Innovation Shared at the ACI Foundation 2024 Technology Forum, Part 1

For over 25 years, the ACI Foundation has hosted Technology Forums to support ACI's expanding focus on advancing the concrete industry. These gatherings have been popular, innovation-focused educational and networking events featuring presentations by researchers, ACI committee representatives, and developers of new technologies for design, construction, and inspection. This article is the first of three articles that summarize the presentations made at the 2024 Technology Forum.

Recognizing that innovation takes on many forms, the ACI Foundation Concrete Innovation Council has renamed its event. The **2025 Concrete Innovation Forum** will provide attendees with the opportunity to connect with others in the industry and learn about current trends, emerging technologies, new products, and other innovations. The event will also provide opportunities for attendees to build strategic relationships and expand their networks. Save the date and join us next year in Denver, CO, USA, at the Hotel Clio from August 12-14, 2025.

Instant Air Meter: Rapid Measurement of Air in Fresh Concrete

Presented by Jed C. Wilbur, Engineer, Creare LLC

Freezing-and-thawing durability of concrete is commonly assessed using two factors: the total air content and the mean spacing between air voids. However, standard methods for measuring these parameters are cumbersome and slow. Wilbur described the ongoing development of a handheld device capable of rapidly measuring parameters that can be correlated to air content and void size in fresh concrete. The project, initially funded through Small Business Innovation Research (SBIR) grants from the U.S. Department of Transportation, is expected to result in a handheld tool that will allow for frequent monitoring of air parameters at a cost competitive with existing approaches. Further, the development team has plans for integrating the core technology into a sensor suitable for in-drum measurements.

Termed the Instant Air Meter, the technology measures a concrete mixture's response to an impulse from a piston (Fig. 1). Intermediate-stage prototypes showed promising results (Fig. 2), and an advanced prototype is now being evaluated at the National Concrete Pavement Technology Center at Iowa State University, Ames, IA, USA. Other prototypes are available for additional evaluation.

SoFi Stadium: Innovations in Structural Design

Presented by Walter Eggers, Chief Bridge Engineer, Kiewit Corporation

SoFi Stadium is east of the Los Angeles International Airport, so designers placed the playing field 100 ft (305 m) below grade to reduce the building's roof height and avoid conflicts with the airport's approach flight paths. The large and complex structure is also close to an active fault. To minimize seismic accelerations, the stadium's seating bowl, the surrounding mechanically stabilized embankment (MSE), and the roof support structure were isolated (Fig. 3). Much of Eggers's presentation focused on the construction of the MSE and the "blade" columns of the roof support structure (Fig. 3 and 4).

The removal of material from the excavation, construction of the blade column foundations, and erection of the columns themselves were all on the critical path for the construction schedule. To minimize cost and schedule impacts, Kiewit proposed design changes that involved isolating the foundation from the embankment, the use of an MSE, precast concrete, segmental bridge technology, and extensive use of post-tensioning. Altogether, the systems used for the final construction allowed the stadium to be completed 18 months earlier than originally planned.

Next-Generation Assessment of Concrete Structures Using Artificial Intelligence

Presented by Ali Khaloo, CEO, Aren, Inc.

Accurate condition assessment of in-service infrastructure systems is critical for system-wide prioritization decisions. Current protocols require lengthy inspections and expensive equipment to examine large systems. Furthermore, changes in inspection protocols over time can create discontinuities in the recording and understanding of the time history of a structure. While recent advancements in remote sensing technologies

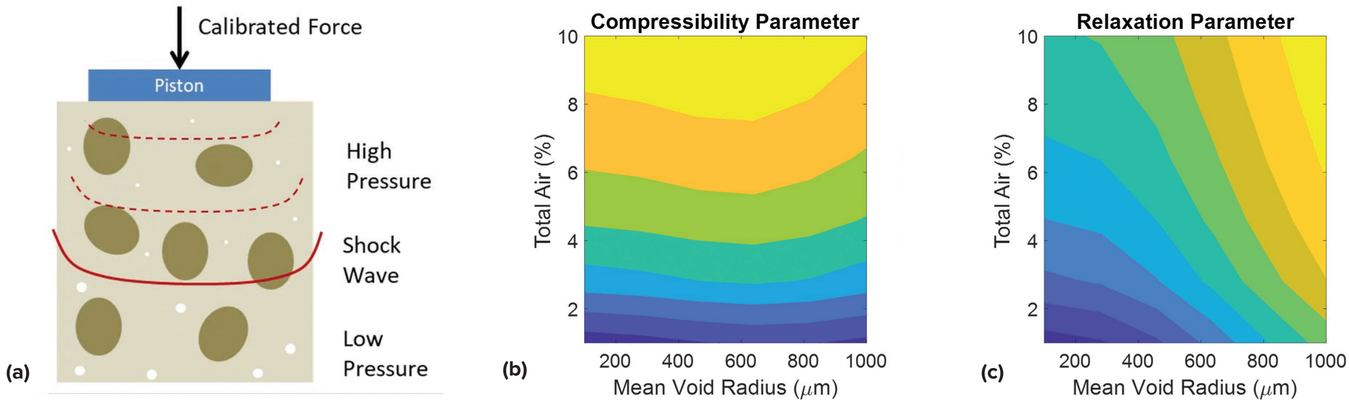


Fig. 1: The basis of the instant air meter: (a) a schematic illustration of the shock wave generated in the concrete by an impulse from a piston; (b) output from a numerical model showing that a compressibility parameter correlates well with the void fraction; and (c) output showing that a relaxation parameter correlates well with the void fraction and the mean void size

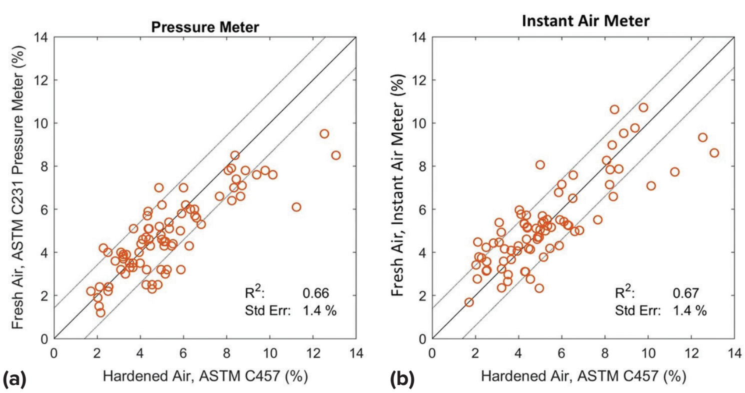


Fig. 2: As part of the SBIR study, tests conducted by researchers at Georgia Tech University showed that the device was capable of accurately measuring air content: (a) air content measured using a pressure meter per ASTM C231/C231M versus air content measured per ASTM C457/C457M; and (b) air content using Instant Air Meter versus air content measured per ASTM C457/C457M

Fig. 3: An aerial view of the construction of SoFi Stadium. The waffle pattern in the foreground is comprised of struts anchoring the blade columns in the soil outside of the MSE fill zone

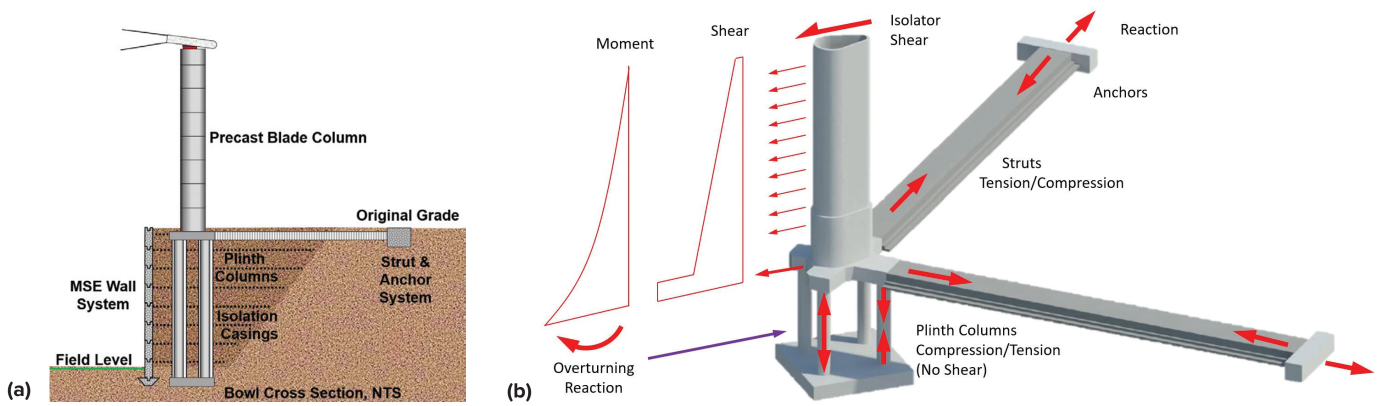


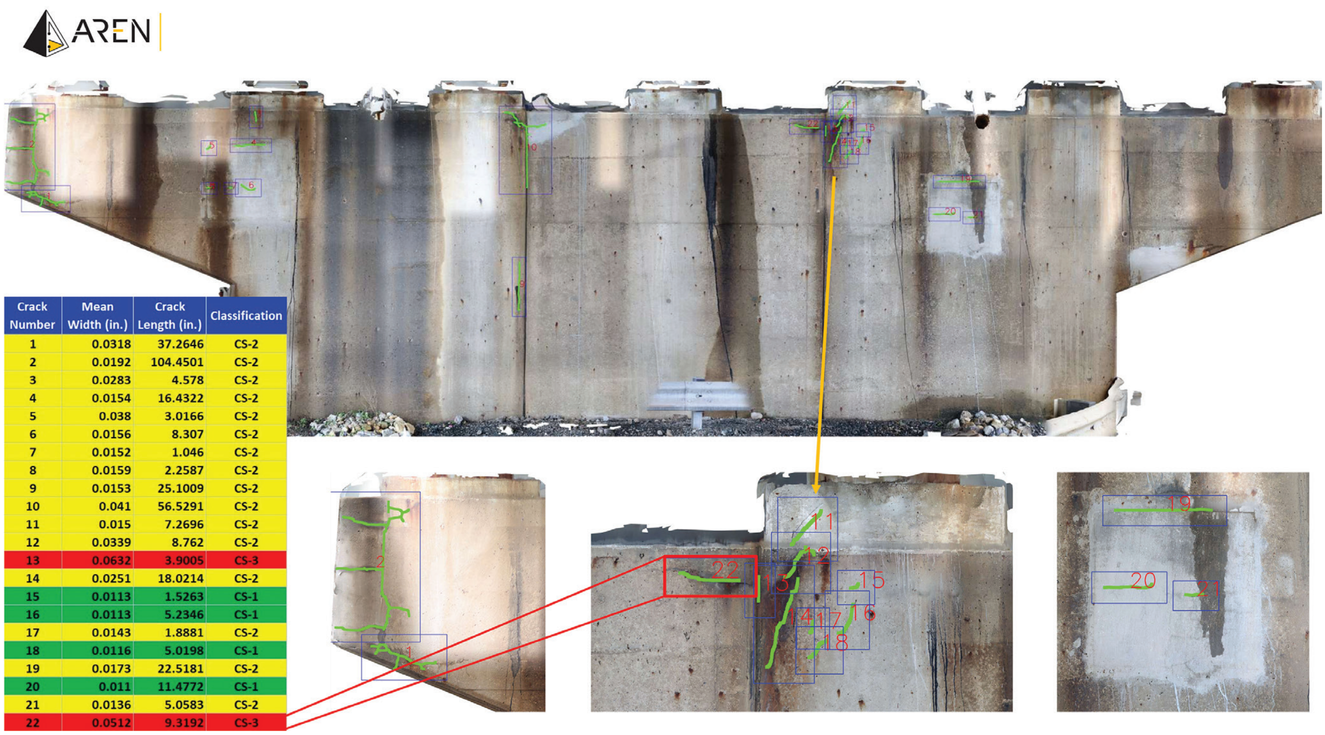
Fig. 4: Schematics of the MSE and blade columns of the roof support structure: (a) blade columns are supported by plinth columns, which were isolated from the MSE fill; and (b) a strut-and-anchor system is provided to transfer shear forces from the roof and blade column to the soil beyond the fill

(for example, autonomous drones) allow the capture of massive amounts of data, manual review of these data sets remains labor-intensive and does not provide explicit information on structural performance and health conditions. Khaloo introduced AREN, a software as a service (SaaS) solution for analyzing and leveraging data. Based on a unique combination of artificial intelligence (AI) and civil engineering knowledge, the software creates a highly detailed three-dimensional (3-D) model from many data sources, including photos, videos, infrared scans, acoustic scans, or LiDAR scans. It then identifies and quantifies damage, such as cracks, spalls, or efflorescence (Fig. 5). Because the data can be collected and analyzed over time, the software also can identify changes and help owners develop maintenance programs (Fig. 6). Case studies were provided to demonstrate the effectiveness of this new approach.

Improving Sustainable Concrete Production Practices Using an On-Board Monitoring System of the Fresh Concrete Properties

Presented by Pierre Siccardi, Product Analyst, Command Alkon (on behalf of Marc Jolin)

Siccardi summarized research activities centered on a sensor designed to be mounted in the drum of a concrete



Crack Number	Mean Width (in.)	Crack Length (in.)	Classification
1	0.0318	37.2646	CS-2
2	0.0192	104.4501	CS-2
3	0.0283	4.578	CS-2
4	0.0154	16.4322	CS-2
5	0.038	3.0166	CS-2
6	0.0156	8.307	CS-2
7	0.0152	1.046	CS-2
8	0.0159	2.2587	CS-2
9	0.0153	25.1009	CS-2
10	0.041	56.5291	CS-2
11	0.015	7.2696	CS-2
12	0.0339	8.762	CS-2
13	0.0632	3.9005	CS-3
14	0.0251	18.0214	CS-2
15	0.0113	1.5263	CS-1
16	0.0113	5.2346	CS-1
17	0.0143	1.8881	CS-2
18	0.0116	5.0198	CS-1
19	0.0173	22.5181	CS-2
20	0.011	11.4772	CS-1
21	0.0136	5.0583	CS-2
22	0.0512	9.3192	CS-3

Fig. 5: The AI in AREN identifies and quantifies damage. Because it creates a 3-D model of an asset, double counting is avoided. Measurements are based on dimensional references at the site, so true length and width of cracks can be determined from pixel data. Damage can be classified using the condition states preferred by the owner (in this case, the cracks are classified per AASHTO condition states)

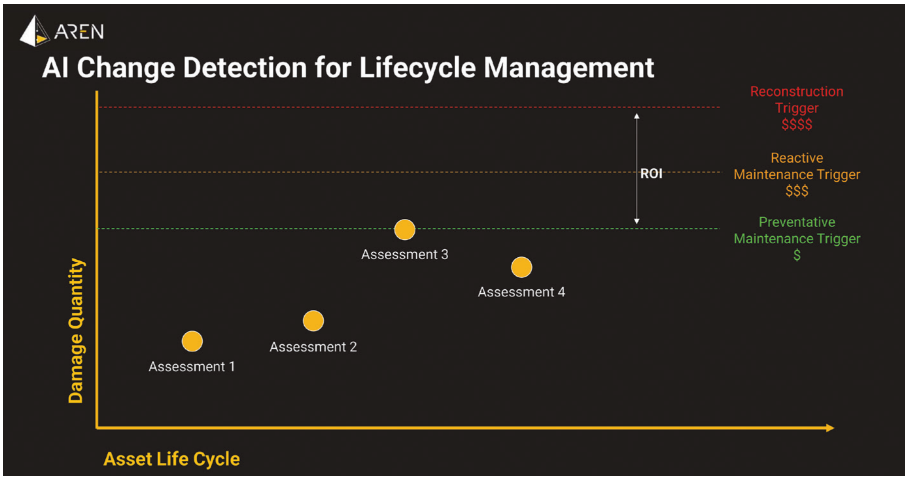


Fig. 6: By collecting and assessing asset conditions over time, preventive maintenance, rather than reactive maintenance, can be implemented

truck (Fig. 7) to measure the homogeneity and rheological properties of concrete in real time (Fig. 8(a)). Additional sensors can monitor air content (Fig. 8(b)), and sensors for evaluating density are in development. Siccardi summarized recent research efforts and field evaluations, including data showing that such sensors can be used to determine if mixing is complete. Both Fig. 8(a) and (b) show that fresh concrete properties, including slump and air content, are evolving during every stage of concrete production and delivery and are affected by mixing history and adjustments. Such evolution of air and slump cannot be identified by standard test methods. He also introduced a new 5-year research project supported by a broad spectrum of industry participants. This project's objectives include exploring the application of onboard sensor technologies to develop more sustainable practices and improve concrete quality, recognizing that new binders and recycled aggregates are seeing increasing use. Lastly, he discussed ongoing work on recognizing onboard sensor technologies in standards and reports, with the goal of enabling adoption by the industry. Examples include a state-of-the-art report being developed by ACI Subcommittee 304-G, In-Transit Ready-Mix Concrete Monitoring.

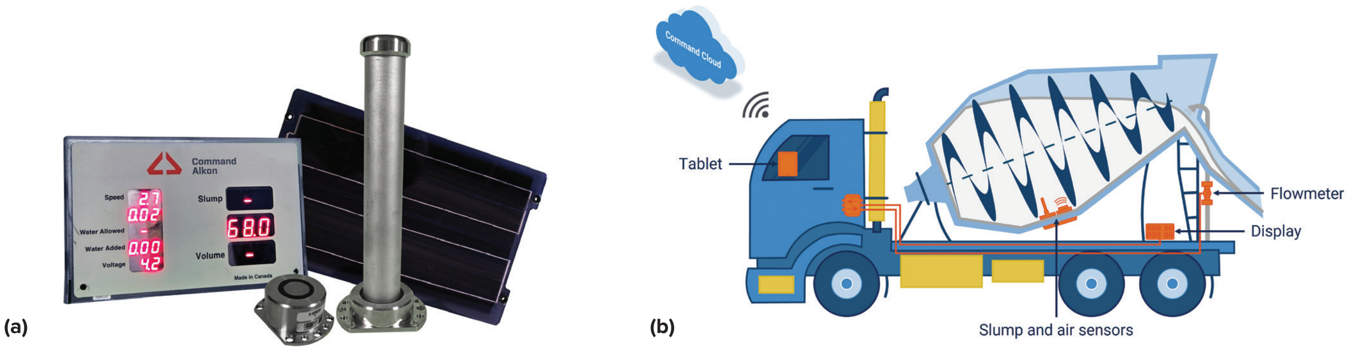


Fig. 7: A sensor mounted in the drum of a concrete truck is subjected to shear and bending forces as the sensor is moved through the concrete: (a) a view of the sensor kit, including the sensor unit, solar panel, and display unit; and (b) schematic representation of the sensor and display mounted on a truck (data from the unit can be uploaded in real time to a cloud server) *(figures courtesy of Command Alkon)*

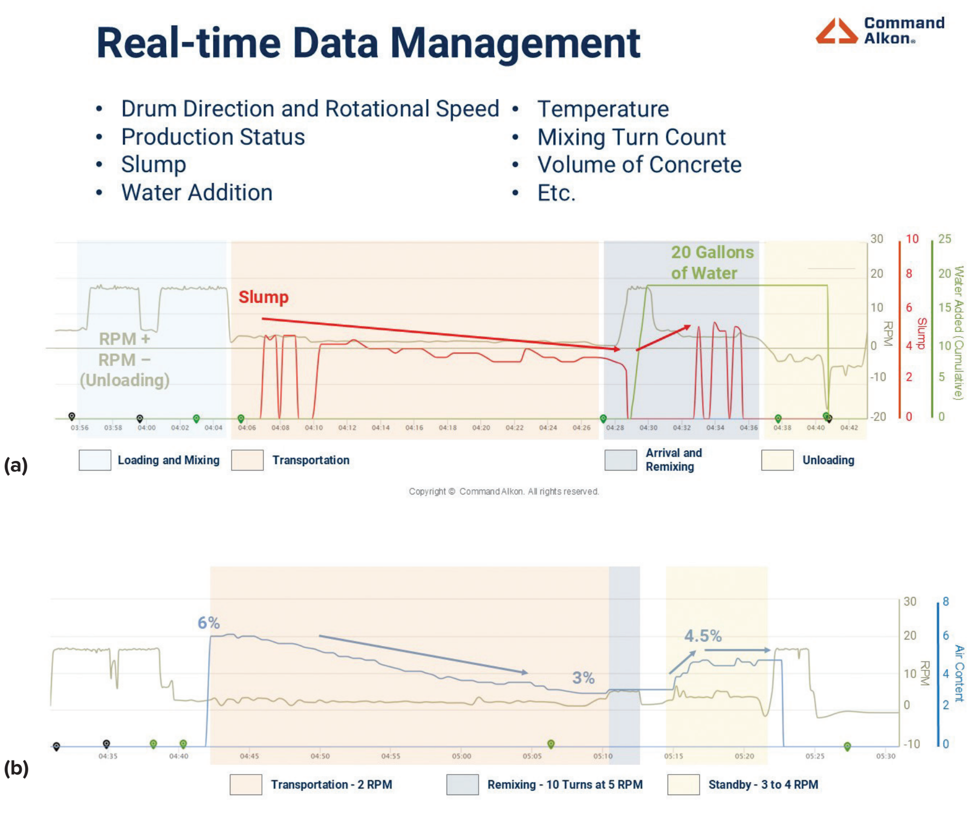


Fig. 8: Real-time collection of data shows that slump and air content vary with time, water additions, and drum speed: (a) slump data; and (b) air content data *(figures courtesy of Command Alkon)*

Why Durability Needs to Be Assessed on Site and How?

Presented by Roberto Juan Torrent, Technical Director, Materials Advanced Services Ltd.

The durability performance of reinforced concrete structures depends on the resistance offered by the near-surface concrete layers against aggressive agents, such as carbon dioxide (CO_2), chlorides, and sulfates. The quality of these outer layers is very sensitive to the way concrete is processed at the jobsite. Therefore, when measured with standard tests on laboratory specimens cast and moist-cured under near-ideal conditions, the surface quality is usually better than that obtained on the real structure. Hence, durability tests conducted on laboratory specimens can be considered to reflect the potential quality of a given concrete mixture. The true quality of the constructed product can only be assessed through suitable nondestructive durability tests applied directly on the structure or through standard laboratory tests applied on samples obtained by core drilling.

Torrent discussed a test method he developed, the double-chamber vacuum cell test (Fig. 9). While this method has been standardized in Switzerland, Japan, Argentina, and Peru, it remains relatively unknown in the United States. The test method measures the coefficient of air-permeability of concrete *kT*, a coefficient which correlates well with other durability lab tests, such as the rapid chloride permeability test and the test for water penetration under pressure (Fig. 10, built with data from a large variety of sources). Relevant applications, as well as the rationale for having the test method standardized by ASTM International, were addressed.

The document cited in Fig. 9 is Torrent, R.J.; Neves, R.D.; and Imamoto, K., *Concrete Permeability and Durability Performance – From Theory to Field Applications*, CRC Press, Boca Raton, FL, USA, 2022, 550 pp.

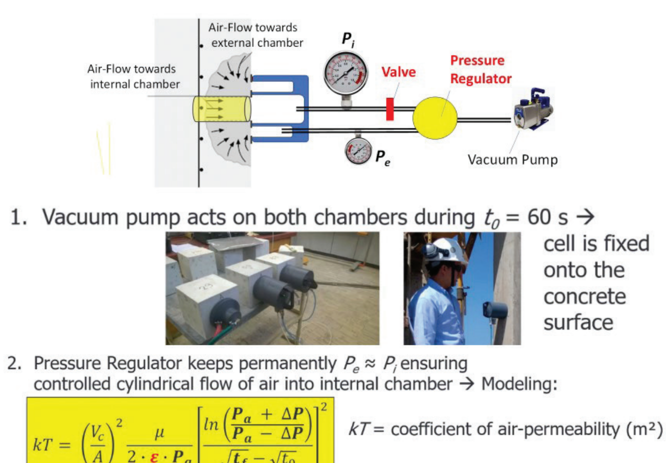


Fig. 9: The double-chamber vacuum cell test is designed to ensure airflow through the concrete cover is within a controlled cylindrical region, allowing reliable determination of the coefficient of air permeability *kT*

Current Landscape of Low-Carbon Concrete Materials

Presented by Dean Frank, Executive Director, NEU

Frank provided an update on NEU: An ACI Center of Excellence for Carbon Neutral Concrete, and the survey NEU is administering to identify companies offering materials and technologies intended to reduce the embodied carbon of cement and concrete.

Initially, the survey was sent to 50 companies that were known to be producing materials. In Part A of the survey, companies were asked to describe their production methodology, environmental claims, and specifications pertaining to their materials. In Part B, they were asked to estimate their future production and in which regions their product will be marketed. They also were asked to describe their challenges. The survey had a high response rate (Fig. 11). A snapshot of the results shows that more than half of the respondents currently have products available. However, about 40% of the respondents indicated they are working to resolve variability issues associated with raw materials. At the conclusion of his presentation, Frank introduced a panel comprising startups involved in the production or assessment of low-carbon materials.

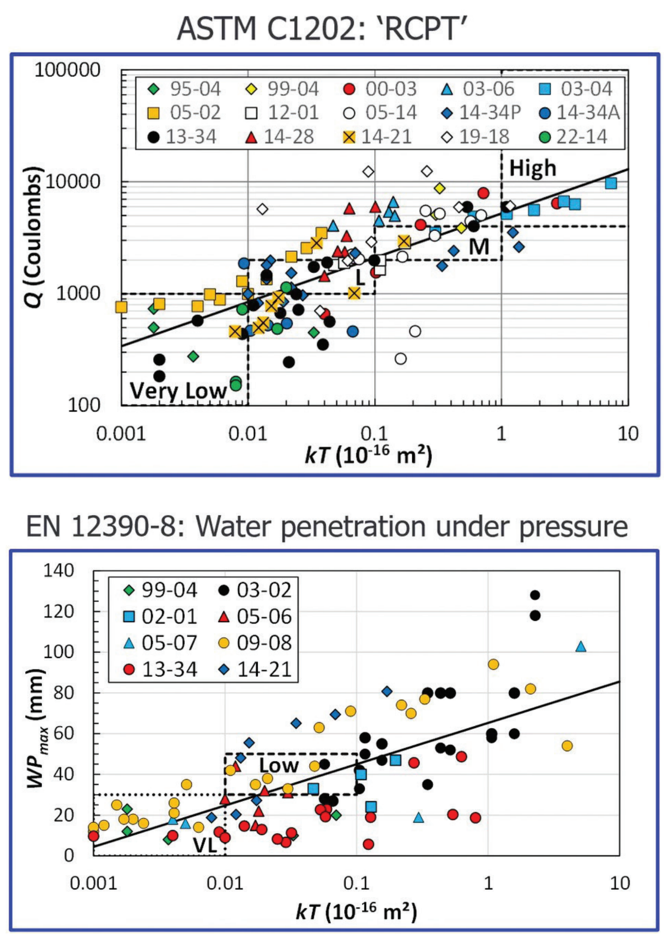


Fig. 10: The *kT* data correlates well with data obtained using ASTM C1202 as well as EN 12390-8

Fig. 11: Logos of the ACI Foundation, NEU, and the 48 companies that responded to NEU's survey

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