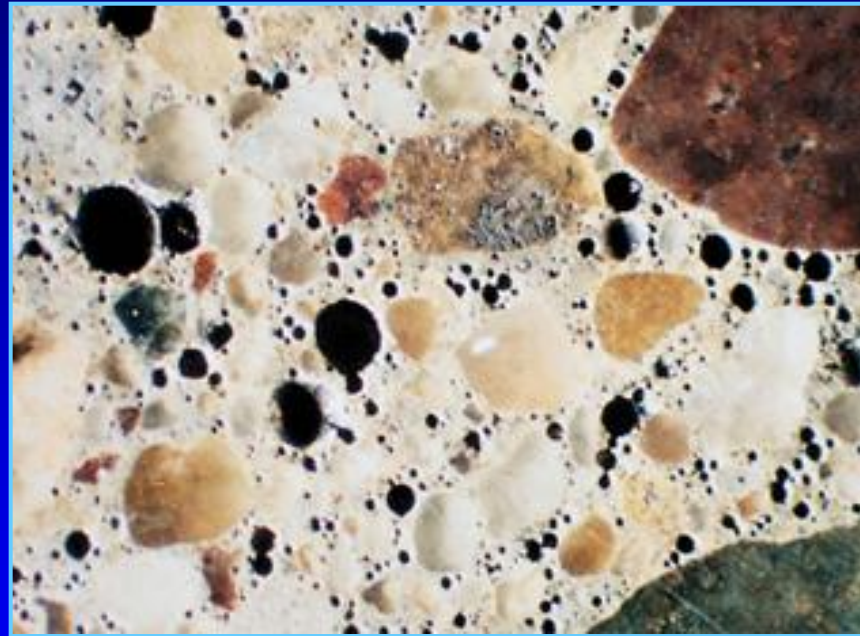
F-T Damage in Pavements



Source: PCA

Test smart – Build right

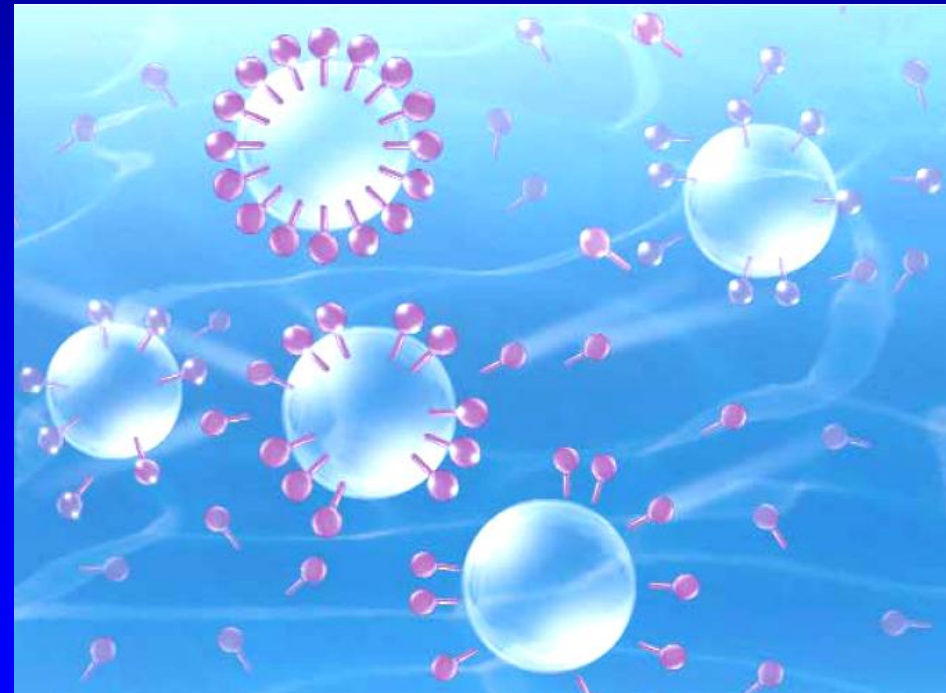
Air-Entrained Concrete



- Air-entraining cement
- Air-entraining agent (an admixture)
 - Lowers surface tension of water → enhances incorporation of bubbles
 - Impedes bubble coalescence
 - Anchors bubbles to cement and aggregate particles

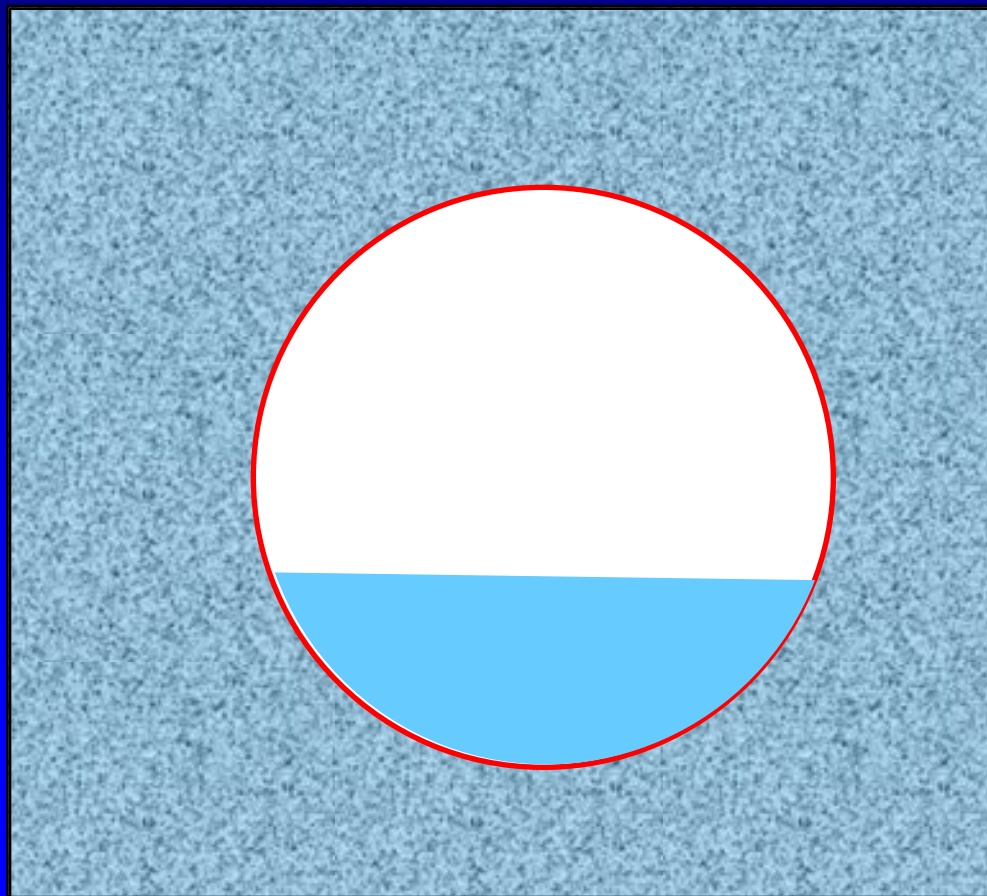
Air Entraining Agents

- Surfactants that allow formation of small, stable air voids during mixing
- Molecules have polar (hydrophilic) and non-polar (hydrophobic) ends
 - Polar end into paste
 - Non-polar end into air
 - Air voids repel



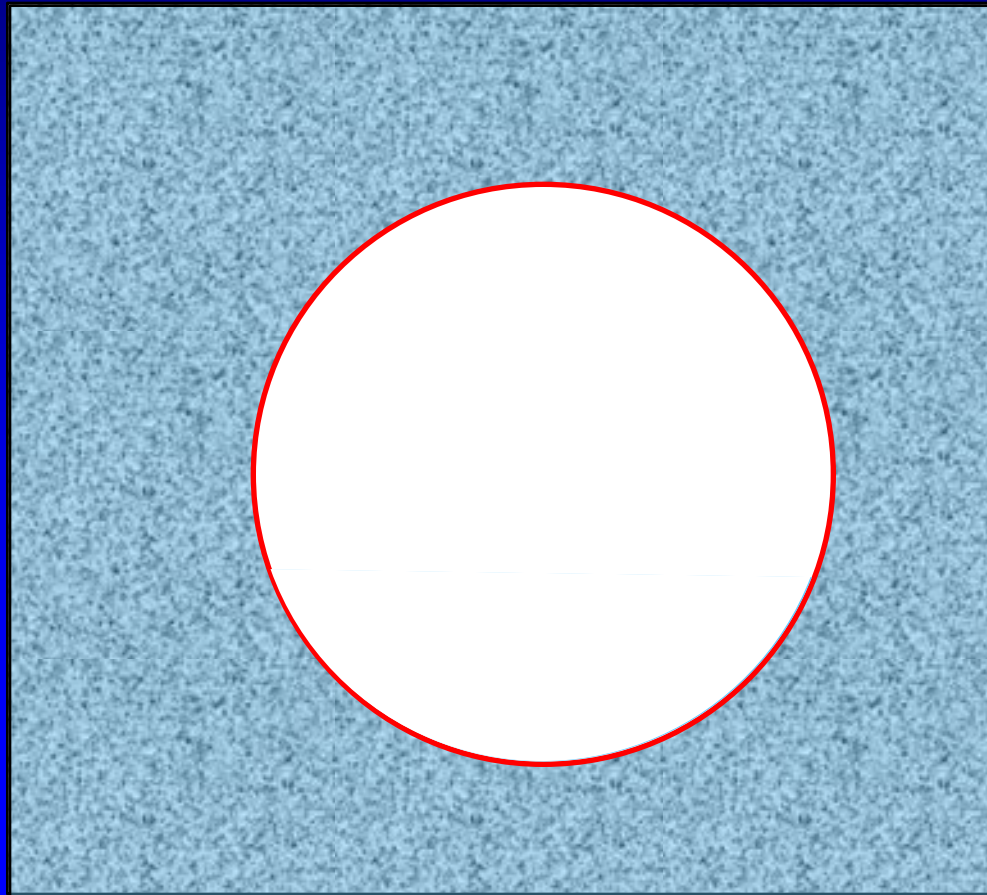
Entrained Air Voids

- During freezing, air void provides space to accommodate expansion of freezing water



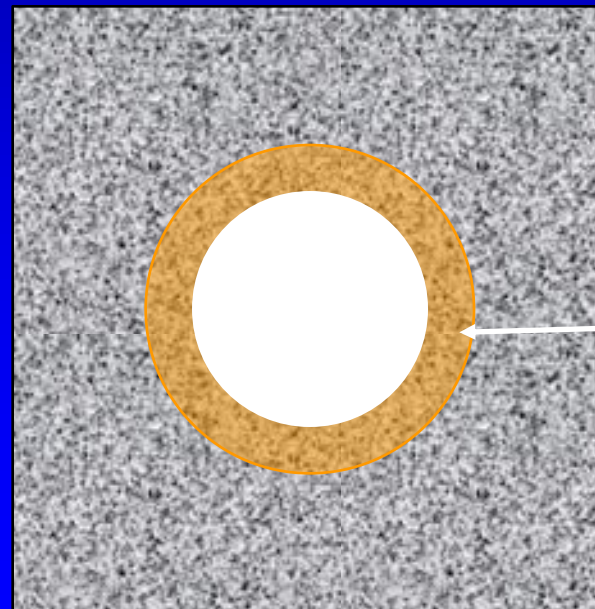
Entrained Air Voids

- During thawing, water is expelled from air void because of hydrophobic layer



Protected Paste Volume

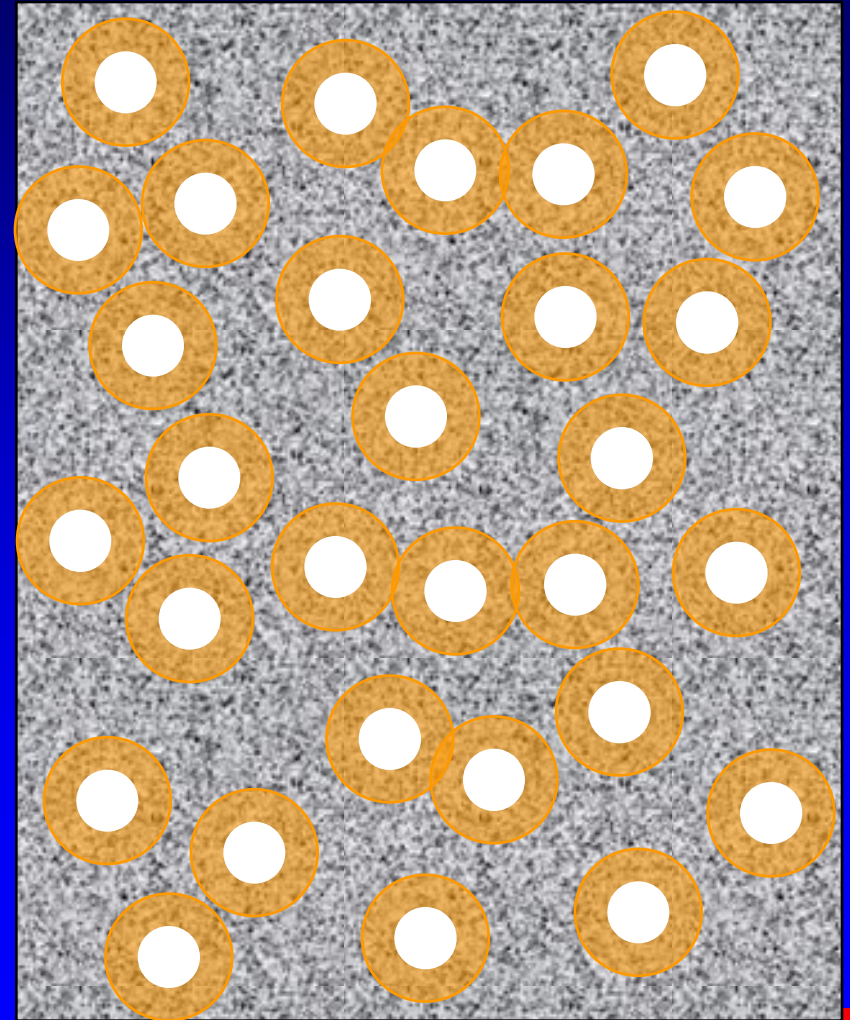
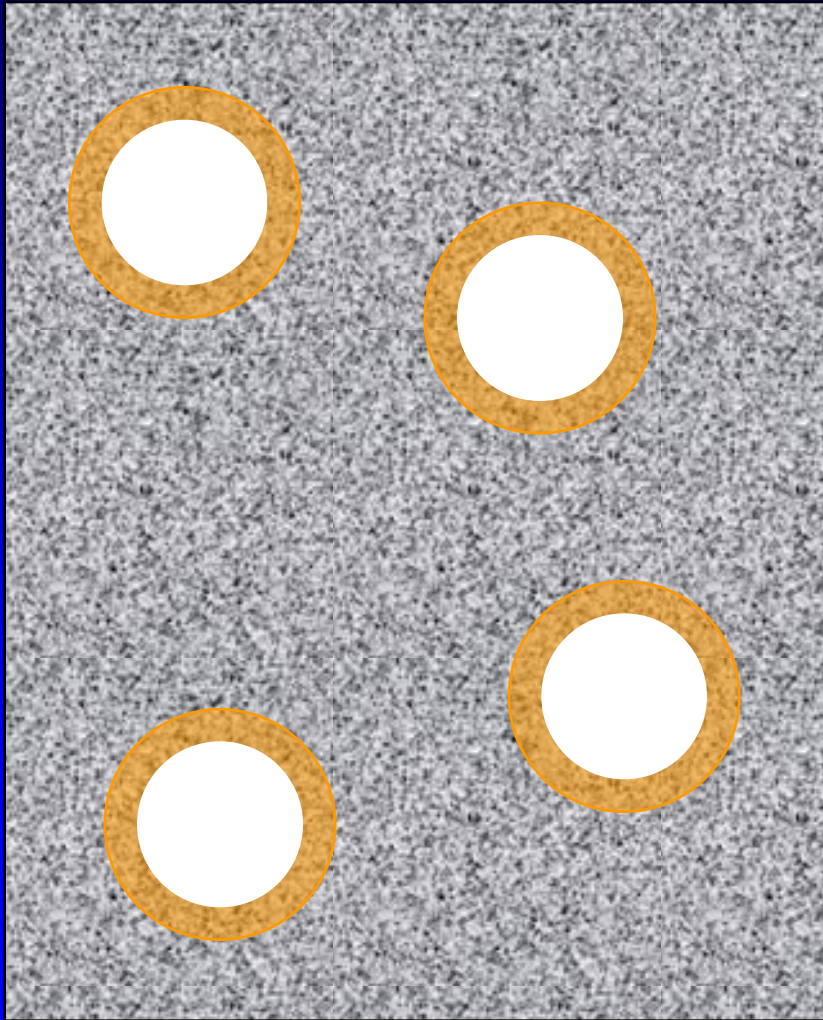
- The portion of hardened cement paste that is protected from the effects of freezing by proximity to an entrained air void



≈ 0.25 mm
thick shell

Effect of Void Size

10 % Air



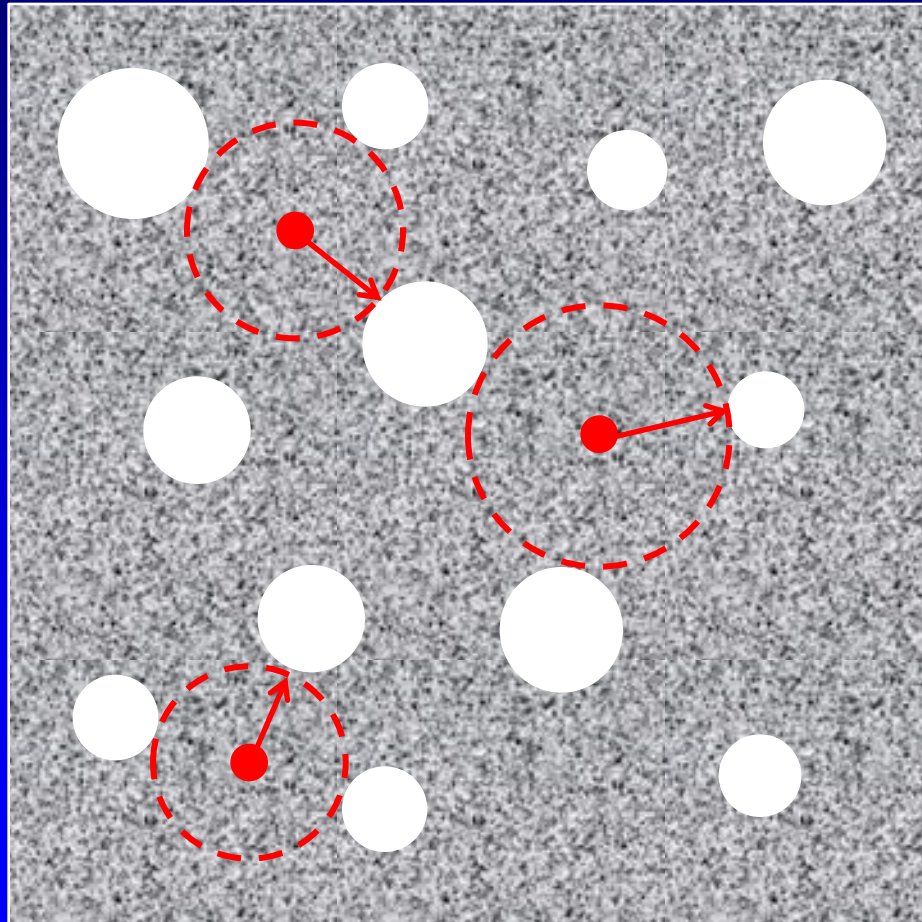
Traditional Air Content Tests



From: PCA

- Measures total air content (entrapped air and entrained air)
- No fixed relationship between total air content and air-void structure
- Need an indicator of the size of the air voids
 - Spacing factor
 - Specific surface

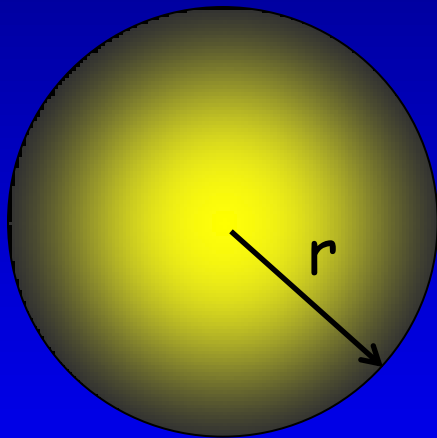
Spacing Factor - \bar{L}



- Index related to the maximum distance of any point in the cement paste from the periphery of an air void.
- Generally: needs to be < 0.2 mm for adequate resistance to freezing and thawing

Specific Surface of Air Void

- Specific surface—surface area per unit volume of air void



$$\text{Surface Area} = A = 4\pi r^2$$

$$\text{Volume} = V = \frac{4}{3}\pi r^3$$

$$\frac{A}{V} = \alpha = \frac{3}{r}$$

- Generally: needs to be $> 25 \text{ mm}^{-1}$ for adequate resistance to freezing and thawing

Air-Void Parameters of Hardened Concrete

ASTM C457/C457M



Polished section



Microscopical Examination

Air-Void Analyzer (AVA)



- Determines the size distribution of air voids in fresh concrete
- Calculates various air-void parameters, including:
 - Air content
 - Spacing factor
 - Specific surface

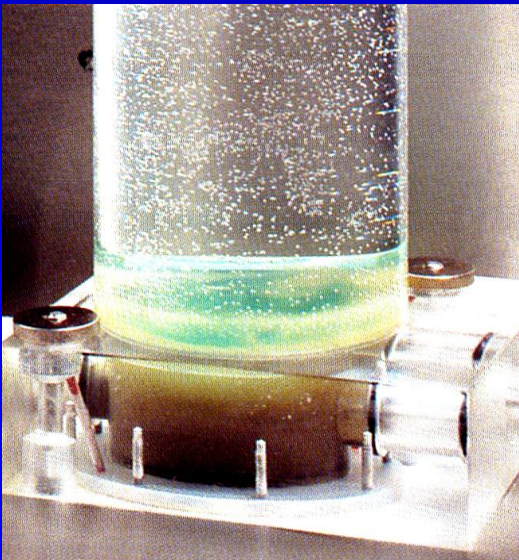
AVA Procedure



Obtain mortar
sample



Place sample in AVA

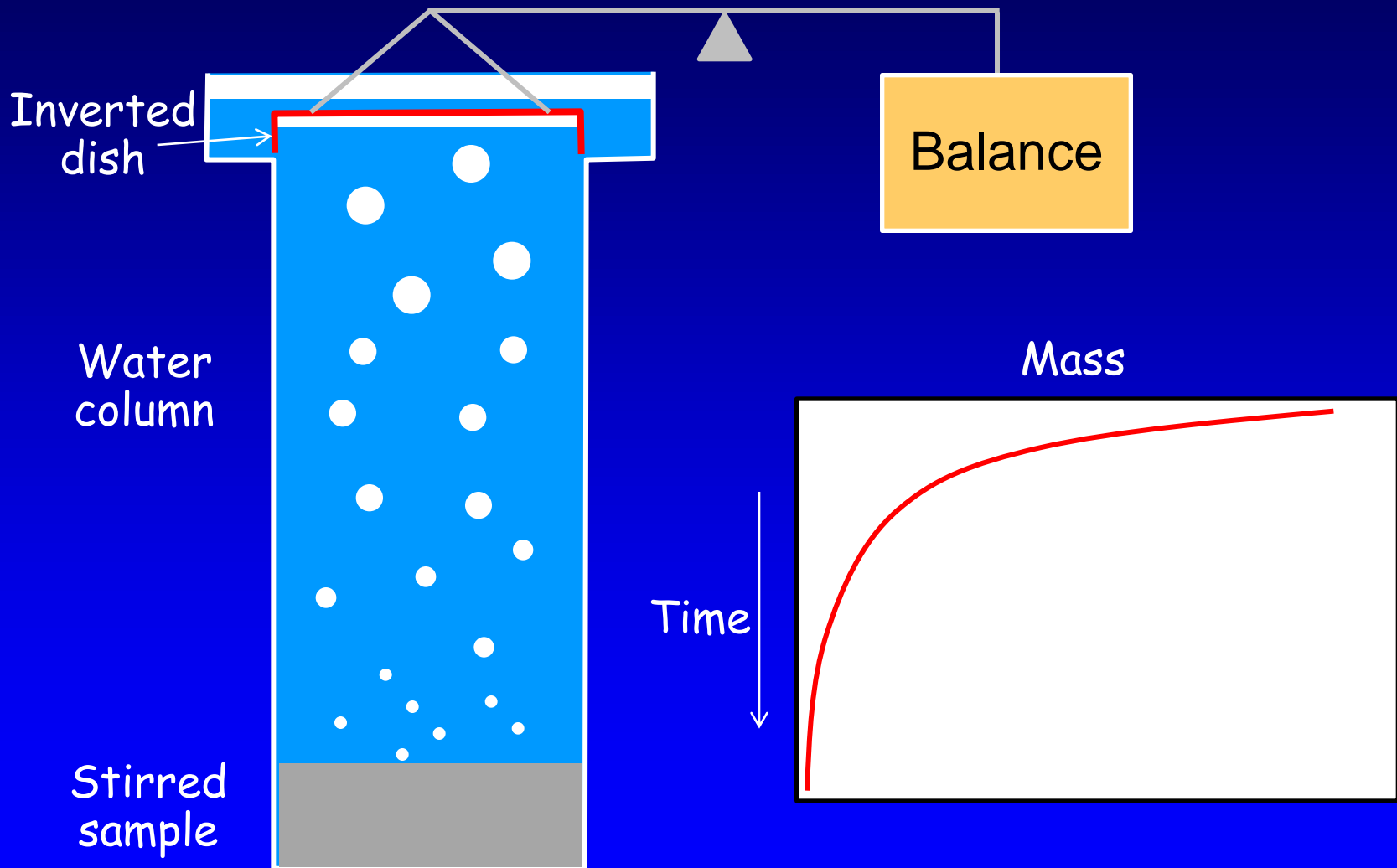


Stir
sample
in
glycerol



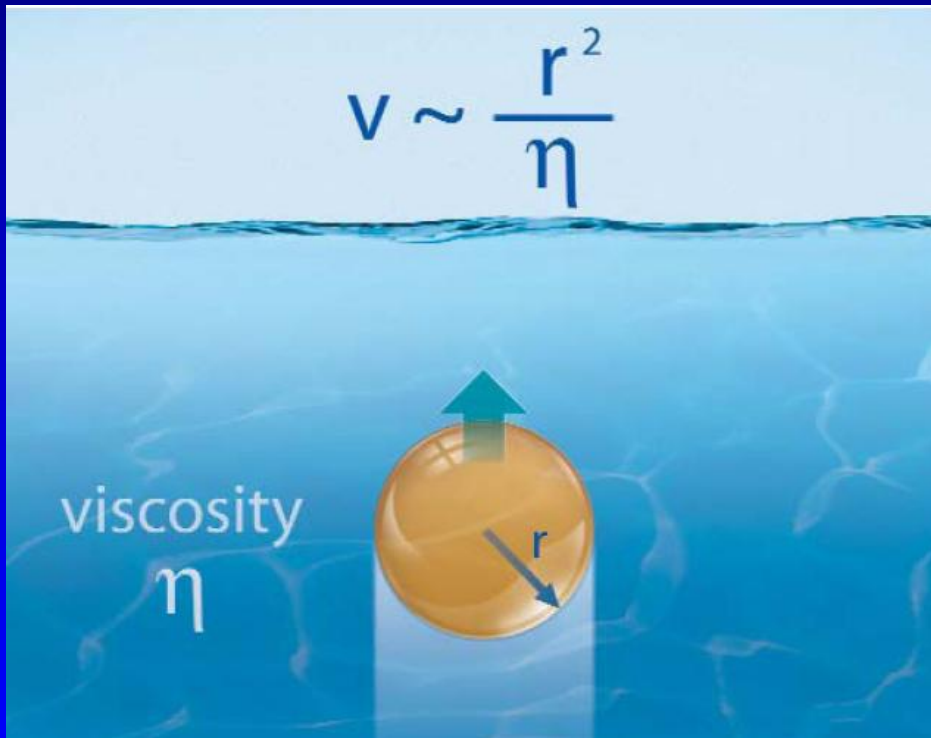
Acquire
data

Measurement



Terminal Speed of Rising Bubble

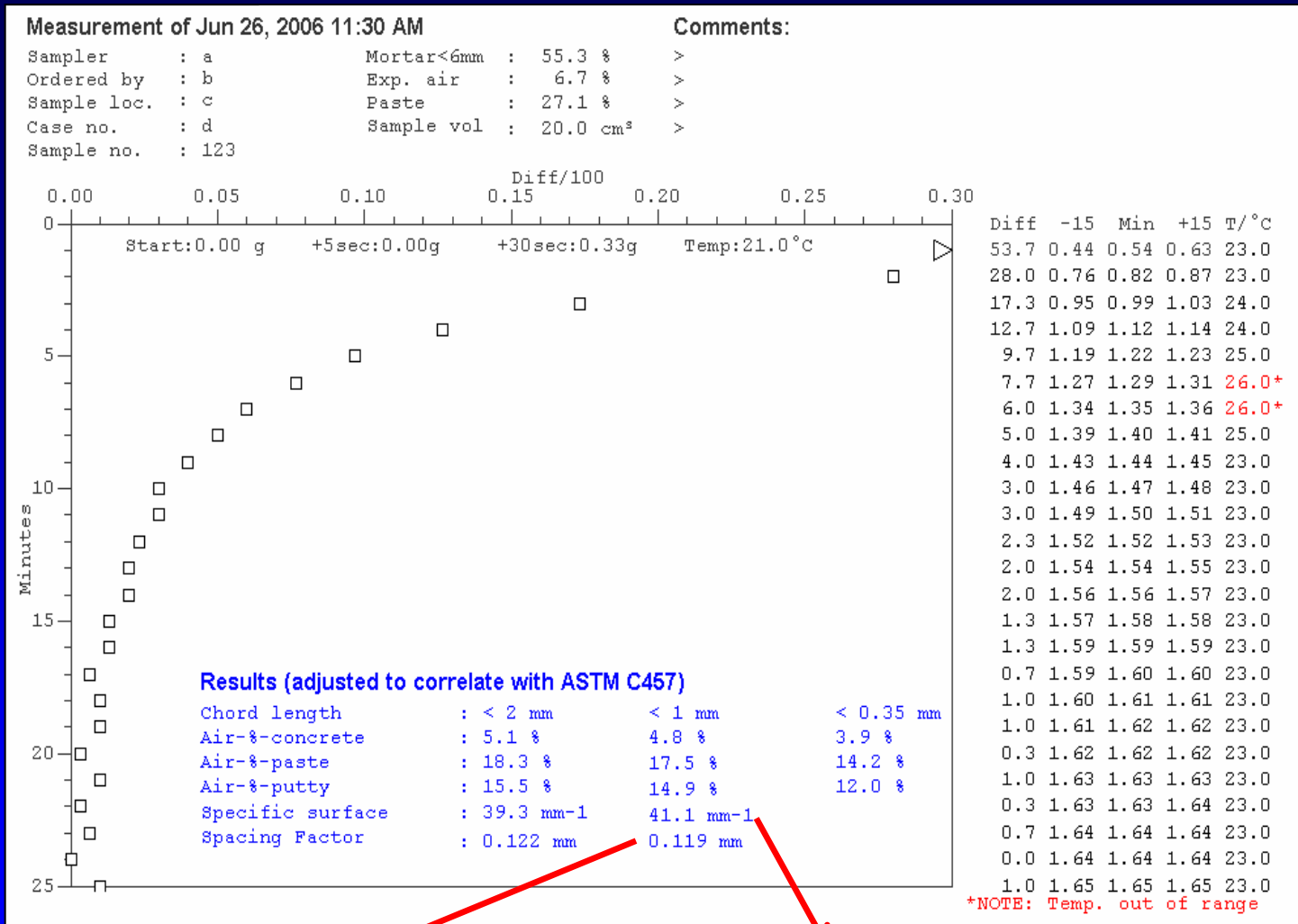
Stokes Law



- Large air voids rise faster
- From mass-time data
 - Determine void size distribution
 - Compute air-void parameters

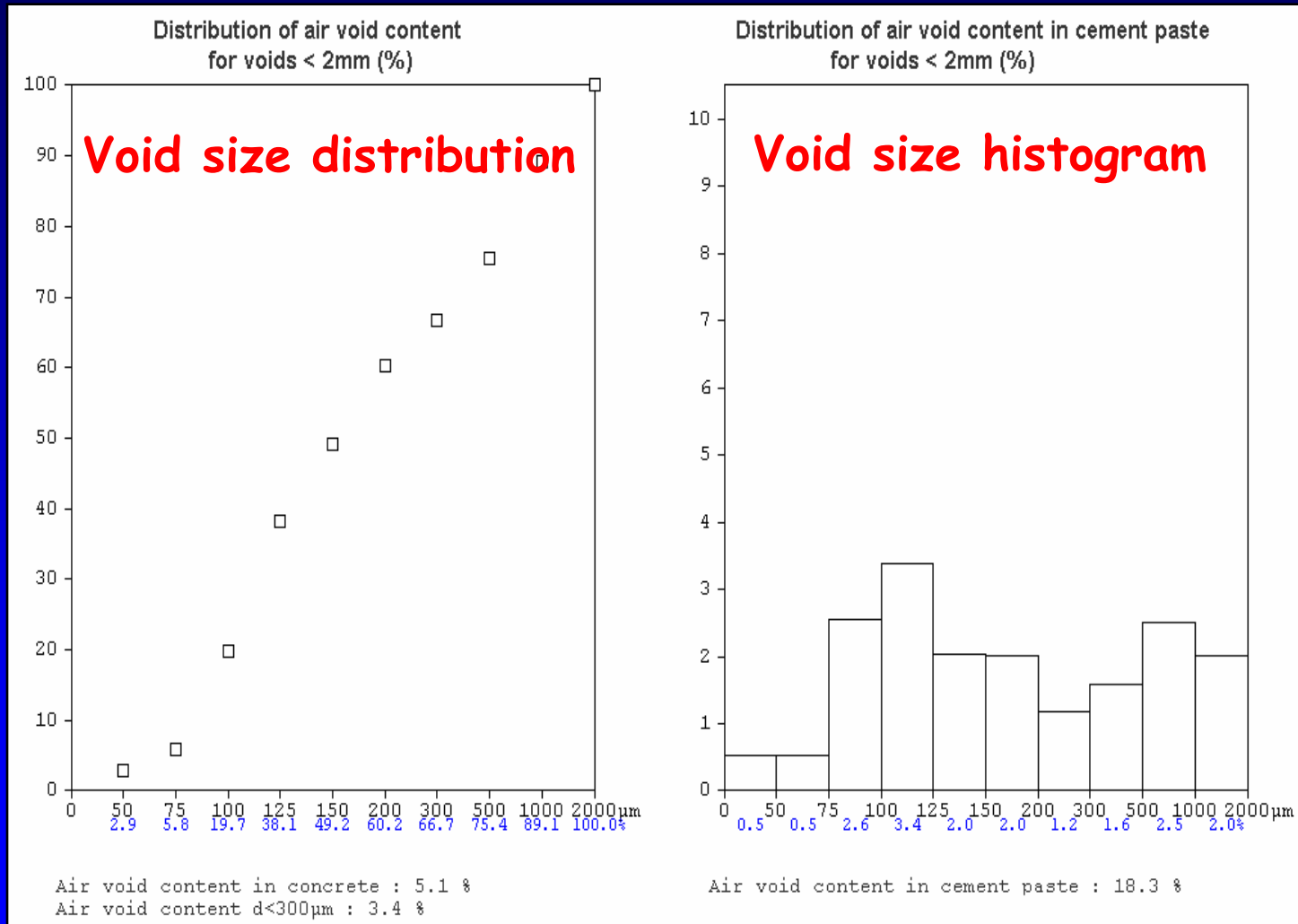
www.tego.de

AVA Printout

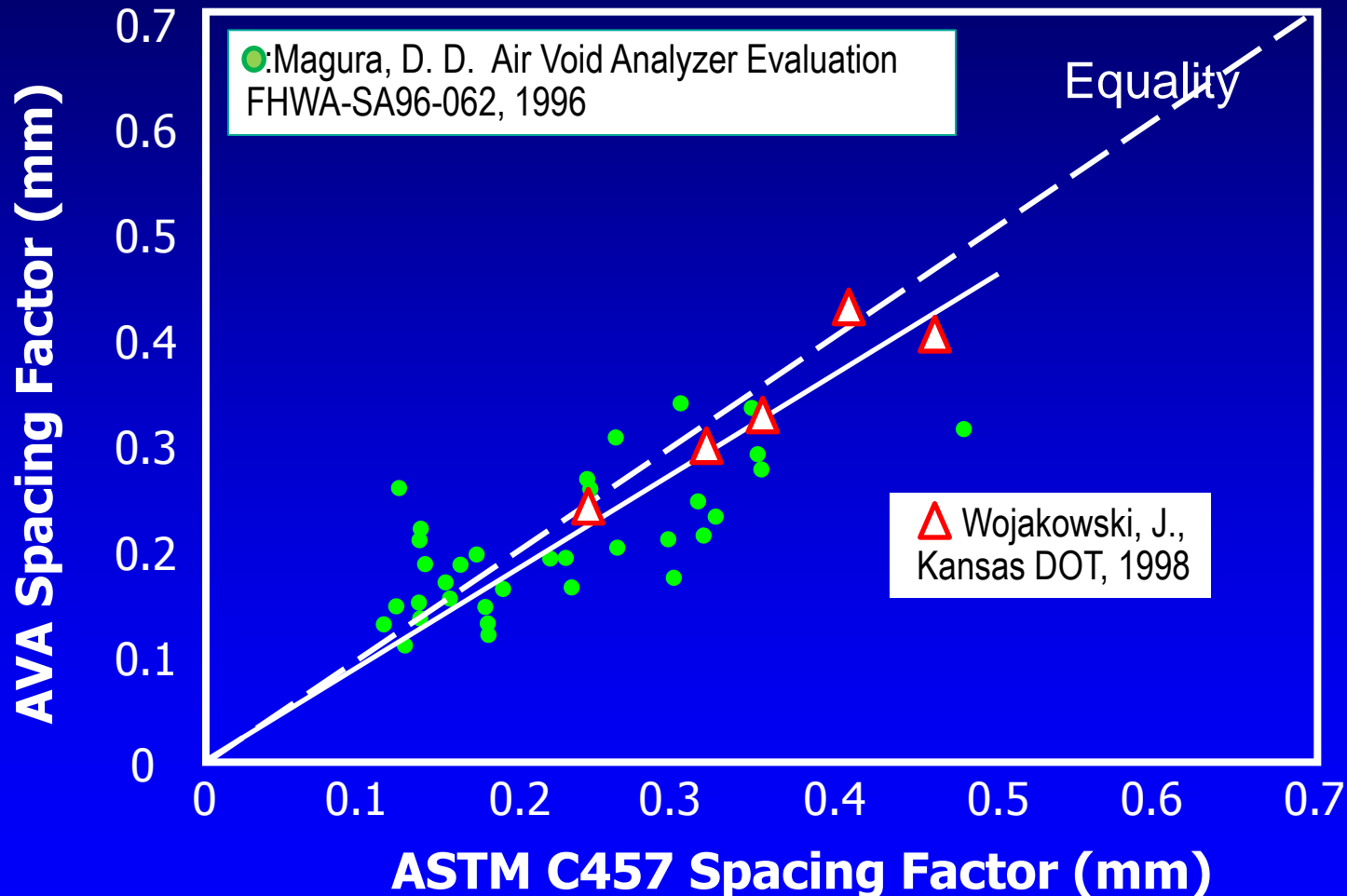


Spacing factor 0.119 mm Specific surface 41.1 mm⁻¹

AVA Additional Information



AVA Comparison with ASTM C457/C457M



AVA Developments in US

- Focus Technology by AASHTO;
 - Kansas DOT as lead agency
<http://tig.transportation.org/Pages/AirVoidAnalyzer.aspx>
- AASHTO provisional standard TP-75-08: "Method of Test for Air-Void Characteristics of Freshly Mixed Concrete by Buoyancy Change"

Benefits of AVA

- Provides information on the air-void parameters at any step in production process
- Provides measure of key parameters that affect in-place durability performance
- Rapid results compared with microscopical examination of hardened samples
- Well suited for performance-based specifications of air-void parameters

K-DOT Video