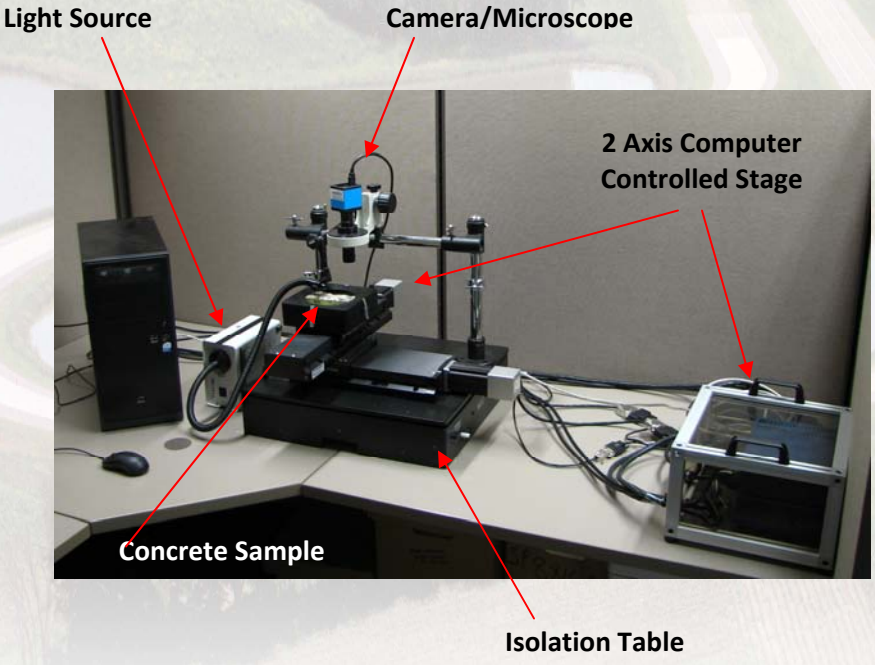
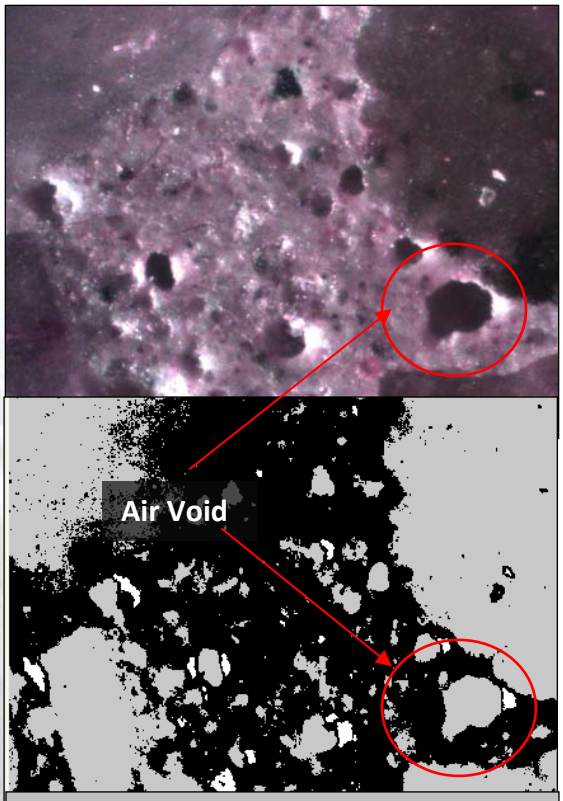
NEXT GENERATION AUTOMATED CONCRETE EVALUATION SYSTEM

The Next Generation Automated Concrete Evaluation (NG-ACE) System is an automated system for determining the air-void structure in hardened concrete according to the ASTM linear traverse method. This technology was developed through cooperative research and development agreements between the Missouri Department of Transportation and National Nuclear Security Administration's Kansas City Plant, operated by Honeywell Federal Manufacturing & Technologies. The NG-ACE system uses a two-dimensional computer-controlled stage to move a concrete sample under a microscope. Image processing and pattern recognition software was developed to identify air voids and void characteristics. A graphical interface links the various components and aids in the image acquisition, analysis, and review processes.



The NG-ACE system uses a light source to illuminate the sample at a grazing angle only from the left side of the sample. The sides of the voids opposite the light are brightly illuminated (a thin crescent) and the bottom of the voids are dark. .

The threshold image is a black, white, and gray representation of the concrete sample. The gray represents dark regions, typically voids and dark aggregate. The black represents the paste or mortar and the white represents bright regions. Air voids are identified in the threshold image as isolated gray with adjacent white crescents.



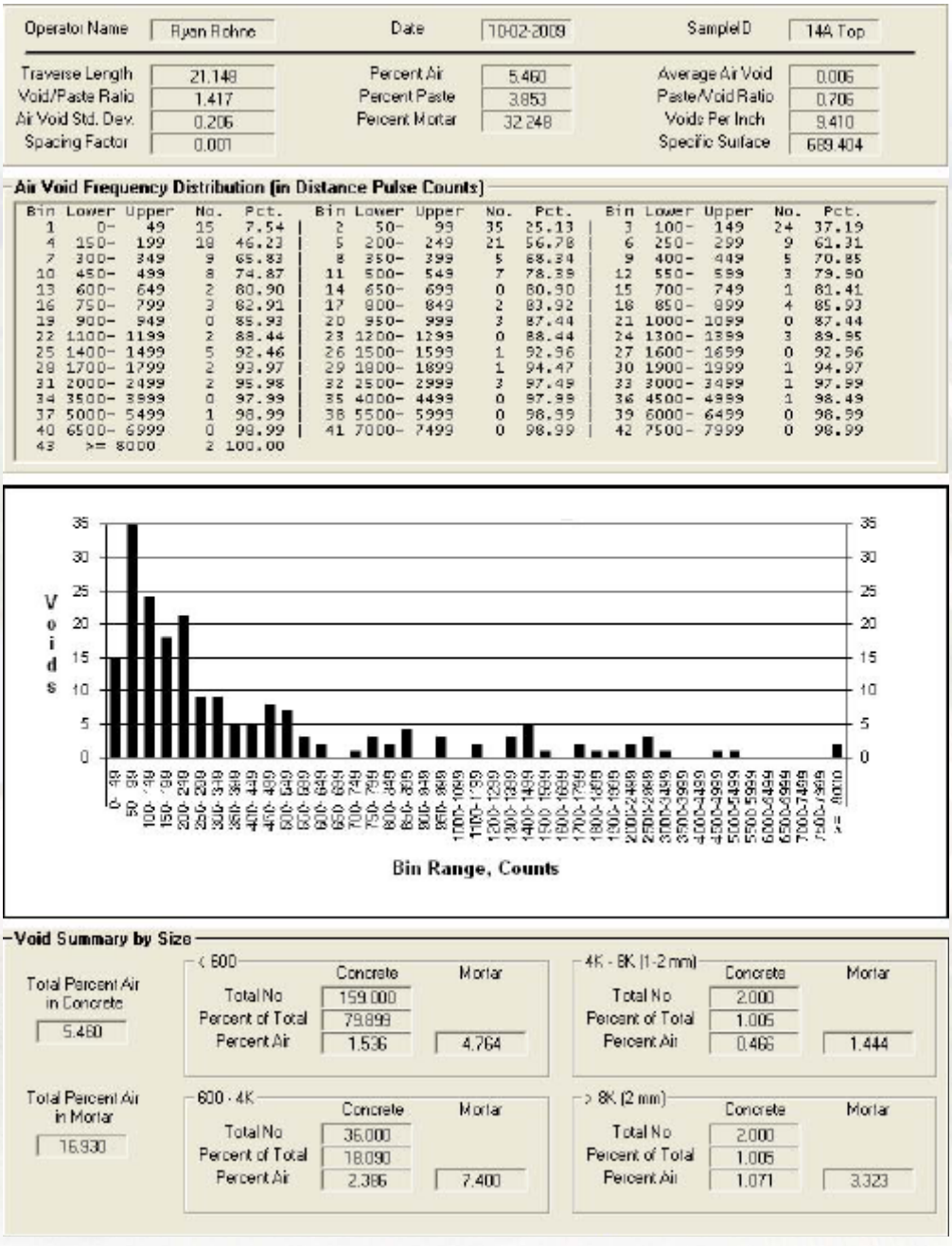
Top: magnified image
Bottom: threshold image

The NG-ACE analysis software uses three analysis methods to identify concrete components. In the first of these, color analysis, the red, green, and blue color values and band ratios of the image are input in a neural network that can identify the specific color of each component. This results in a color map of the original image. The second approach uses morphological image analysis to identify voids in the concrete based on their shape. This method segments each image into individual objects and then analyzes each object for its unique shape and intensity characteristics. A fuzzy logic correlation algorithm is used to identify voids based on the key image components which are correlated with the voids. The third analysis technique uses the unique light intensity structure of a void to generate a filter that analyzes the intensity profile along the selected traverse line.

Round Robin Testing

Round Robin testing was conducted by Baumgart, Blair, and Linder. There were two phases of round robin testing. In the first phase five concrete specimens with air contents ranging from 4.5% to 8.0% were sent to nine different labs. At each lab a total of nine linear traverse tests were done; one linear traverse on four of the specimens and five linear traverses, using five different sets of traverse lines, on the fifth specimen. In the second phase the five concrete specimens were collected and surfaces were prepared again, but by one lab. The five concrete cylinders were then analyzed by the five laboratories from phase one that demonstrated the most consistency in their measurements.

The NG-ACE derived results were within the 95% confidence interval of the nine laboratory phase one results, and all but two of the values were within the 95% confidence interval of the more restrictive five laboratory results. In the two cases where the NG-ACE estimated parameter was outside the 95% confidence interval, the deviation was not far outside the interval limits.



Operator Name	Ryan Rohne	Date	10-02-2009	Sample ID	14A Top
Traverse Length	21.148	Percent Air	5.460	Average Air Void	0.006
Void/Paste Ratio	1.417	Percent Paste	3.853	Paste/Void Ratio	0.706
Air Void Std. Dev.	0.206	Percent Mortar	32.248	Voids Per Inch	9.410
Spacing Factor	0.001			Specific Surface	689.404

Air Void Frequency Distribution (in Distance Pulse Counts)

Bin	Lower	Upper	No.	Pct.	Bin	Lower	Upper	No.	Pct.	Bin	Lower	Upper	No.	Pct.
1	0-	49	15	7.54	2	50-	99	35	25.13	3	100-	149	24	37.19
4	150-	199	18	46.23	5	200-	249	21	56.78	6	250-	299	9	61.31
7	300-	349	9	65.83	8	350-	399	5	68.34	9	400-	449	5	70.85
10	450-	499	8	74.87	11	500-	549	7	78.38	12	550-	599	3	79.90
13	600-	649	2	80.90	14	650-	699	0	80.90	15	700-	749	1	81.41
16	750-	799	3	82.91	17	800-	849	2	83.92	18	850-	899	4	85.93
19	900-	949	0	85.93	20	950-	999	3	87.44	21	1000-	1099	0	87.44
22	1100-	1199	2	88.44	23	1200-	1299	0	88.44	24	1300-	1399	3	89.95
25	1400-	1499	5	92.46	26	1500-	1599	1	92.96	27	1600-	1699	0	92.96
28	1700-	1799	2	93.97	29	1800-	1899	1	94.47	30	1900-	1999	1	94.97
31	2000-	2499	2	95.98	32	2500-	2999	3	97.49	33	3000-	3499	1	97.99
34	3500-	3999	0	97.99	35	4000-	4499	0	97.99	36	4500-	4999	1	98.49
37	5000-	5499	1	98.99	38	5500-	5999	0	98.99	39	6000-	6499	0	98.99
40	6500-	6999	0	98.99	41	7000-	7499	0	98.99	42	7500-	7999	0	98.99
43	>=	8000	2	100.00										

Void Summary by Size

Total Percent Air in Concrete	5.460

< 600	Concrete	Mortar
Total No	159.000	
Percent of Total	79.899	
Percent Air	1.536	4.764

4K - 8K (1-2 mm)	Concrete	Mortar
Total No	2.000	
Percent of Total	1.005	
Percent Air	0.466	1.444

Total Percent Air in Mortar	16.930

600 - 4K	Concrete	Mortar
Total No	36.000	
Percent of Total	18.090	
Percent Air	2.386	7.400

> 8K (2 mm)	Concrete	Mortar
Total No	2.000	
Percent of Total	1.005	
Percent Air	1.071	3.323

NG-ACE report example

Benefits of the ACE System

- Only 5 to 10 minutes of operator time are required to mount the sample and set the scan parameters
- Repeatability is comparable to the manual linear transverse process and there is no operator bias
- Provides microscopical properties of interest, as defined in the ASTM standard. These include:
    - Percent of air in paste and concrete
    - Voids per inch
    - Spacing factor
    - Specific surface
    - Average air void size
    - Standard deviation of air void size
    - Percent paste
    - Void/paste ratio
    - Distribution of void diameters
    - List of voids by size, number, and percent of total voids

Limitations of the ACE System

- Although only 5 to 10 minutes of operator time are required, 7 to 8 hours of computer time are required
- The maximum concrete sample size is 6x6 inches and 2 inches thick
- Concrete samples still need to be cut and polished

For More Information, Contact:

Ryan Rohne at *Ryan.Rohne@state.mn.us*
Bernard Izevbekhai at *Bernard.Izevbekhai@state.mn.us*

References

C. Baumgart, R. Blair, and K. Linder (2006). "Image Analysis of Hardened Concrete; Performance Enhancement of the Automated Concrete Evaluation System," *Report No. OR 07-004*, Missouri Department of Transportation, Jefferson City, MO.