



**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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Washington, DC**



# Outline

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- **Background**
- **Project status**
- **2D image analysis**
  - **Effect of temperature & pressure of compaction**
  - **Verification of results from KCKIM**
- **Defining aggregate structure**

# Background

- **The objective of the research is to develop tools other than density to identify mixture micro-structure.**
- **LCPC test track material available for laboratory compaction - 6 different methods**
- **Specimens will be evaluated using:**
  - **Gamma-ray densometer (field slabs)**
  - **X-ray computed tomography**
  - **2-D scanned image analysis**
  - **Mechanical testing ( $E^*$ , FN)**

# Project Status

- **Specimens from UW, Mich Tech, UCPRC, AIT, TU-Braunschweig being imaged at Turner Fairbank Highway Research Center using X-Ray CT.**
- **Specimens from LCPC, EMPA, TU-B, Parma at LCPC for gamma-ray density scanning**

# Specimen Status

		Task #1							
		COMPACTION METHODS							
		1	2	3	4	5	7		
LAB No.	LAB name	Gyratory – US	Gyratory - CE	French Roller	German sector	Marshall	Hveem	Sent for X-Ray CT	Sent for GRD
10	AIT					X		X	
14	UC – Davis			X			X	X	
2	EMPA	X		X		X			X
7	LCPC		X	X					X
9	Liverpool				X				
3	Michigan Tech	X						X	
10	Technical Univ. of Braunschweig		X		X	X			X
5	Total			X					X
8	TU-Delft	<b>Shear Box Compaction</b>							
11	University of Parma				X				
1	UW – Madison	X						X	
16	Nottingham		X						
21	University of Palermo				X				

# 2D Image Analysis – KCKIM Software

- **MATLAB-based interface is available for download at:**

<https://mywebspace.wisc.edu/cmjohnson3/RILEM/TG2.html>

- **Additionally, Dr. Clara Celauro's group at the University of Palermo has compiled the MATLAB code into a stand-alone package.**
  - **Please contact Carl Johnson if you'd like to download (~ 250 MB).**

# 2D Image Analysis – KCKIM Software

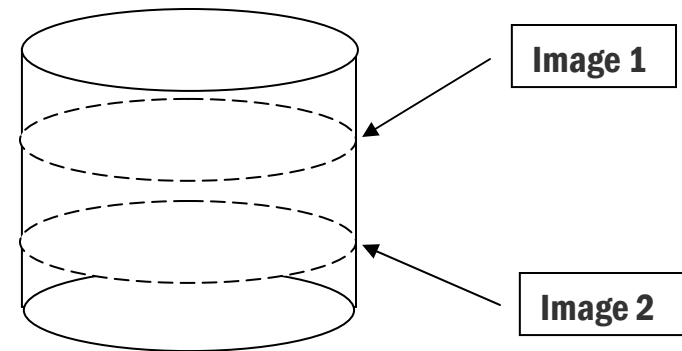
- **Preliminary results performed on field-sampled mix (from Wisconsin) compacted in lab:**
  - **3 temperatures: 120 °, 90 °, and 60 °C**
  - **2 pressures: 600 and 300 kPa**
  - **Compacted in the Superpave Gyrotory to 75 gyrations ( $N_{max}$ )**
  - **Crushed limestone aggregate, 12.5mm NMAS**

# 2D Image Analysis – KCKIM Software

- **Cut horizontally into three slices**

- **Scanned images were processed and analyzed for:**

- **Vector magnitude ( $\Delta$ )**
- **Aggregate angle distribution**





# 2D Image Analysis – KCKIM Software

## Results:

$\Delta_N$ : Unweighted

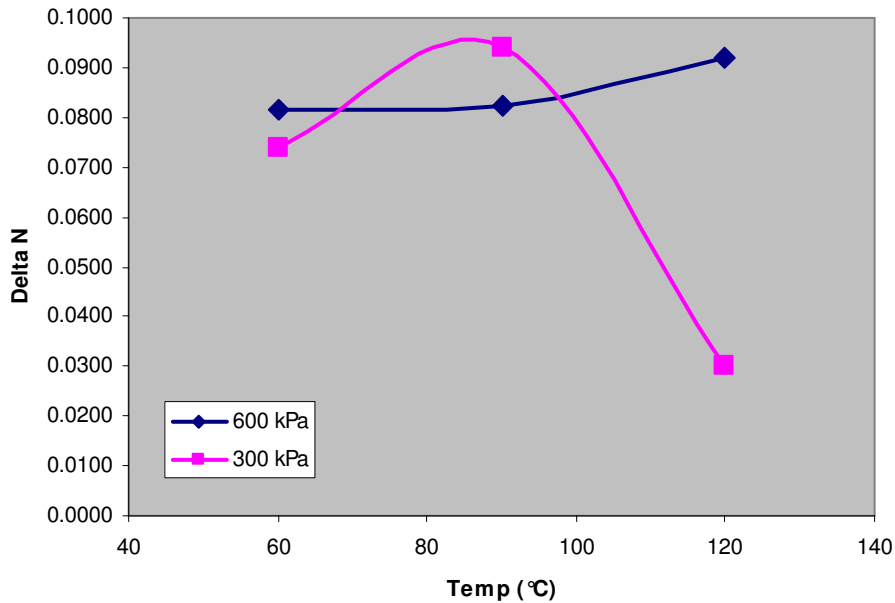
$\Delta_L$ : Weighted by Length

$\Delta_A$ : Weighted by Area

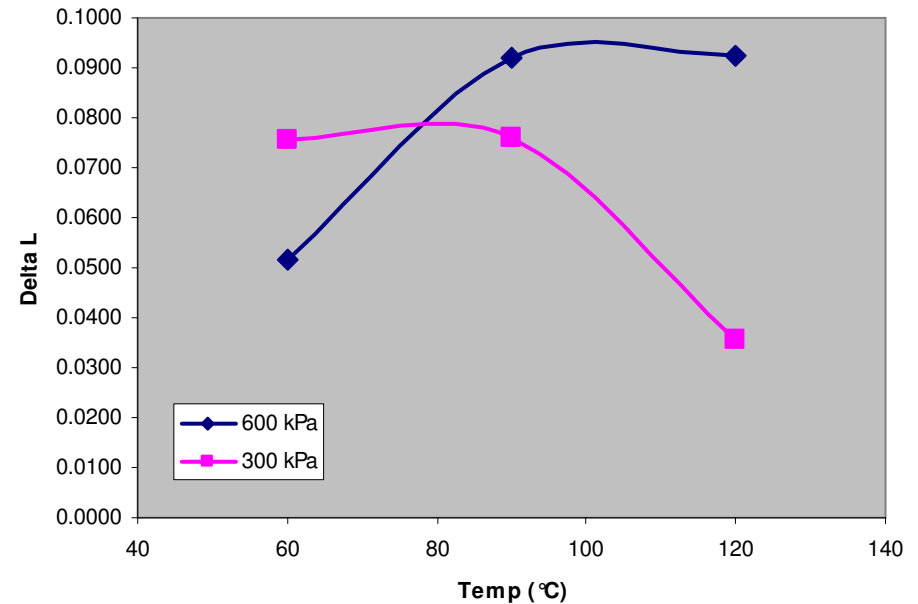
	Pressure kPa	Temp °C	Image 1	Image 2	Average	COV
Delta N	600	120	0.1249	0.0592	0.0921	50.5%
	600	90	0.1215	0.0434	0.0825	67.0%
	600	60	0.0257	0.1371	0.0814	96.8%
	300	120	0.0396	0.0203	0.0300	45.6%
	300	90	0.1145	0.0735	0.0940	30.8%
	300	60	0.0638	0.0840	0.0739	19.3%
Delta L	600	120	0.1000	0.0846	0.0923	11.8%
	600	90	0.1336	0.0504	0.0920	63.9%
	600	60	0.0130	0.0904	0.0517	105.9%
	300	120	0.0611	0.0102	0.0357	101.0%
	300	90	0.0756	0.0763	0.0760	0.7%
	300	60	0.0537	0.0978	0.0758	41.2%
Delta A	600	120	0.0724	0.1635	0.1180	54.6%
	600	90	0.1285	0.0736	0.1011	38.4%
	600	60	0.0170	0.0731	0.0451	88.1%
	300	120	0.1184	0.0097	0.0641	120.0%
	300	90	0.0750	0.0433	0.0592	37.9%
	300	60	0.0413	0.1262	0.0838	71.7%

# 2D Image Analysis – KCKIM Software

Vector Magnitude vs. Temp (Unweighted)

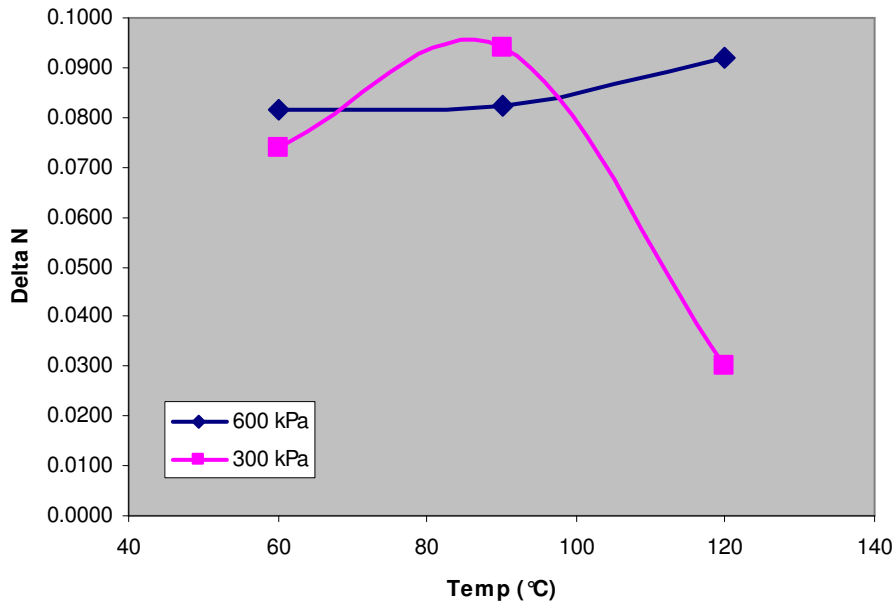


Vector Magnitude vs. Temp (Length Weighted)

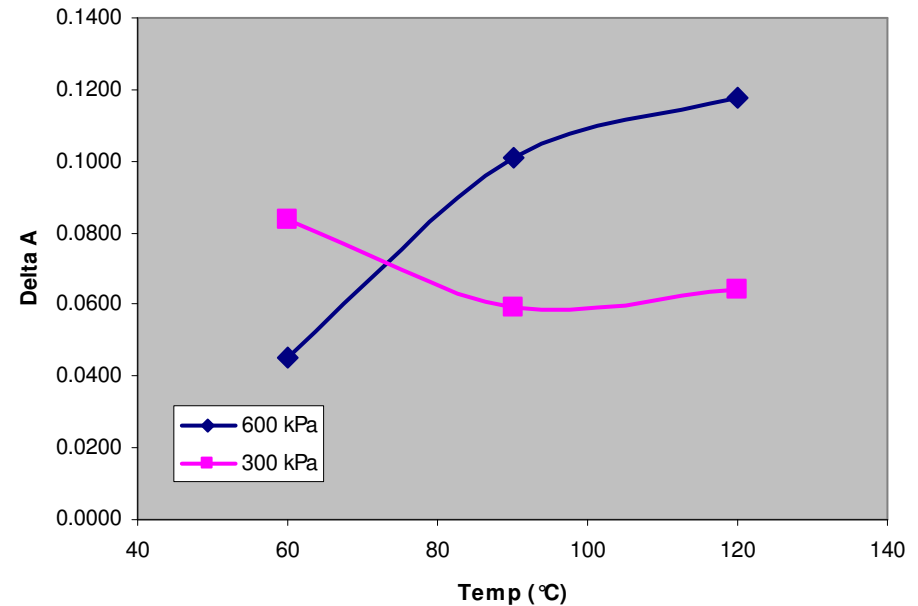


# 2D Image Analysis – KCKIM Software

Vector Magnitude vs. Temp (Unweighted)



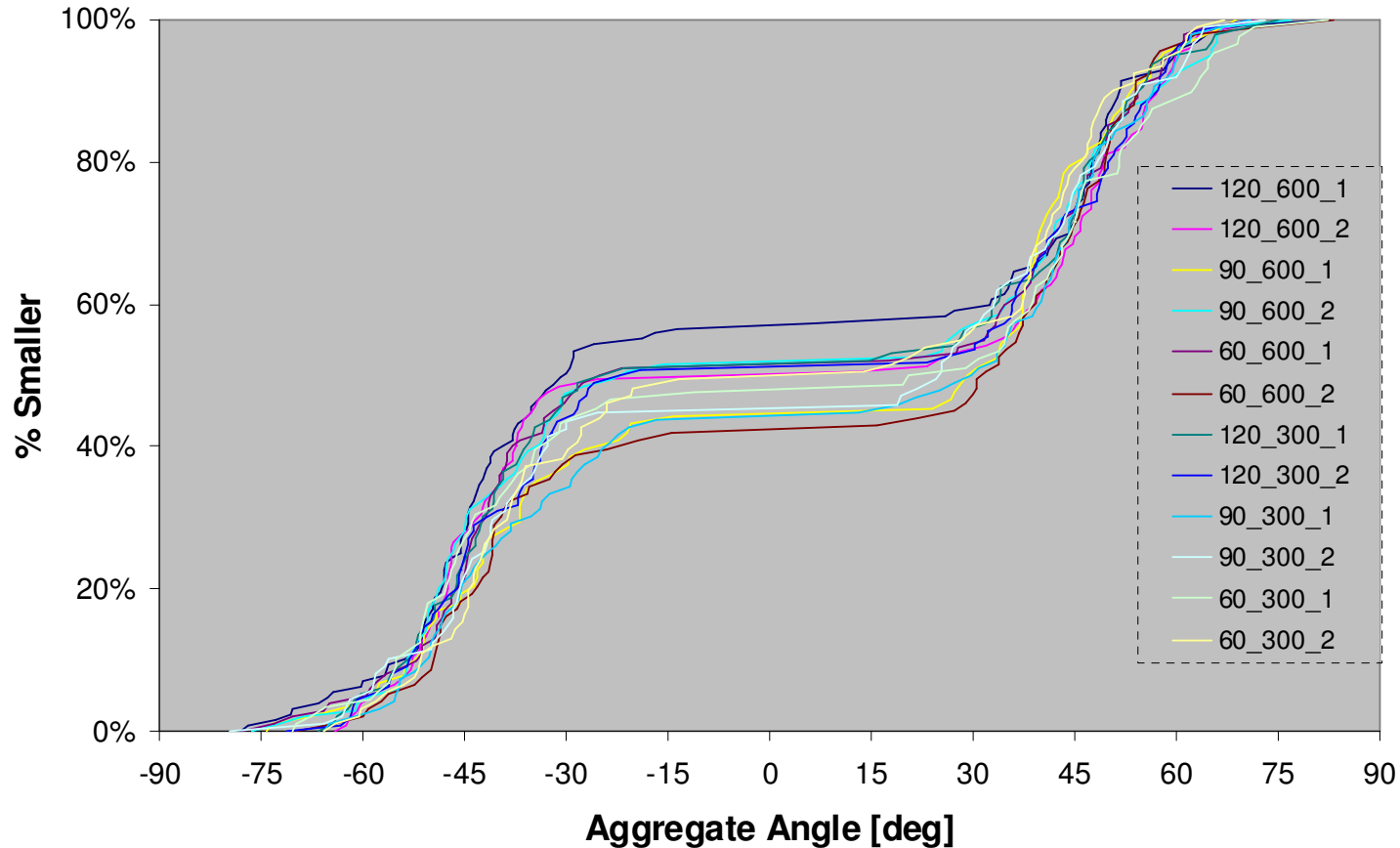
Vector Magnitude vs. Temp (Area Weighted)



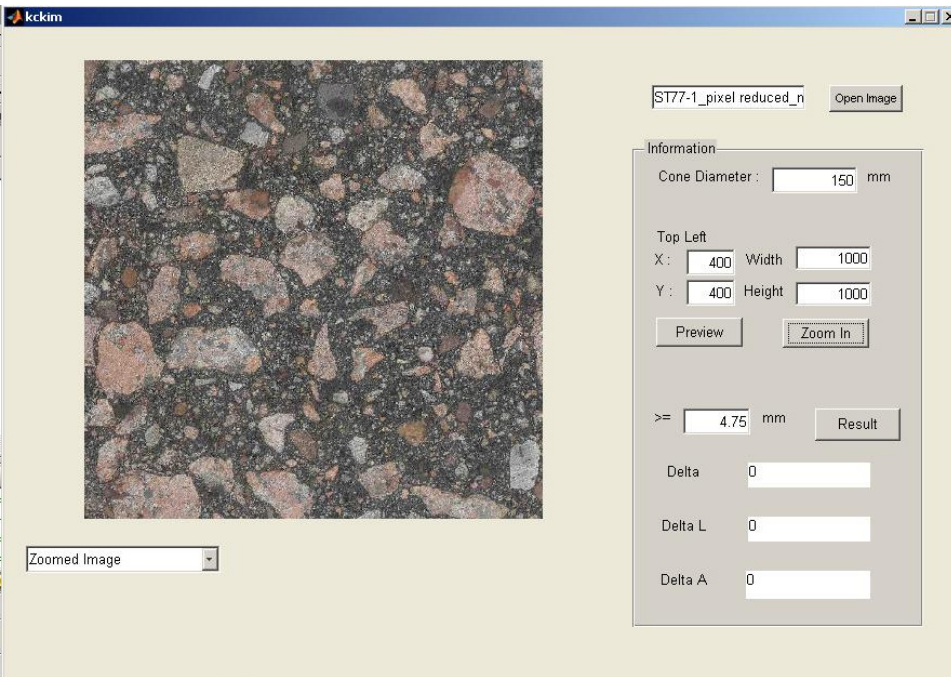
- **No discernable trend**

# 2D Image Analysis – KCKIM Software

## Aggregate Angle Distribution



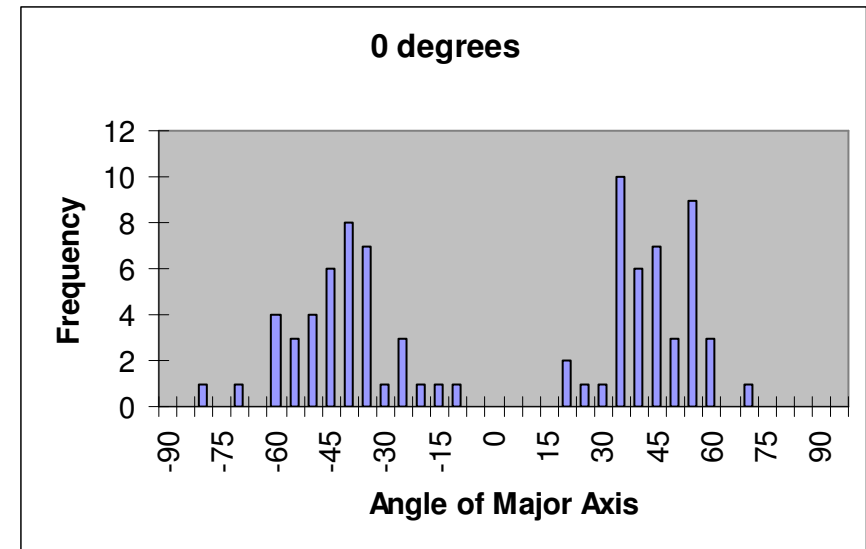
# Typical Results



KCKIM Screenshot

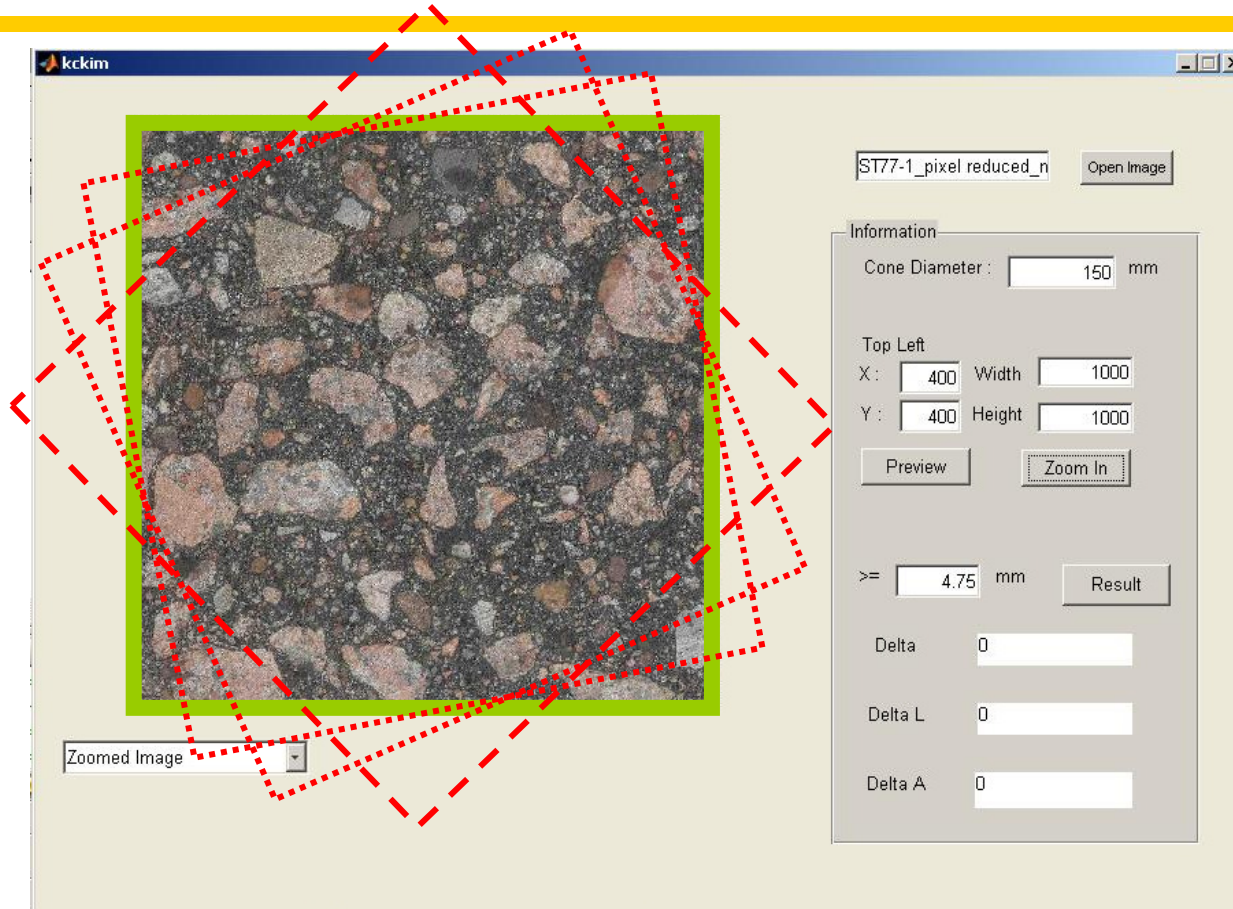
number	Xmin	Ymin	Xmax	Ymax	Xc	Yc	long dist	area	angle	angle(rad)
1	1	1	35	98	18	50	8.48	22.44	-70.68	-1.23
2	1	110	168	214	85	162	16.23	118.16	31.91	0.56
3	1	225	114	321	58	273	12.23	73.81	-40.35	-0.7
4	1	481	36	539	19	510	5.59	13.81	-58.89	-1.03
5	1	553	392	811	197	682	38.64	686.33	33.42	0.58
6	1	862	352	1001	177	932	31.14	331.94	21.6	0.38
7	5	386	73	475	39	431	9.24	41.18	52.62	0.92
8	17	55	78	94	48	75	5.97	16.19	32.59	0.57
9	25	824	95	922	60	873	9.93	46.67	54.46	0.95

Table of Results



Histogram of Results

# Back to Basics: Verification via Rotation



**Rotation & Analysis of Image. Zoomed Image?**

# Verification via Rotation (2)

ST77-1\_pixel reduced\_n

Information

Cone Diameter :  mm

Top Left

X :  Width

Y :  Height

>=  mm

Delta

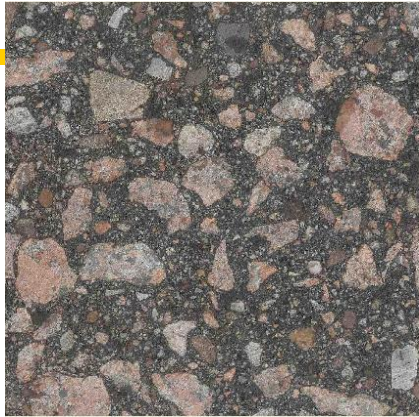
Delta L

Delta A

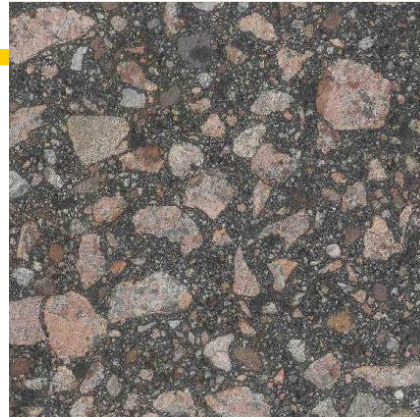
Cropped Image

Rotation & Analysis of Image from Original

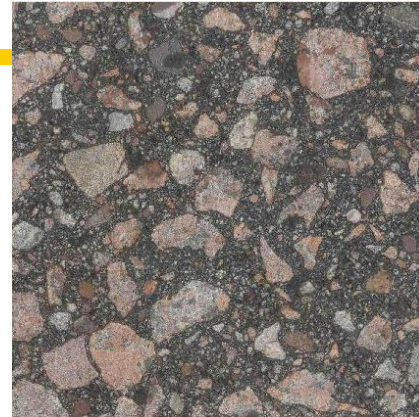
# Zoomed Images of Rotations



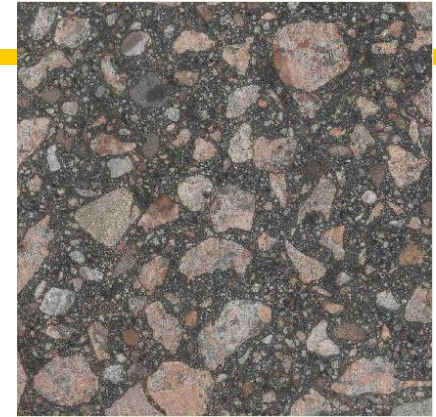
0 degrees



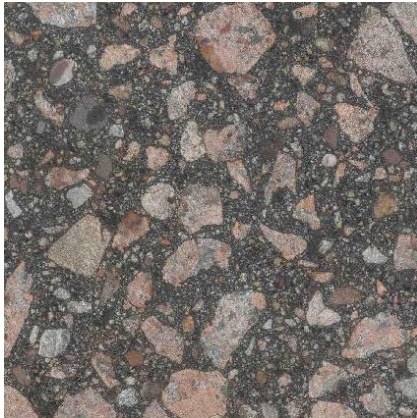
15 degrees



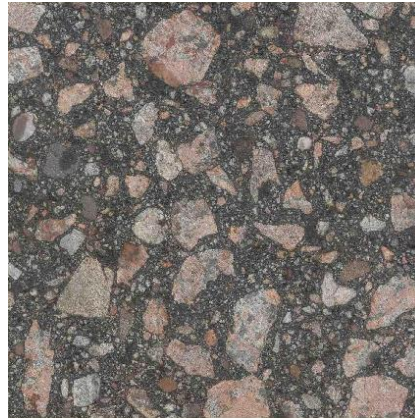
30 degrees



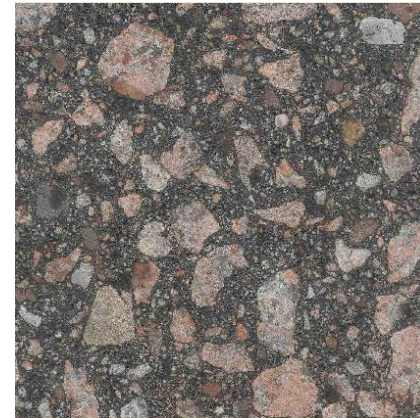
45 degrees



60 degrees



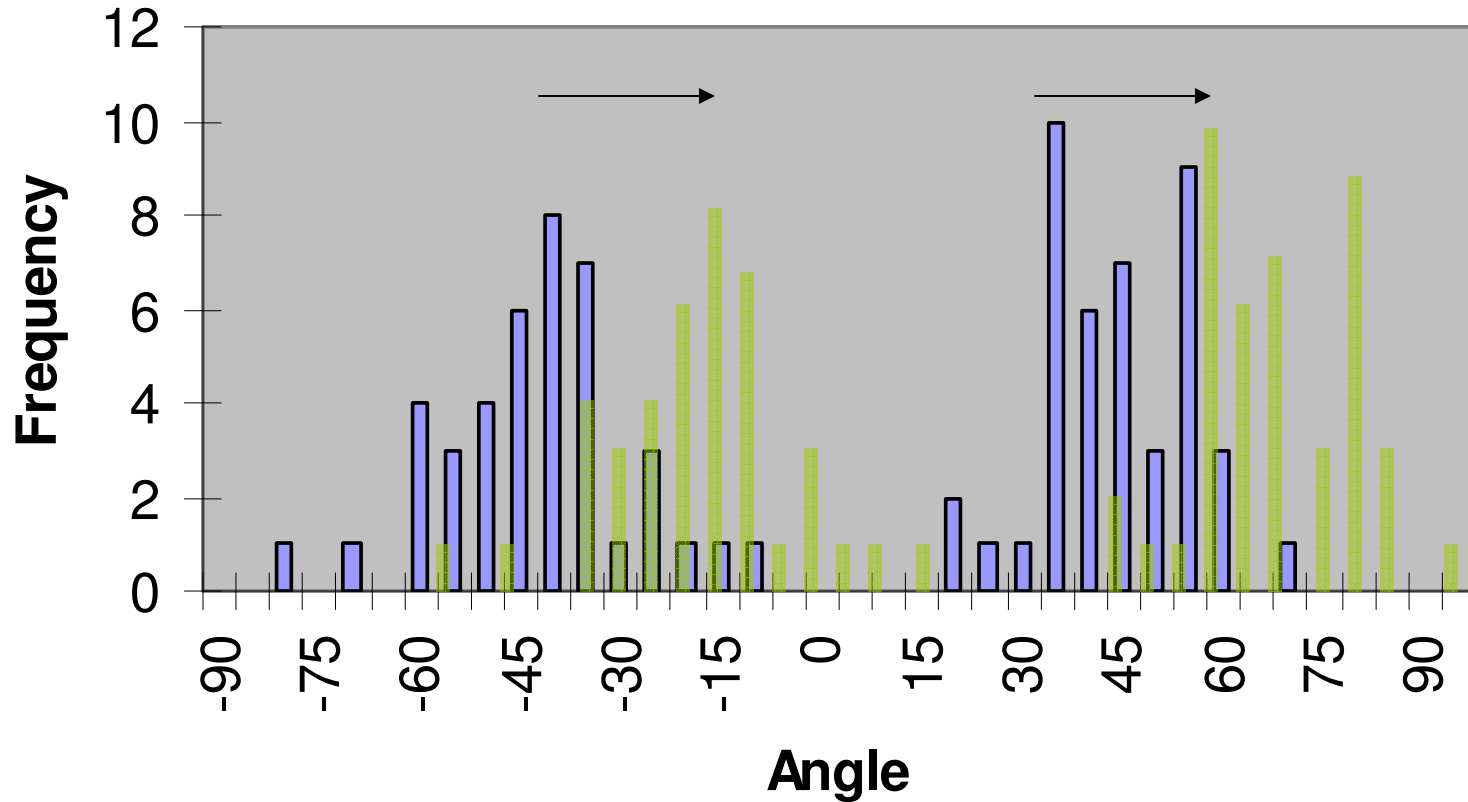
75 degrees



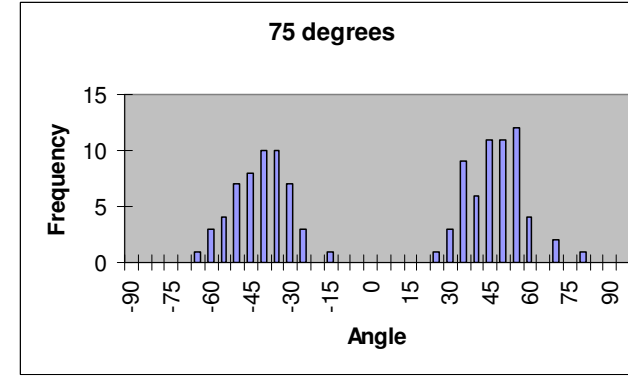
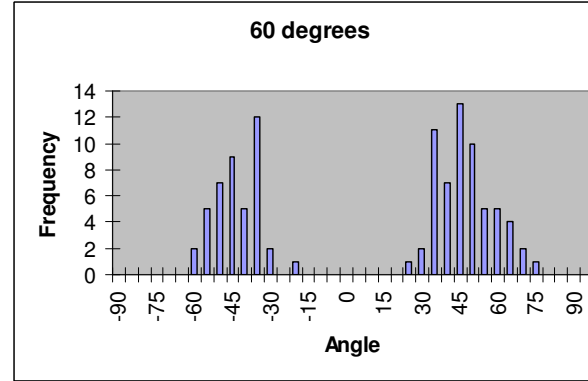
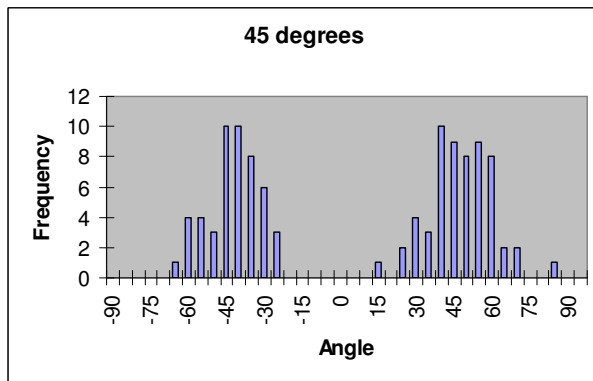
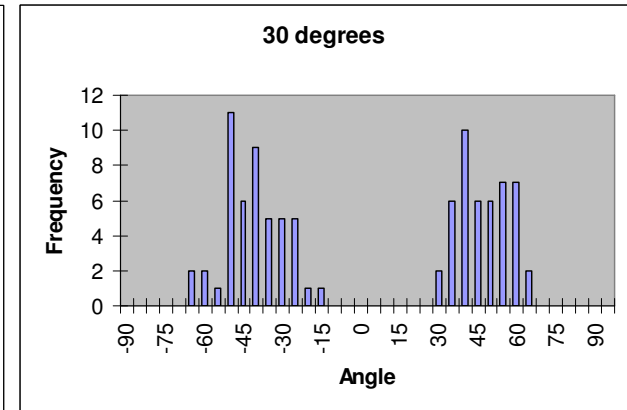
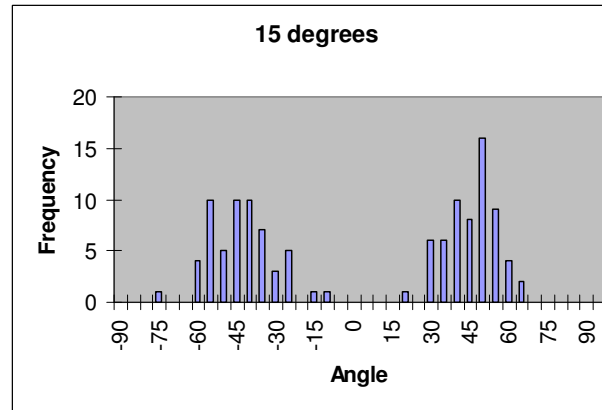
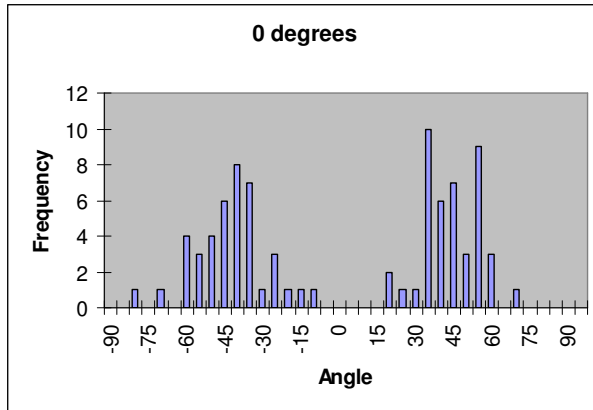
90 degrees



# Expected Results

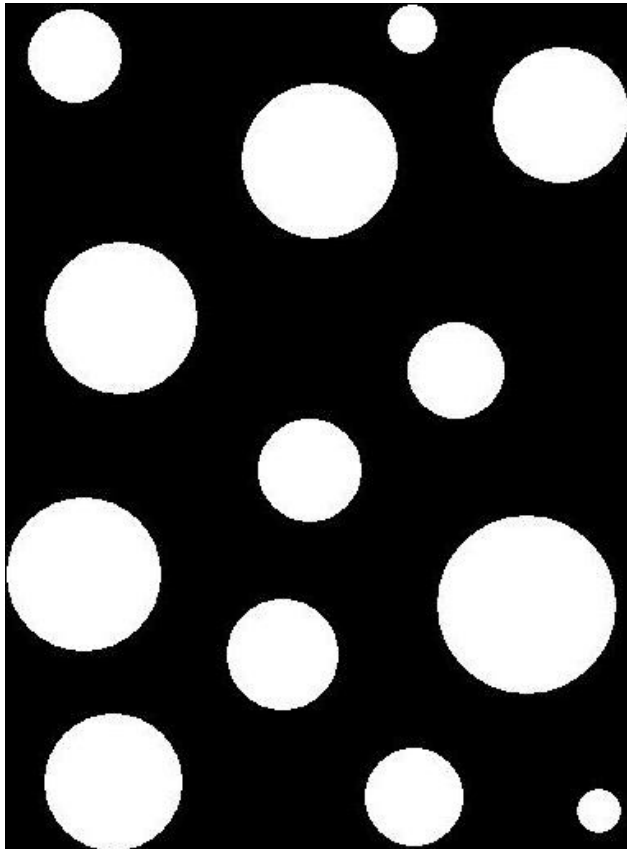


# Actual Results



Not much SHIFT in histogram!! Underlying Assumption??

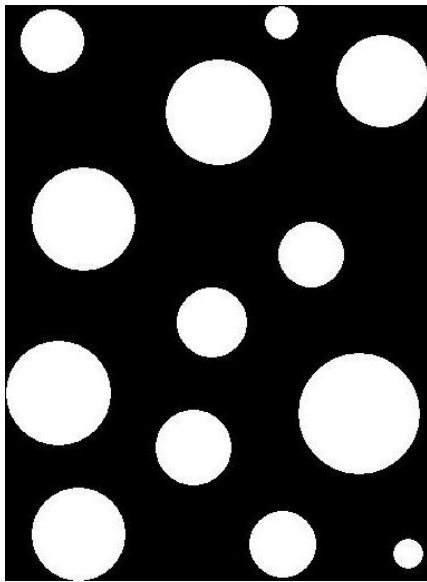
# Test for Assumption vs Calculation via Intentional Confusion



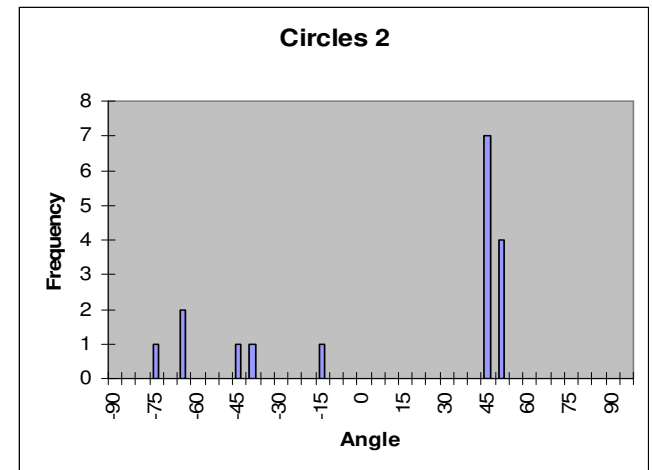
The software should become confused when trying to identify and measure the major axis of each perfectly circular “aggregate”

# Circular “Aggregate” Results

Original Image

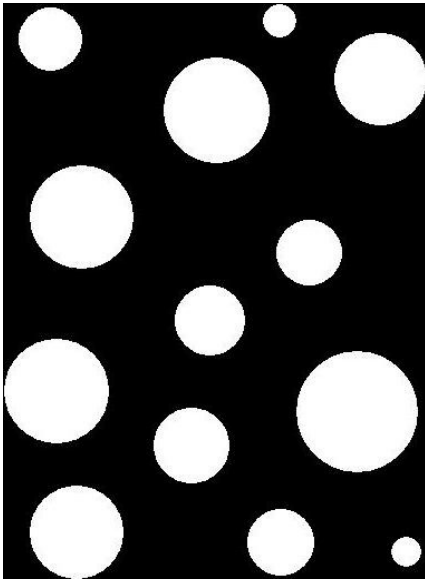


Histogram

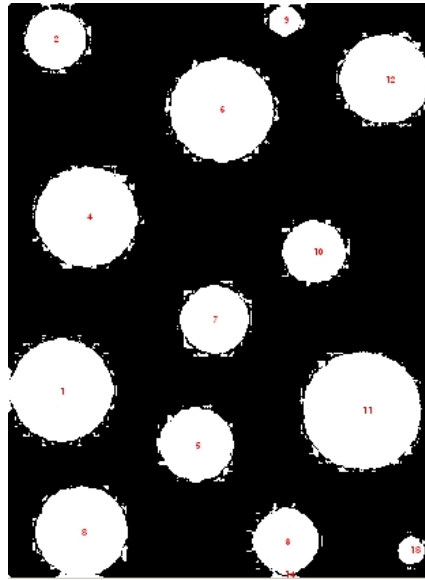


# Circular “Aggregate” Results

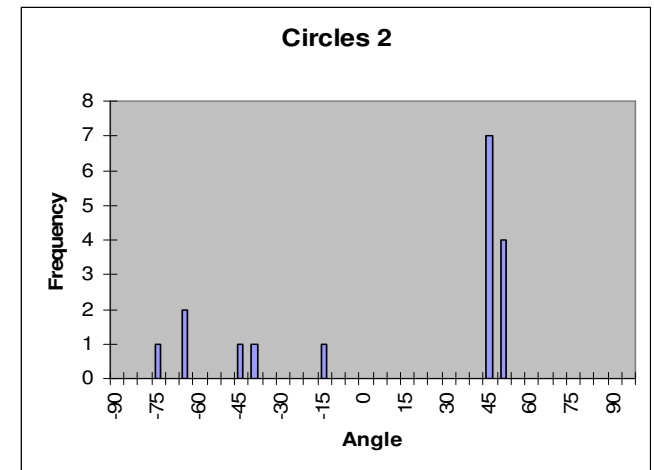
Original Image



Results Image



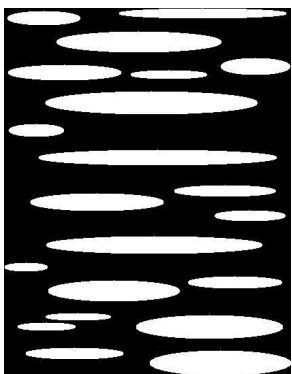
Histogram



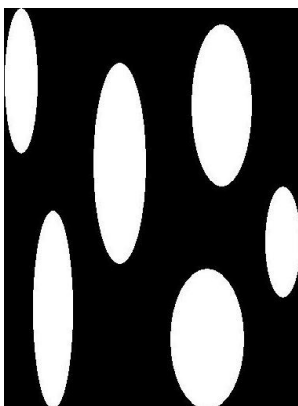
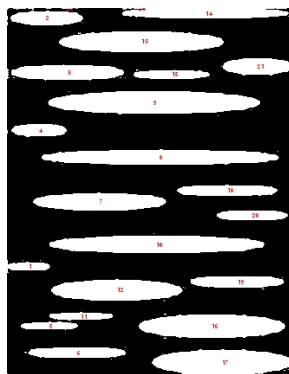
# Additional Check

using drawn images

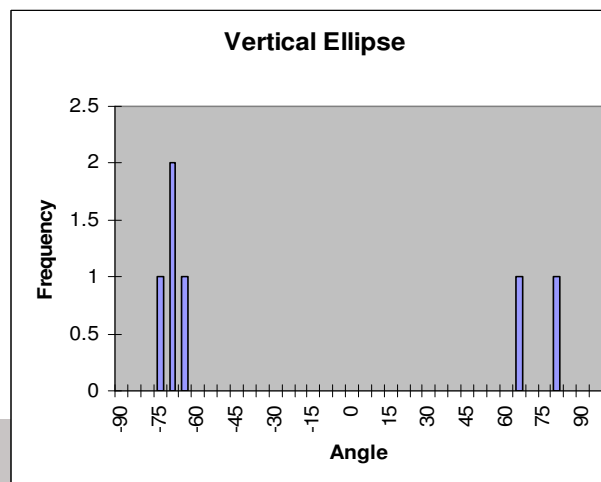
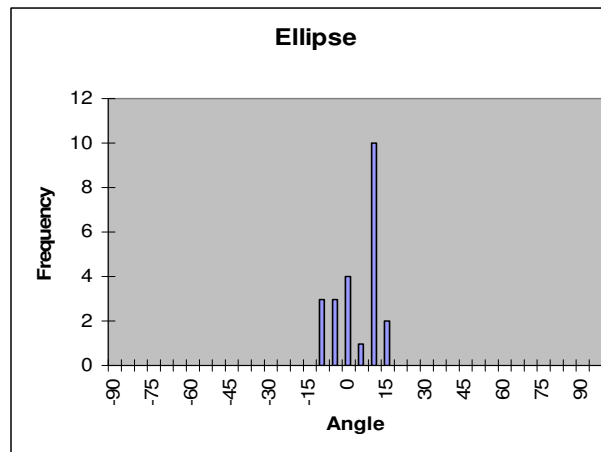
Original Image



Results Image



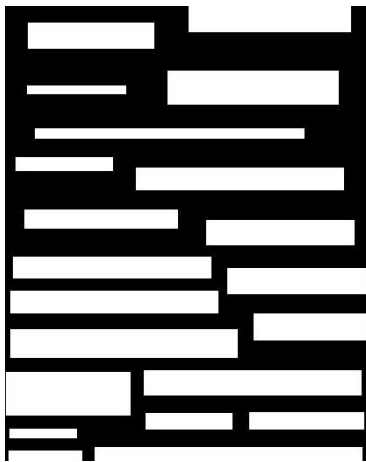
Histogram



# Additional Check (2)

using drawn images

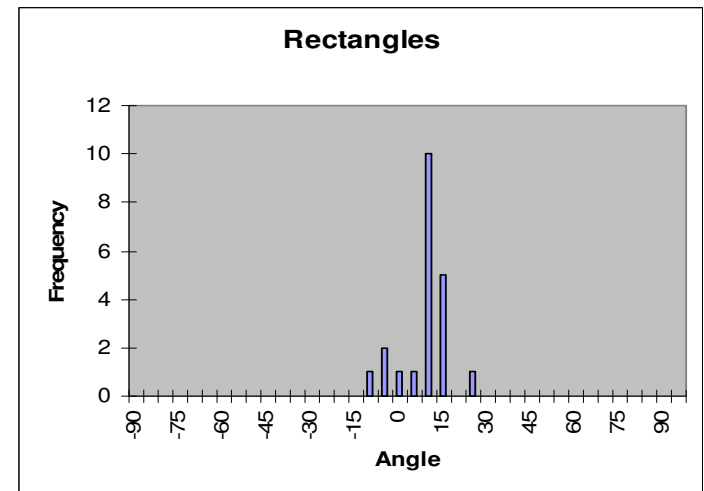
Original Image



Results Image

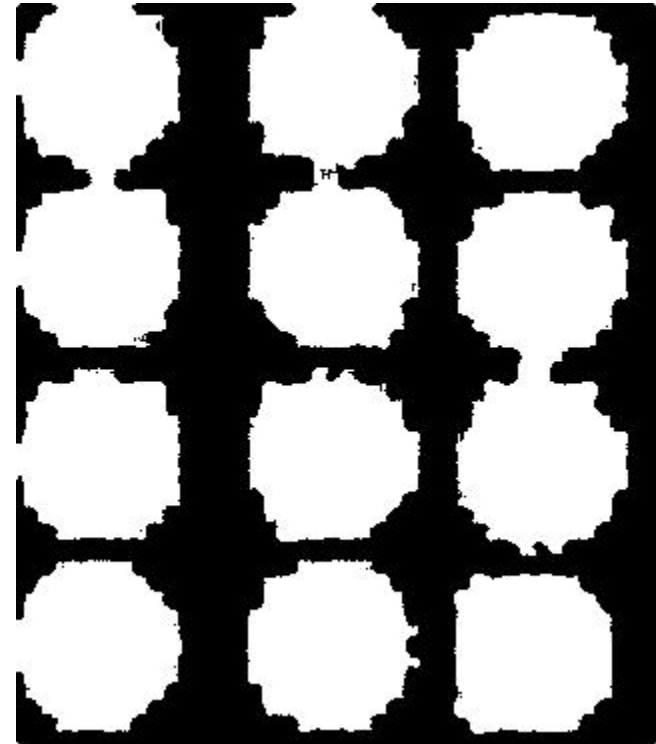
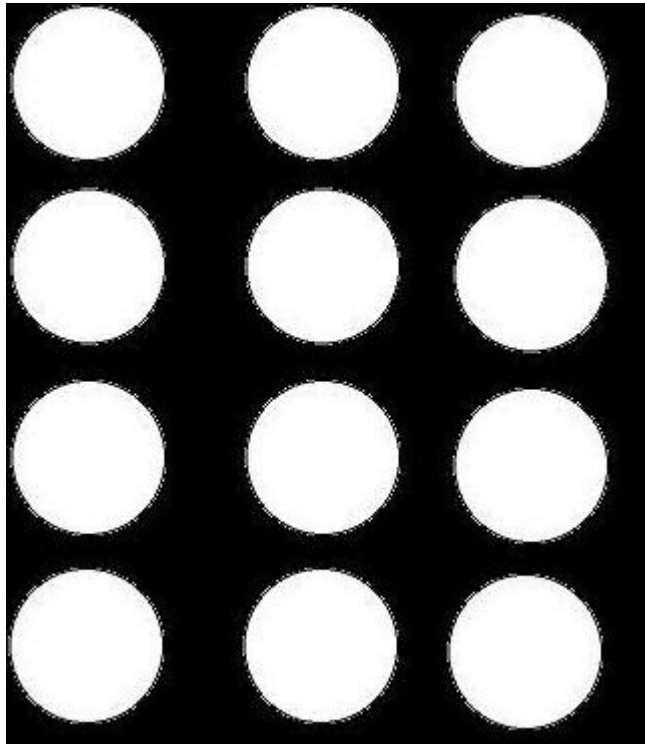


Histogram



# Problem – Exaggerated

yet very real



Aggregates close to one another or in contact might be seen as a single aggregate by software.



# Possible Correction

## Adjusting Threshold Values

- **MATLAB Script:**

```
452  
453 -     sizeIm = size(I);  
454 -     I = reshape(I, sizeIm(1)*sizeIm(2),1);  
455 -     TH(1,1) = 1 - double(prctile(I,72))/255;  
456 -     TH(2,1) = 1 - double(prctile(I,82))/255;  
457 -     TH(3,1) = 1 - double(prctile(I,92))/255;  
458
```

- **Compiled version (courtesy University of Palermo):**

- **Need a priori knowledge of threshold values when compiling**

# NEXT STEP

- **The following steps are planned for immediate action:**
  - **Sort aggregates by size to determine recognition consistency**
  - **Limit rotation to 90 degree increments so identical image is used**
  - **Adjust threshold values in stand-alone version**
  - **Determine level of correction to distortion from various threshold values**
  - **Minimize ± error in distribution for B&W images**
  - **Apply changes to asphalt images**

# Summary of Concepts to Define Aggregate Structure

- **Vector magnitude ( $\Delta$ )**
  - So far has shown significant variability
- **Aggregate angle distribution**
  - May yield more information than  $\Delta$ , but needs further investigation
- **Contact/Influence zones?**
- **Cross-check aggregate gradation?**

# Thank you!

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- **Questions?**
- **Up next: Dr. Gibson on TFHRC activities**