International Union of Laboratories and Experts in Construction Materials, Systems and Structures

RILEM Technical Committee 206 - ATB

Task Group 2: Mixture Design & Compaction

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October 19-20, 2009, Warsaw, Poland

Outline

- Project overview
- Project progress
  - Imaging Software & Analysis
  - TG2 Member Feedback
  - Initial Analysis
  - Development of Standard Procedure
  - State-of-art Report
- Moving forward

Project Overview

- **Essential Tasks:**
  - Comparison of compaction temperature & pressure
  - Comparison of compaction methods
  - Comparison of laboratory compaction to field samples
- Measurements
  - Aggregate Structure : contact points, orientation, & segregation
  - Density
  - Mechanical Properties
- State-of-the-art report
  - Lab compaction methods
  - Field compaction methods

Project Overview- Steps

1. Establishing protocols for compaction methods
2. Shipping, preparing and compacting loose LCPC mix.
3. Coring and shipping field samples from LCPC – France.
4. Performing **x-ray tomography** on lab and field samples.
5. Performing **scanned image** (2D) analysis.
6. Performing **gamma-ray analysis** on lab and field samples.
7. Performing **mechanical testing**
   - On samples with high variability in internal structure.
8. Collecting, analyzing and compiling the results into a common database.

Project Status - Samples

- Specimens from Superpave gyratory, German Steel Sector, Marshall, and Kneading Compactor (UW, AIT, UC-Davis, MTU, TU-B) have been:
  - X-rayed at Turner Fairbank Highway Research Center
  - Shipped to UW, cut and 2D imaginged with flatbed scanner.
  - Processing and analysis is underway.
- Specimens from French roller, CE Gyratory, German Sector, and Marshall (LCPC, EMPA, TU-B, Parma)
  - at LCPC for gamma-ray density scanning

Project Status – Samples

- Nottingham and Palermo have completed compaction
  - Specimens at Palermo are being sawn and imaged for 2D analysis
- Additional material sent to TU-Braunschweig for further compaction and mechanical testing

Specimen Status-Updated Oct '09 – 12 Labs

LAB No.	LAB name	Gyratory – US	Gyratory - CE	French Roller	German sector	Marshall	Hveem	Status
10	**AIT**					X		At UW via FHWA
14	**UC – Davis**			X			X	Hveem @ UW via FHWA, French Roller specs compacted & on hold
2	**EMPA**	X		X		X		Compaction data received, waiting for update/request from group
7	**LCPC**		X	X				Compaction data received
9	**Liverpool**				X			Compaction data received
3	**Michigan Tech**	X						At UW via FHWA
10	**Technical Univ. of Braunschweig**		X		X	X		Compaction completed, German sector at UW via FHWA, Gyratory & Marshall at LCPC
5	**Total-France**		X	X				Unsure
8	**UFC – Petrobras**	X		X		X		Unsure
11	**Univ. of Parma**				X			At LCPC
1	**UW – Madison**	X						Compaction data received, additional specimens used for compaction temp/pressure analysis
16	**Nottingham**		X					Compaction completed, no additional news
21	**Univ. of Palermo**				X			Delayed due to lab move/construction

Project Status – Software

- Completed major improvement 2D Software
- Latest version distributed to TG2 members.
  - Trials performed by members, feedback is used in next iteration of software.
- Analysis of gyratory specimens complete, data analysis underway.
  - Variables include: compaction temperature & pressure, NMAS, ESALs, binder grade and aggregate type.
- Draft ASTM standard completed (hard copies available)

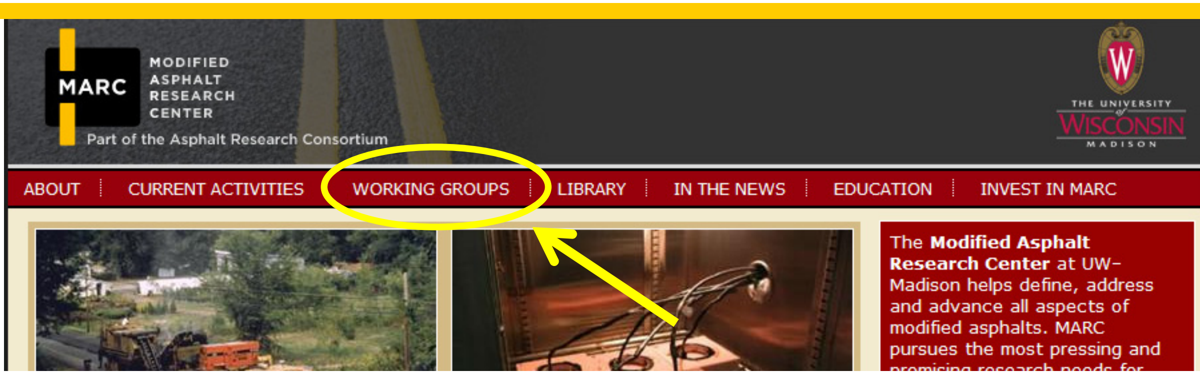
Imaging Software & Analysis

- Updated 2D Software distributed to TG2 Members along with:
  - Step-by-step instructions for installation & use
  - Two trial images and accompanying files
  - Survey for members to provide feedback

Files still available for download through:

http://www.uwmarc.org

Software Access - @www.UWMARC.org



- **International Union of Laboratories and Experts in Construction Materials, Systems, and Structures (RILEM)**
  MARC members serve on several RILEM technical committees, including Technical Committee 206-ATB on Advanced Testing and Characterization of Bituminous Materials. Hussain Bahia chairs this committee's Task Group 2 on HMA compaction methods and models.

  Task Group 2 Web page
  RILEM Technical Committee 206-ATB Web site

Image Analysis Software

- Software installation package [EXE, 261 MB]
- Supplementary files, including an instruction manual (with a feedback survey) and sample images [ZIP]

Survey Response

	No		Not Sure		Yes
• Was the software easy to use?	1	2	3	<u>4</u>	5
• Was the Step-by-step procedure easy to follow?	1	2	3	<u>4</u>	5

- How much time did you spend adjusting filtering values to obtain what you considered acceptable?

First Image	5min	15min	25min	<u>more</u>
Second Image	5min	<u>15min</u>	25min	more

For those new to image processing, 25 or more minutes for the first attempt but much less (15 minutes) by the second trial.

For those with prior imaging experience, 10-15 minutes was the typical time .

*ONLY A HANDFULL OF FEEDBACK SURVEYS HAVE BEEN RECEIVED, PARTICIPATION AND COMMENTS ARE STILL WELCOME

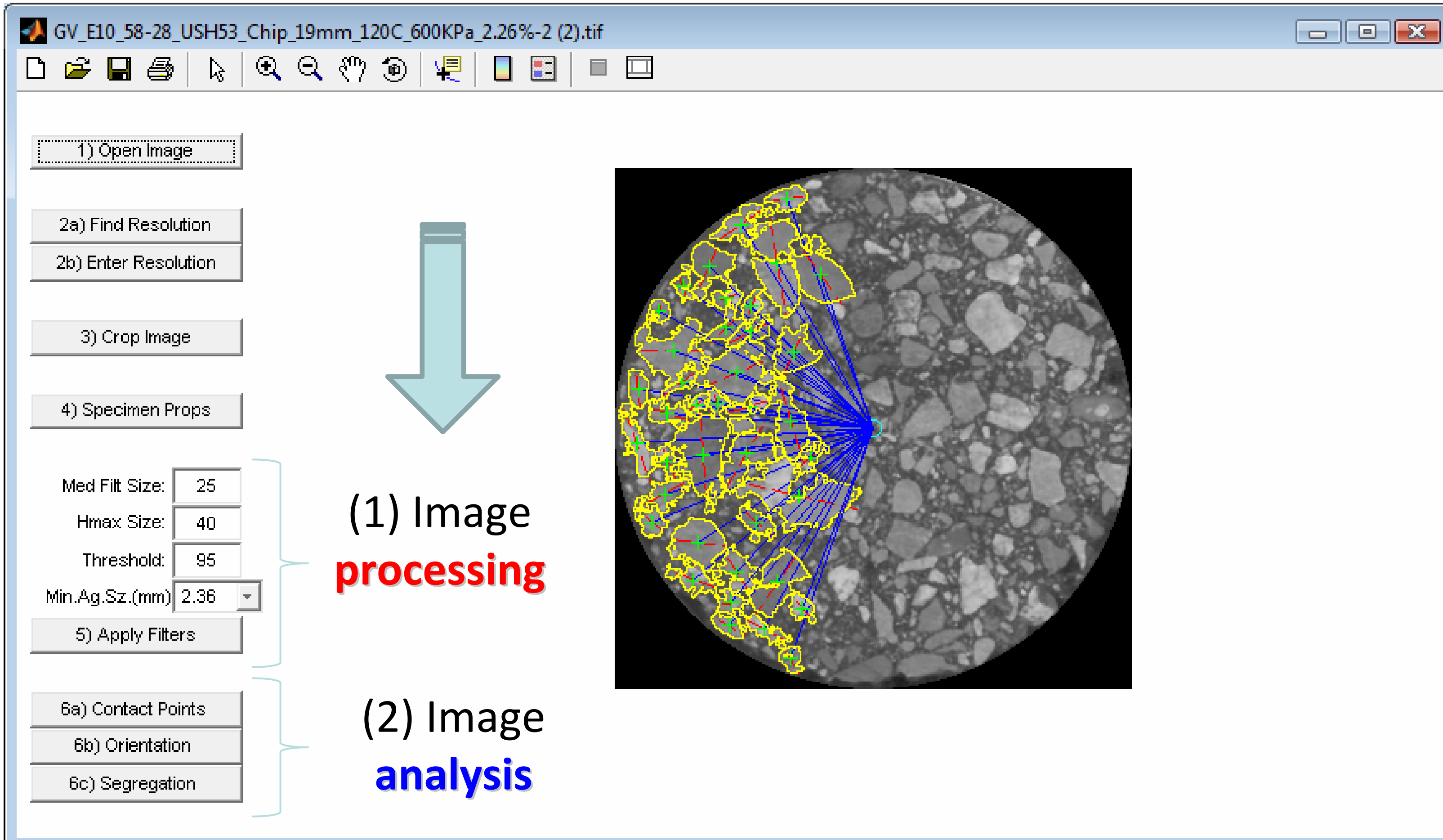
Survey sent to…

AARON R COENEN
ALLEX ALVAREZ
ANDREW HANZ
ANTONIO MONTEPARA
ARIANNA COSTA
ARTAMENDI IGNACIO
BERND OLDE SCHEPER
BERTRAND POUTEAU
CARL MONISMITH
CHANTAL DE LA ROCHE
CHICHUN HU
CHRISTIANE RAAB
CLARA CELAURO
DAVID HELDT
EDITH ARAMBULA
EMAD KASSEM
EMMANUEL CHAILLEUX
ENAD MAHMOUD
EYAD MASAD
FERHAT HAMMOUM
GILLES GAUTHIER
GORDON AIREY
HAIZHU LU
HUSSAIN A. KHALID
HUSSAIN U. BAHIA
HYUNWOOK KIM
IAN RICKARDS
IRWIN GUADA
JAMES GRENFELL
JAMILLA LUTIF
Janet Jackson
JEAN-PASCAL PLANCHE
JOHN HARVEY
JORGE SOARES
JOSEPH ANONCHIE-BOATENG
KITAE NAM
KONRAD MOLLENHAUER
KUNNAWEE KANITPONG
LINBING WANG
LUIS NASCIMENTO
M. EMIN KUTAY
MANFRED PARTL
MASSIMO LOSA
MICHAEL P. WISTUBA
MICHELE DAL TOE CASAGRANDE
MURAT GULER
PETER RENKEN
ROLF LEUTNER
SANJEEV ADHIKARI
SHU WEI GOH
SILVIA RASTELLI
XINJUN LI
YONGRAK KIM
YU LIU
ZHANPING YOU

RED names indicate individuals that have provided feedback via survey. Thank you!

Software Updates of '09

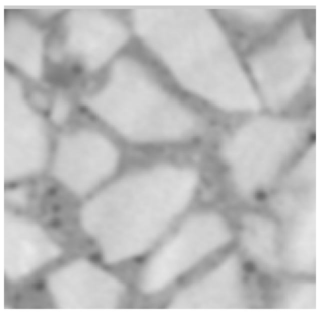
Clear distinction of two parts to software

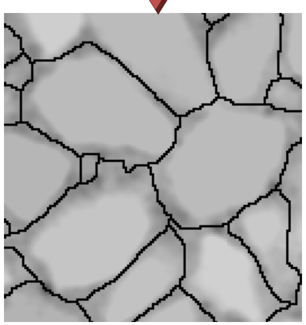


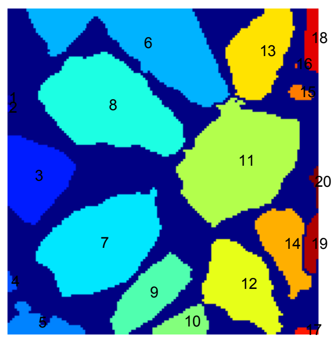
Software Updates of '09

Detail of two part process

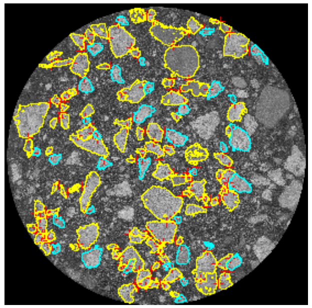
(1) Image **processing**



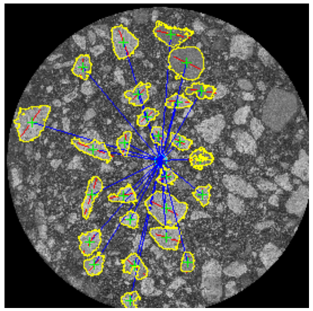




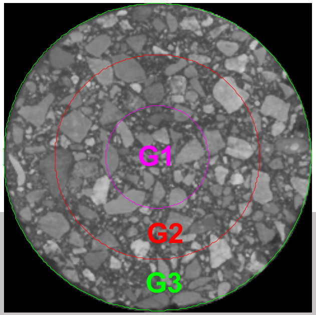
(2) Image **analysis**



Contact points



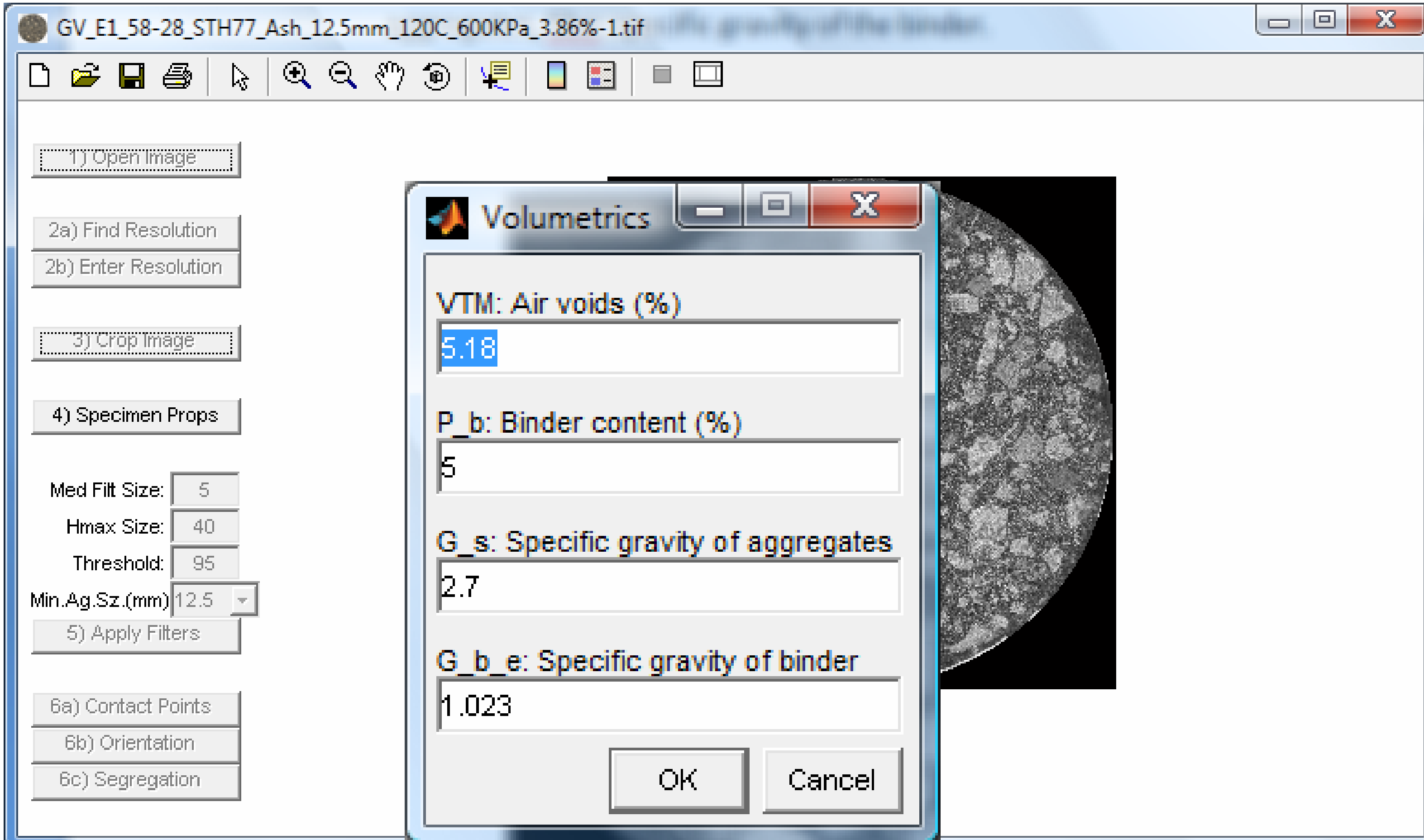
Orientation



Segregation

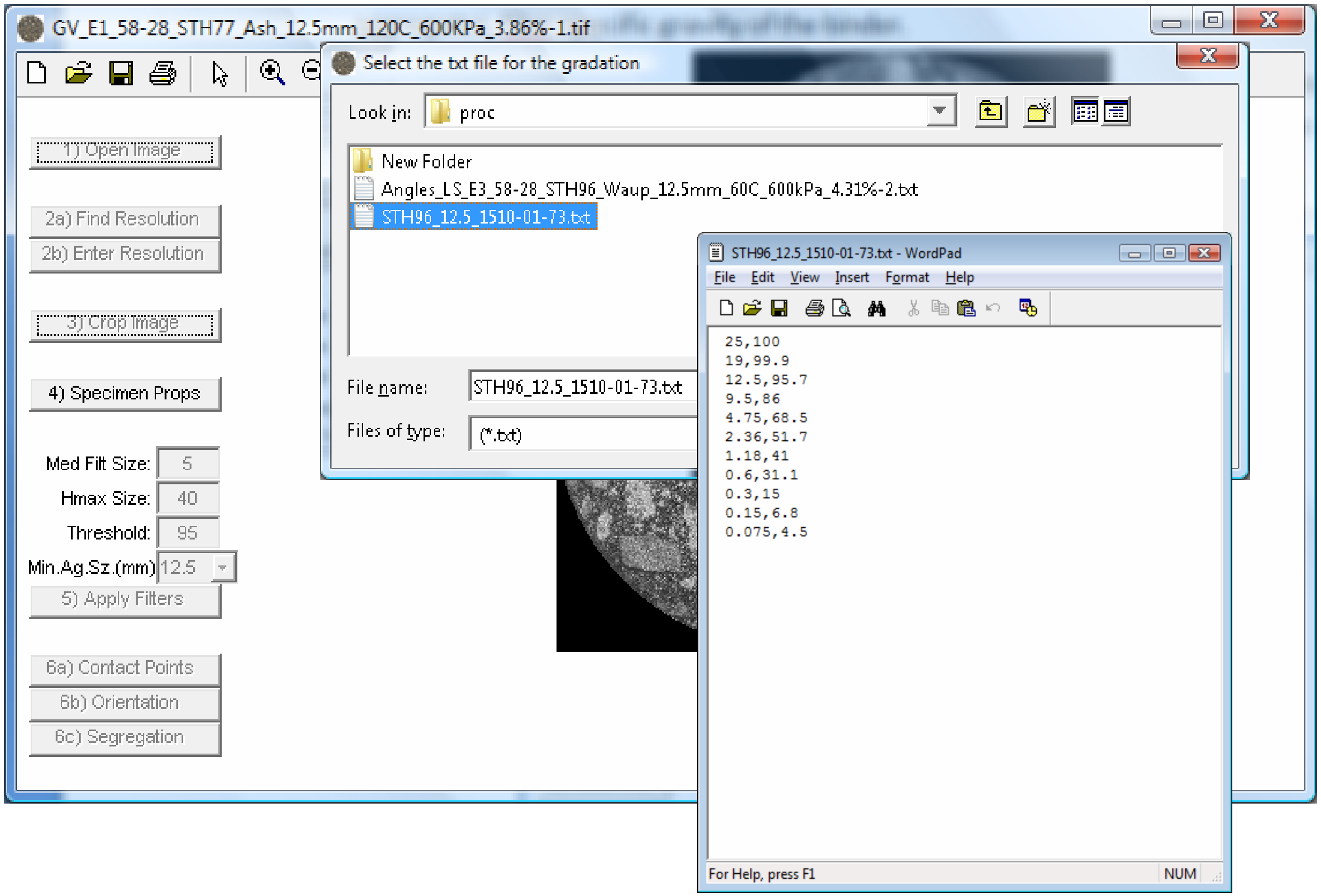
Software Updates of '09

Accounting for specimen properties



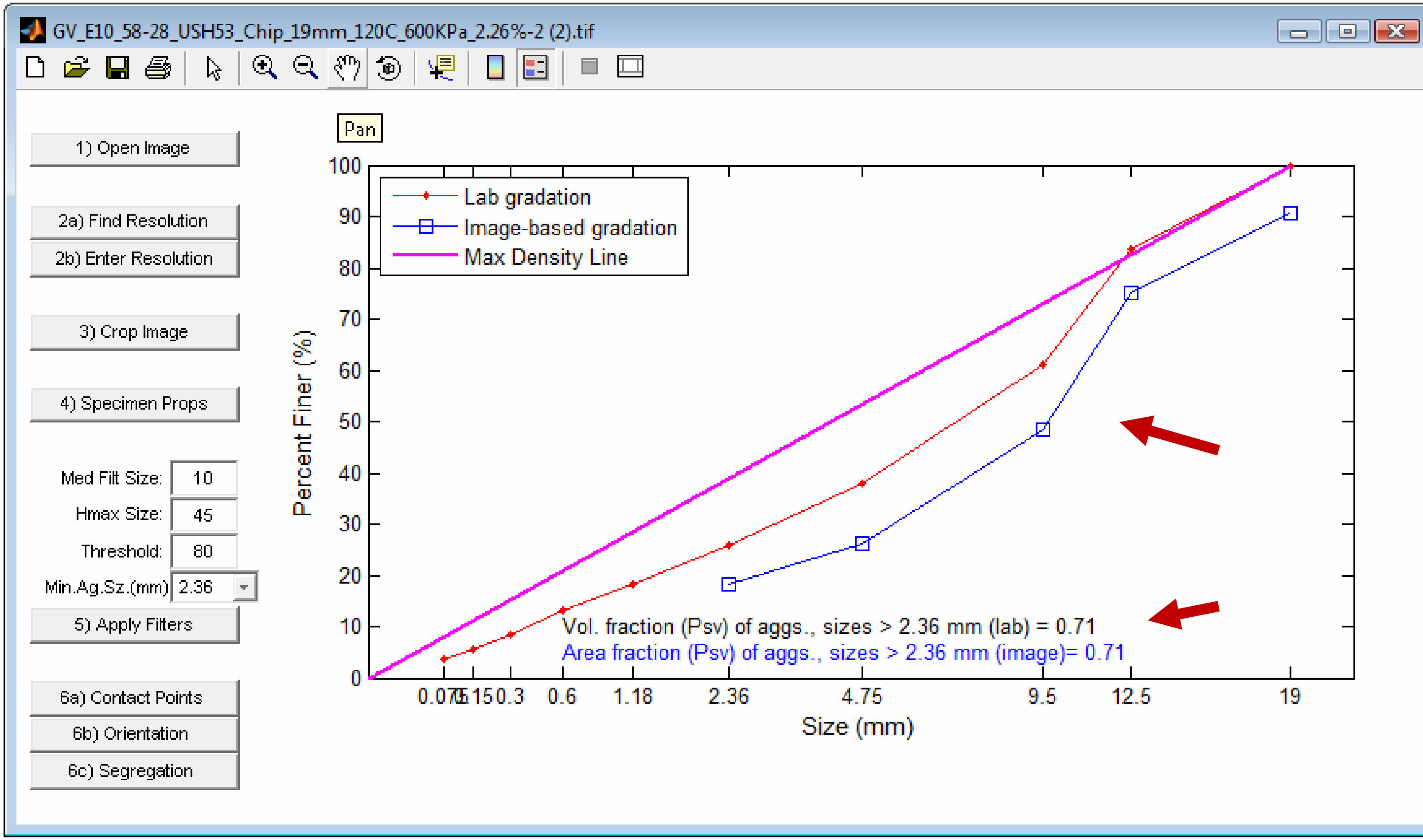
Software Updates of ‘09

Entering laboratory aggregate gradation of mix

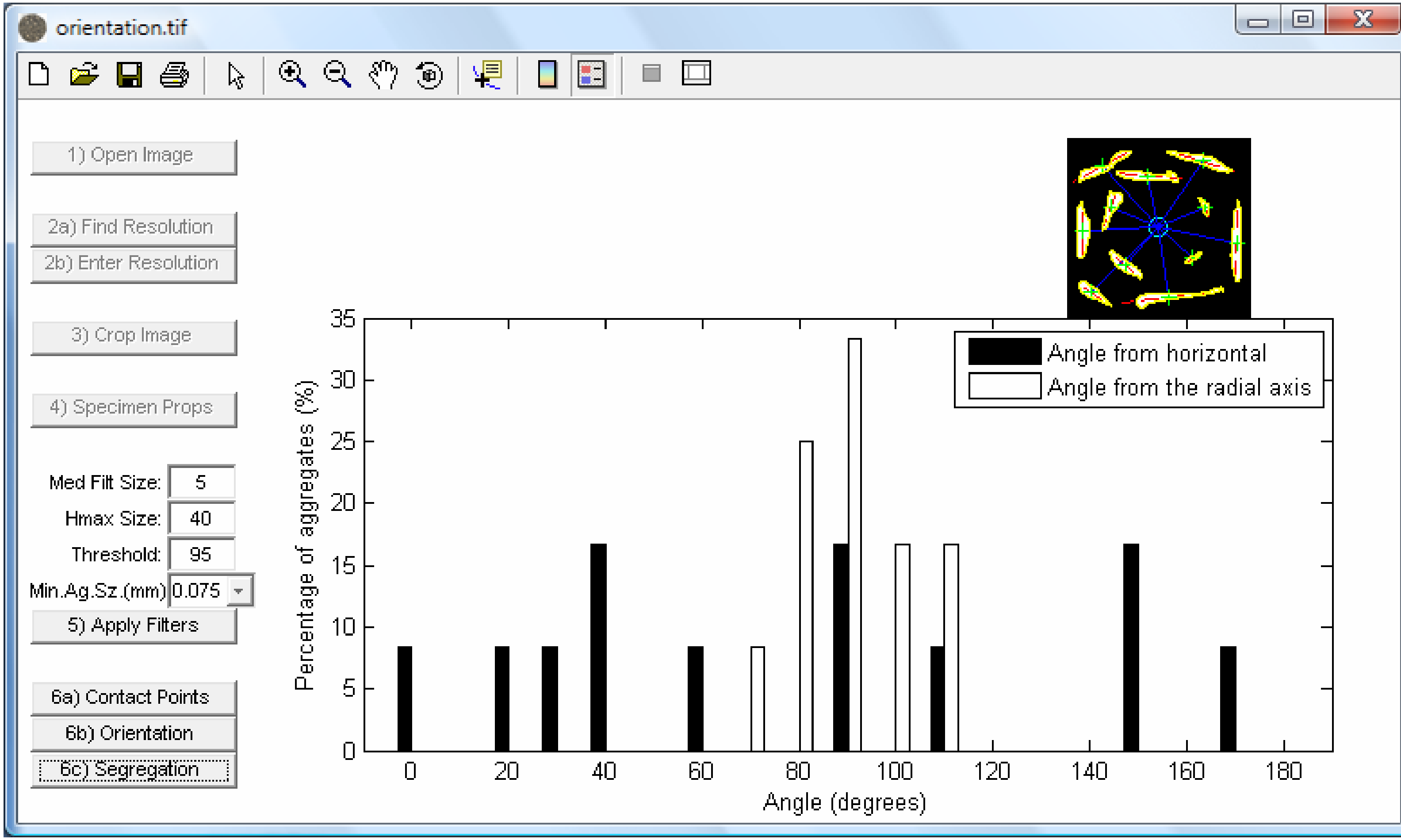


Software Updates of '09

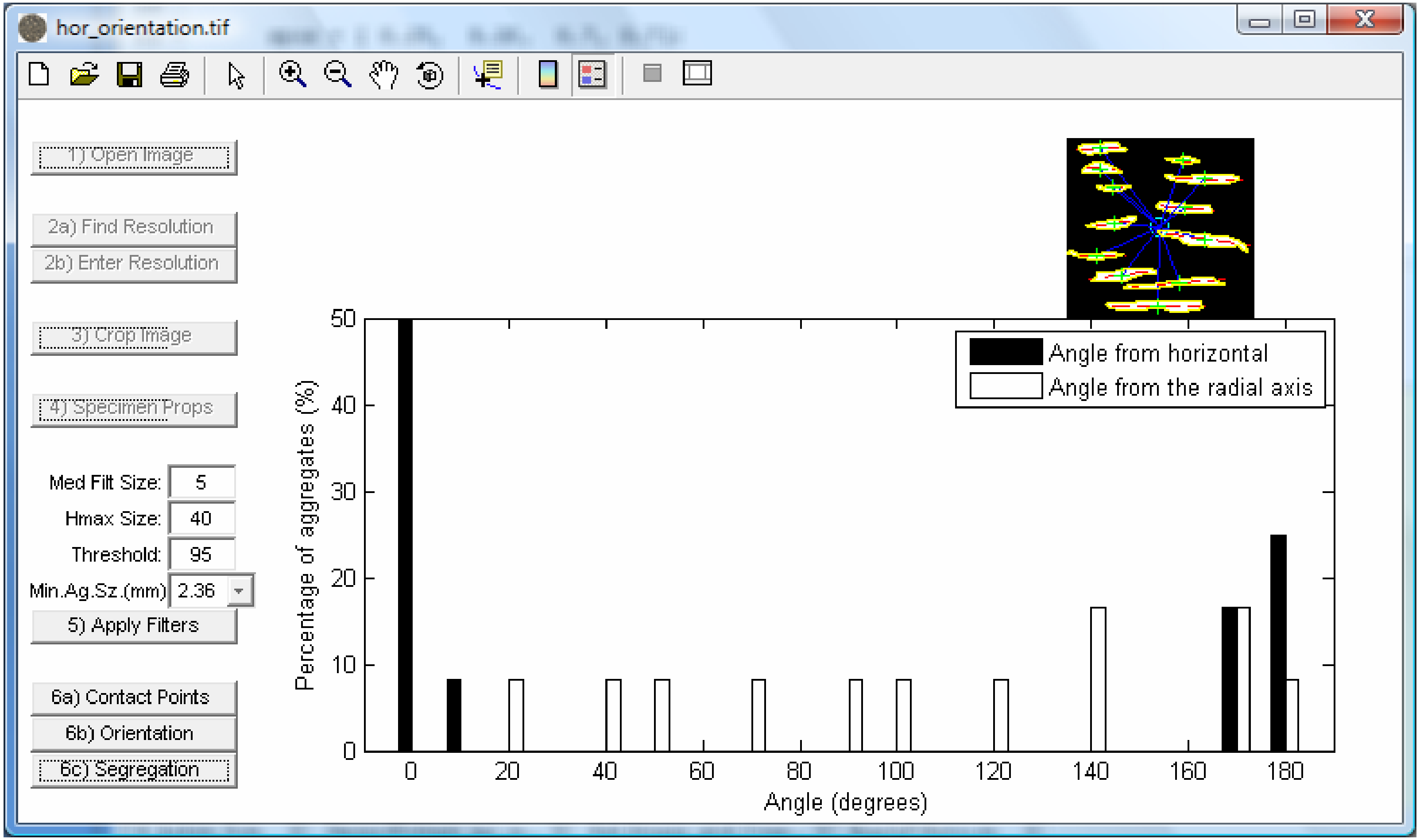
Matching of laboratory gradation & volumetric fraction with image based findings



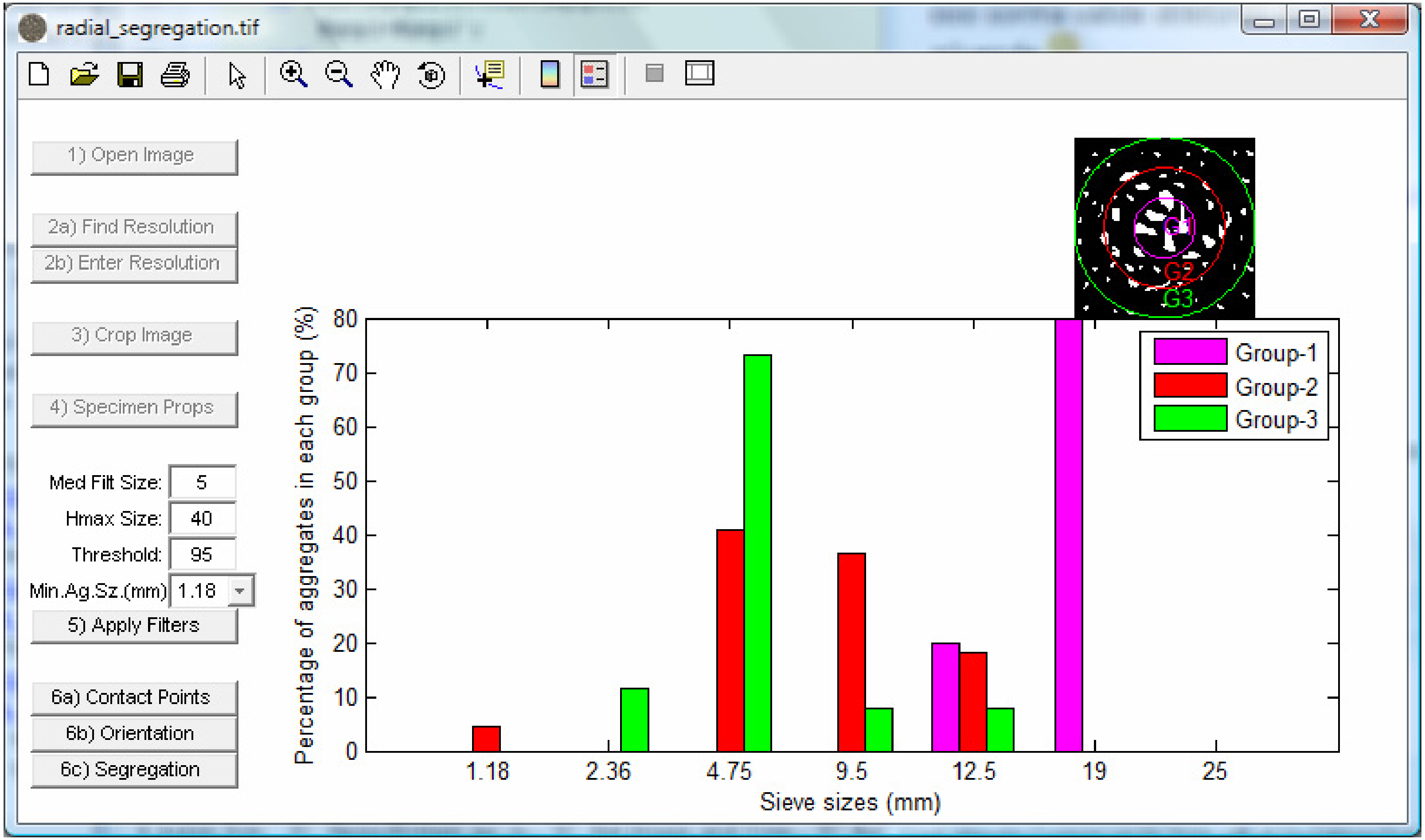
Sample Output: Orientation (uniform radial)



Sample Output: Orientation (uniform horizontal)

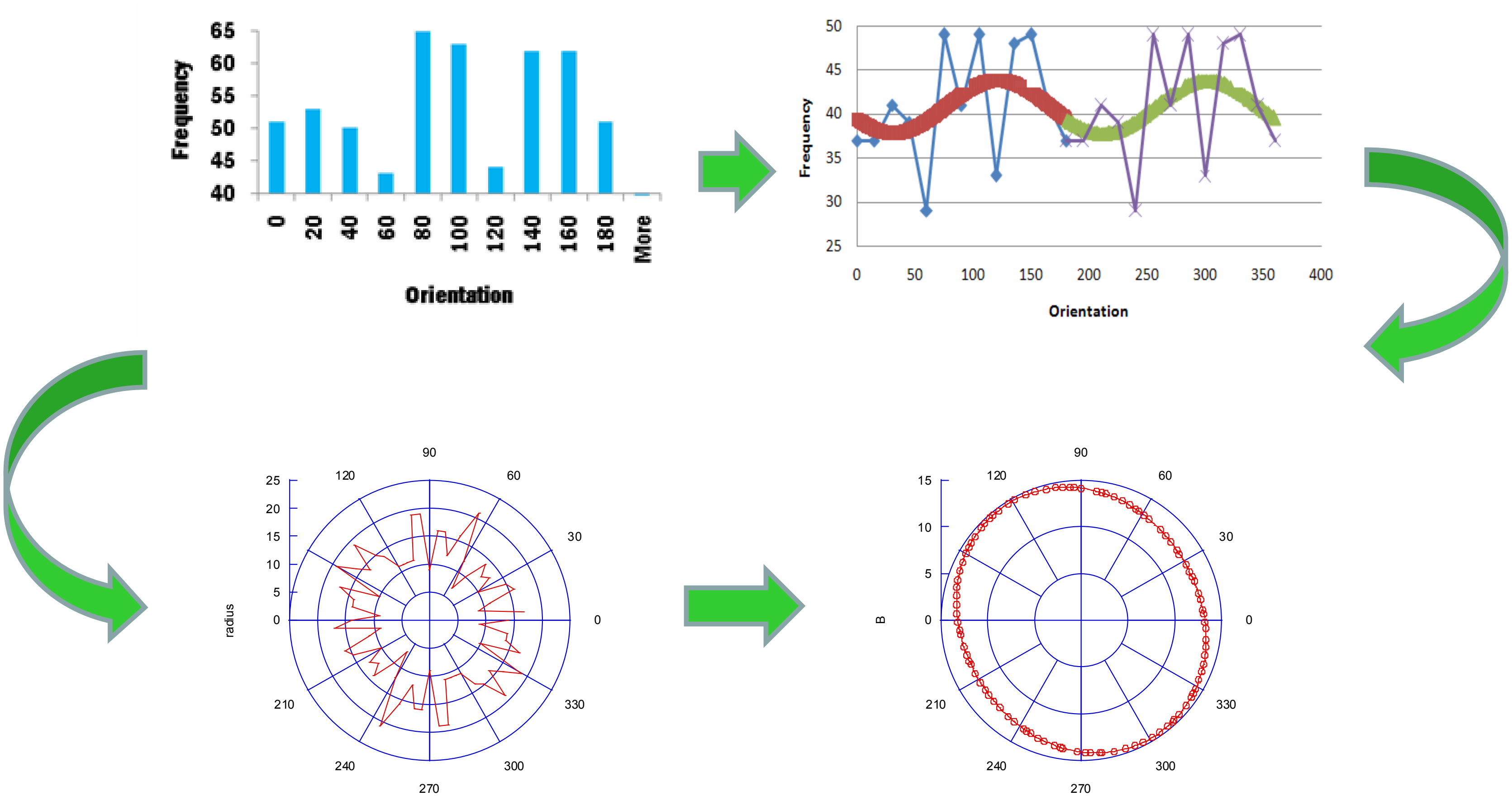


Sample Output: Segregation



Initial Analysis – Aggregate Orientation
Procedures after Tashman et al. 2001-AAPT

Currently working on data presentation for better understanding by readers/viewers. This is done by converting from original histogram to polar coordinate system by fitting a harmonic function to data.



Harmonic Fit Calculations
After Masad et al. 1998

Frequency Fit :

$$freq_{harm} = freq_{ave}\,(1 + a*\cos^2\theta + 2b*\sin\theta\cos\theta - a*\sin^2\theta)$$

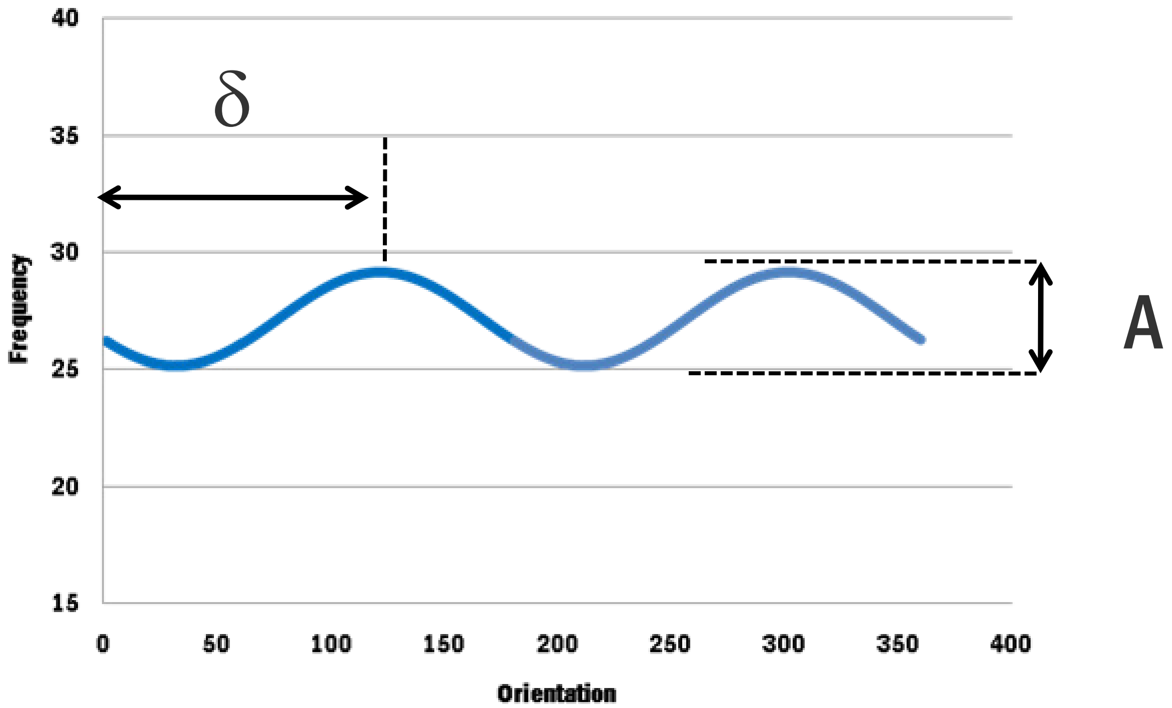
where: $a = \dfrac{2\sum_{k=1}^{N}\cos(2\theta_k)}{N}$ $\quad$ $b = \dfrac{2\sum_{k=1}^{N}\sin(2\theta_k)}{N}$

and N=total number of aggregates accounted for in image

A, Amplitude: $= MAX(freq_{harm}) - MIN(freq_{harm})$

δ, peak position: $e_x\,[MAX(freq_{harm})]$ or angle of the $MAX(freq_{harm})$

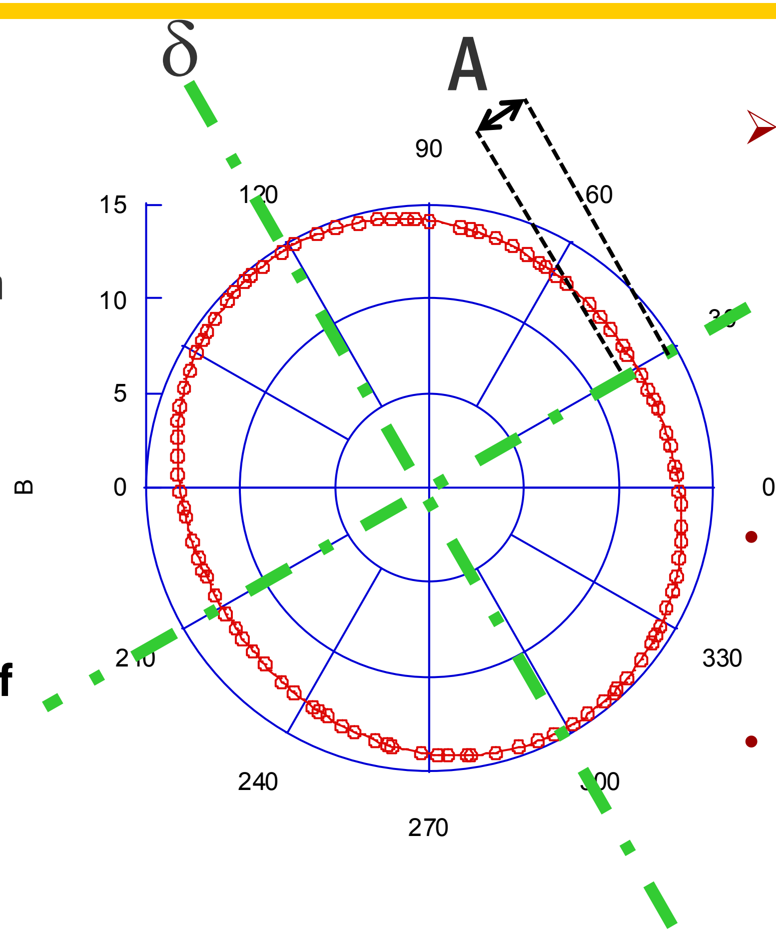
Harmonic Fit Parameters



$\delta =$ Predominant angle, A= Severity of angle dispersion

Polar Representation

- **Major Axis** – Identifies predominant aggregate orientation & represents maxima of harmonic fit

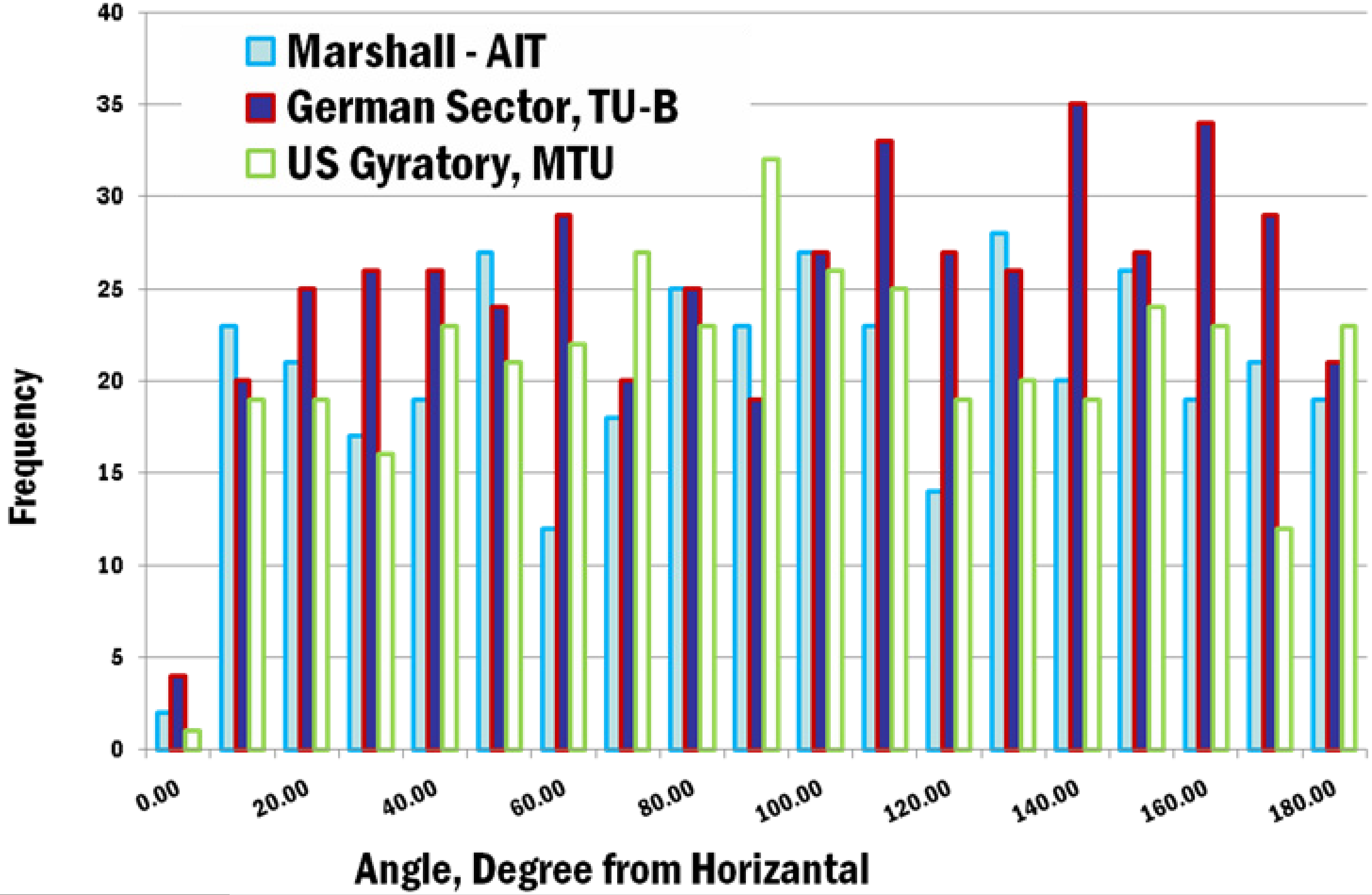


- **Minor Axis** – Represents minima of harmonic fit

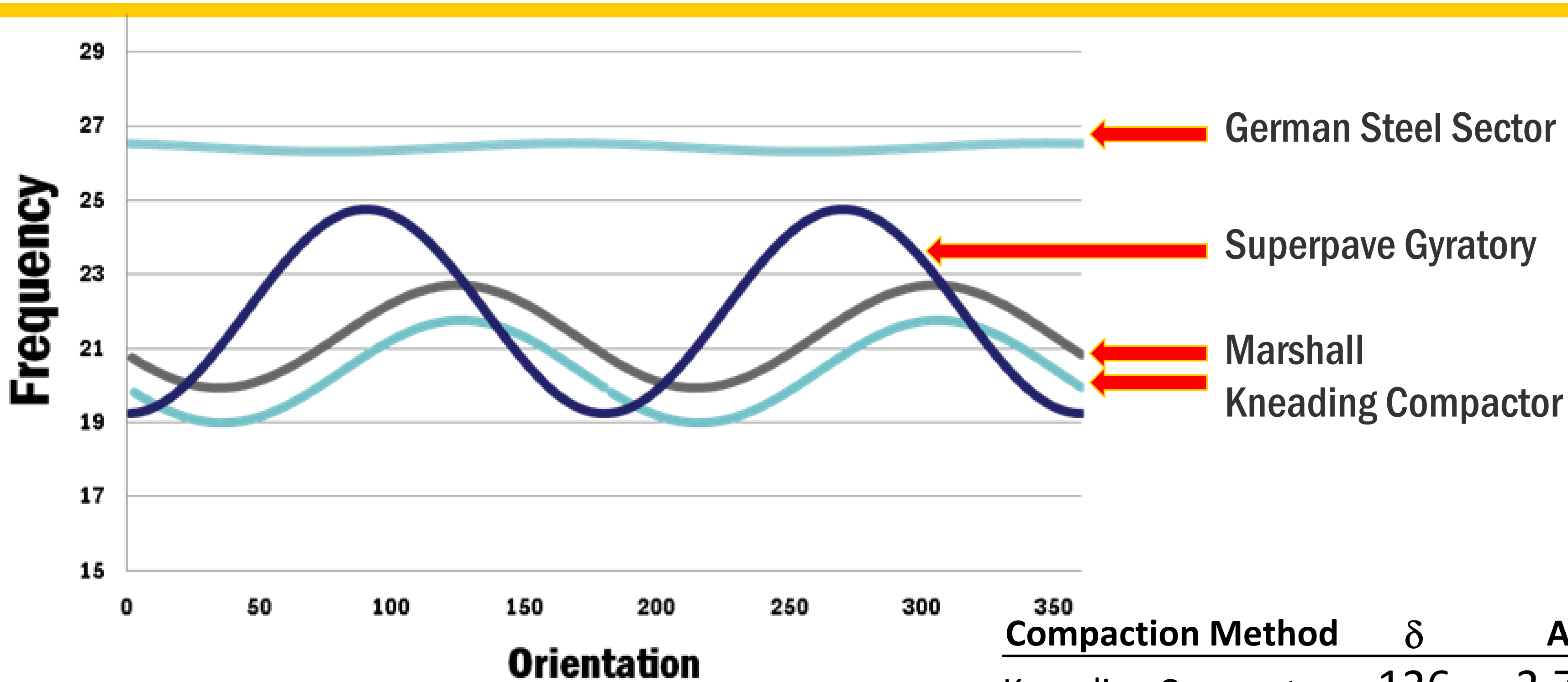
➢ **Difference between max & min represents (A=amplitude of harmonic fit) . It indicates level of uniformity.**

- ***A uniform distribution is represented by a perfect circle in Polar coord.***
- ***As angles deviate more from uniform, the ellipse is more "pinched" in Polar coordinates.***

Initial Analysis-
Effect of Compaction Method on Orientation



Effect of Compaction Method – Initial Analysis



δ: Indicates the predominant orientation angle
A: represents the amplitude or severity of deviation from uniform (zero=uniform)

Compaction Method	δ	A
Kneading Compactor	126	2.78
Marshall	125	2.76
German Steel Sector	167	0.22
Superpave Gyratory	90	5.54

Preliminary Results

- Effect of Compaction Method on Orientation
  - The software is capable of measuring the orientation angle with respect to two reference points, from horizontal & from the radial arm from center of image
- We need to work more on the polar plots or the harmonic representation
  - Least square fit of harmonics will be tried
  - Improve d representation of dispersion

Standard Procedure

- A Standard Procedure has been drafted to detail:
  - Image processing
  - Image analysis
  - Critical parameters
  - Consistent reporting format/units

Standardization is Underway

Standard Method for

Determining Aggregate Structure in Asphalt Mixes by Means of Planar Imaging

Designation: xx-xx

1. SCOPE

1.1. *This standard covers the measurement of aggregate structure indicators of asphalt mixes using digital image analysis techniques.*

1.2. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

State-of-Art Report: Outline

- Introduction
  - Motivation for Study
  - History of Laboratory Compaction
  - Engineering Considerations (e.g. How to approximate field compaction efforts)
- SuperPAVE Gyratory Compactor
  - History
  - Engineering Principles - Concepts behind using compactor
  - Standard Procedure – Standards/Specifications etc.
  - Current Usage – Distribution of usage, frequency of usage
- Marshall Compactor
  - Same
- California Kneading Compactor
  - Same
- French Roller Compactor
  - Same
- German Sector Compactor
  - Same

Outline Continued

- Laboratory Comparison, testing results, and ability to estimate field conditions
- Relating laboratory compaction to field compaction & to mechanical properties and imaging
  - Application of Imaging Technology to compare laboratory and field compaction
  - Effect of Compaction Methods on Air Void Distribution Using Image Analysis Techniques
  - Relationship of Field Compaction Pattern to Air Void Distribution
  - Effect of compaction method on mechanical properties of asphalt mixtures
  - Comparison of Laboratory and Field Mechanical properties: Hamburg test, overlay test, and permeability
- Image Capturing and Analysis Related to Internal structure
  - Digital Camera
  - X-Ray Tomography
  - Air Void Distribution (effect of compaction method)
  - Aggregate Orientation (angle of inclination and vector magnitude)
  - Aggregate Contacts
  - Aggregate Segregation
- Imaging Standard
- References

Summary of Outline

Section assignments/sources

- Introduction
- SuperPAVE Gyratory Compactor
- Marshall Compactor
- California Kneading Compactor
- French Roller Compactor
- German Sector Compactor

} UW Graduate Student Underway

- Laboratory Comparison, testing results, and ability to estimate field conditions
- Literature Review relating lab to field compaction & both to mechanical properties and imaging

Application of Imaging Technology to improve the laboratory and field compaction of HMA

Effect of Compaction Methods on Air Void Distribution Using Image Analysis Techniques

} TTI Report

Relationship of Field Compaction Pattern to Air Void Distribution

Comparison of Lab and Field Mechanical properties: Hamburg test, overlay test, and permeability

Effect of compaction method on mechanical properties of asphalt mixtures } European Synthesis Report

- Image Capturing and Analysis Related to Internal structure } Paper in progress, Coenen
- Imaging Standard } In preparation, Mahmoud & Kutay
- References

Moving forward…

- Completed preliminary analysis of effects of compaction temperature and pressure as well as compaction method
  - Subsequent studies to include laboratory comparison with field cores
- Mechanical testing of specimens
- Development of relation between lab and field compaction
- **Draft State of the Art report by March 2010**

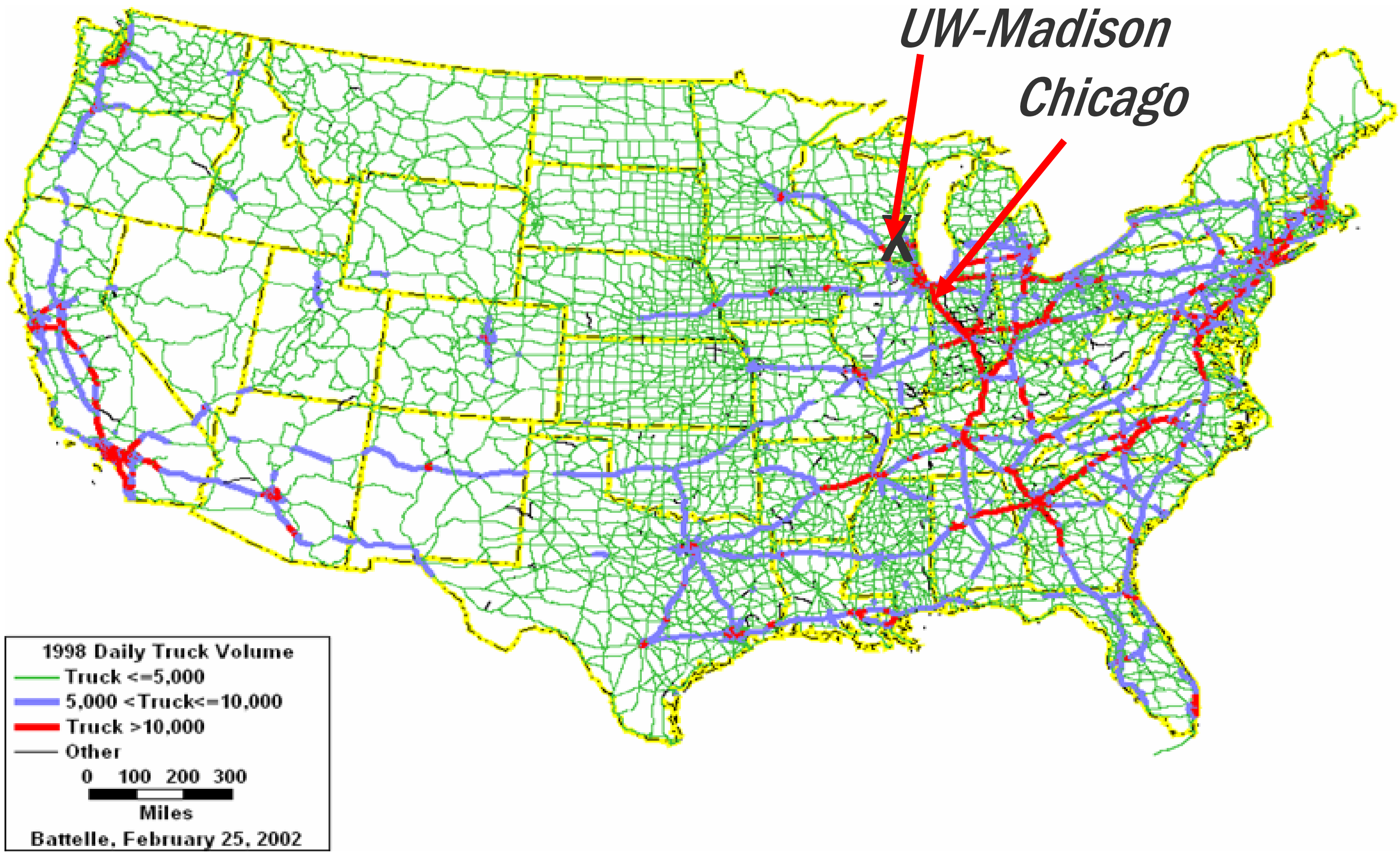
Thank you!

- Questions?

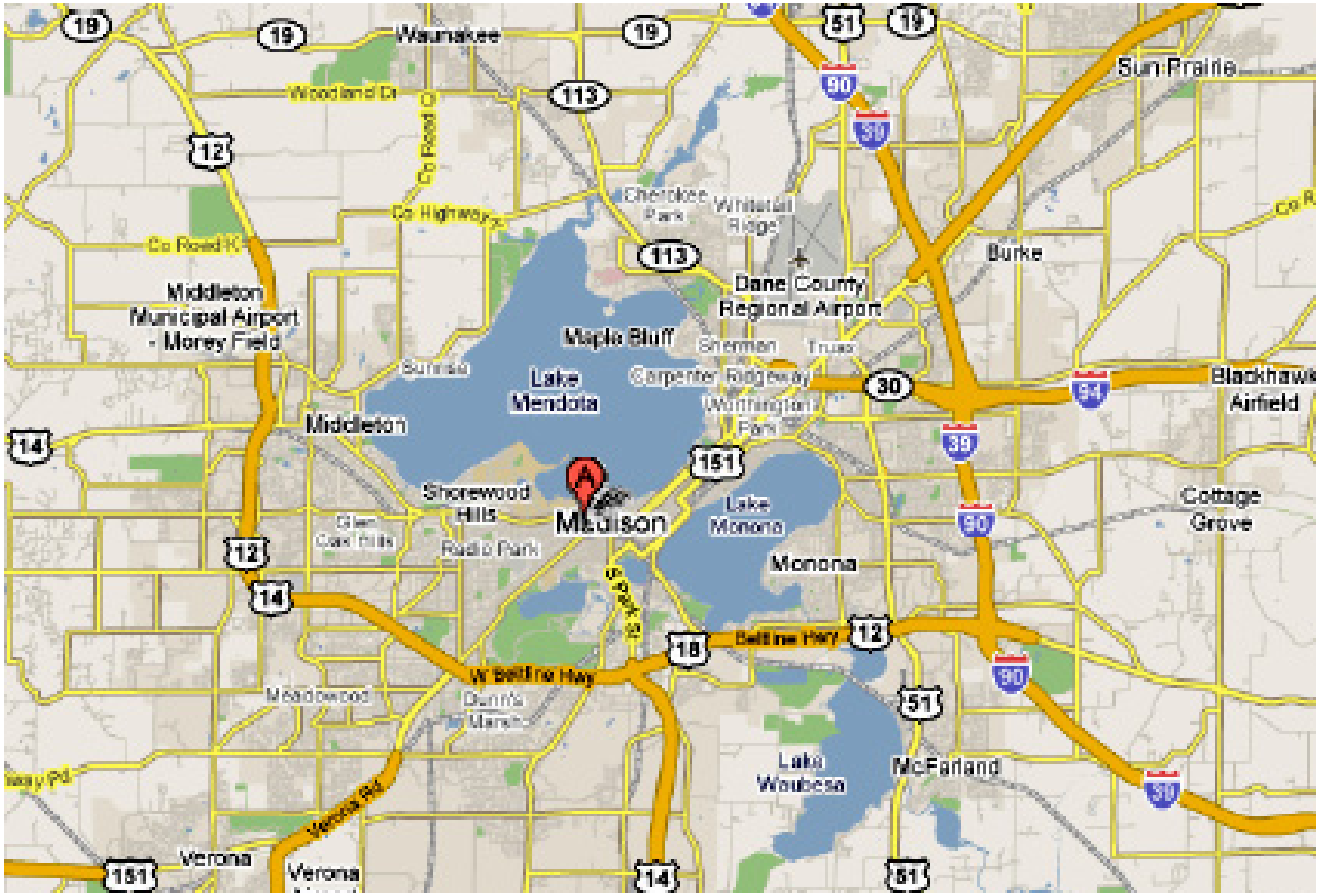
- For more information,

  Please contact Mr. Aaron Coenen:
  - arcoenen@wisc.edu

Next Year Meeting – Would like to welcome you to UW - Madison



Madison- A city between lakes



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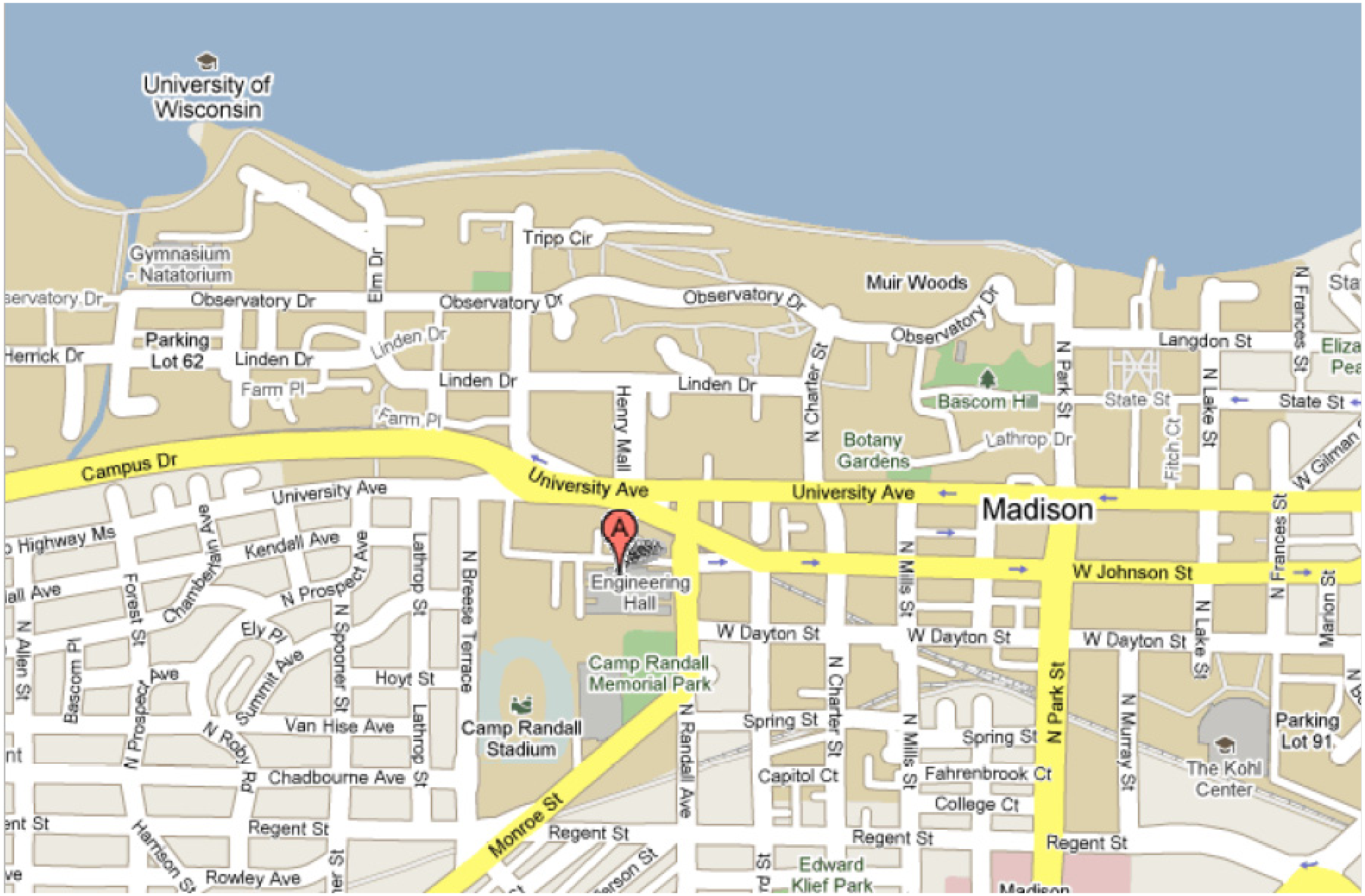
Engineering Complex



Logistics

- Two hotels within walking distance
  - Many within a short bus ride or drive
  - Parking next door to building
- One of the most beautiful capital buildings within 25 minutes walk
- Free campus bus morning to mid night
- 40,000 + students running around
- October is when fall tree colors peak

Fly to Chicago or to Madison

- Bus from Chicago airport terminal to campus
  - 6 times a day
- Many direct flights to Madison airport (MSN)
  - United, AA, NWA-Delta, Continental,
    - Washington DC
    - Detroit
    - Dallas
    - Newark and NY –LaGuardia
    - Minneapolis

Possibility of organizing workshops
Site visits

- Rilem TGs
- ISAP working groups
- One of the largest Recycling HMA plants
- Weekend before –
  - Chicago cultural tour – one day
  - Frank Lloyd Wright Museum – ½ day