Key learning objectives

At the end of this class, you will be able to:

▪ Understand and explain the basics of reality capture
▪ Learn about applications of laser scanning in building construction
▪ Discover the process of analyzing laser-scan data to achieve FF/FL report
▪ Understand the current discussions revolving around the development of new ACI standards that leverage 3D laser scanning
Agenda

new ways to measure floor flatness

• Introductions
• Laser Scanning Basics
• Laser Technology Implementation
• Enabling the Future
Introductions
Get to know your presenters

• Rithm founder
• Chair of Technology US Institute of Building Doc.
• ASTM 1155 Committee (2014 Revision)
• UC Berkeley Guest Lecturer
• ACI Laser Scanning Committee

PRODUCT MANAGER
Philip Lorenzo
What is laser scanning?
What is a laser scanner?

- Phase-based laser scanner
  - 1 million points per second
  - Accuracy to 1/8"
  - Class 1 Laser – Safe in all cases
  - Self-Leveling Inclinometer
How is 3D laser scanning done?

1. Turn on
2. Press the “scan” button
3. Move
4. Repeat steps 2-3 until complete
How to put scans together

- “Registration”
- Takes a day to learn
- A week to master
About Philip

- Worked for large GC, scanning for concrete flatness, deflection monitoring & beam camber
- Founded Rithm
- Joined ASTM E06
- Partnered with Faro Technologies
How Rithm Started

\[
\begin{align*}
  f'(x_0) &= \lim_{h \to 0} \frac{f(x_0 + h) - f(x_0)}{h} = \lim_{h \to 0} \frac{(x_0 + h)^{1/2} - (x_0)^{1/2}}{h} \\
  &= \lim_{h \to 0} \frac{[(x_0 + h)^{1/2} - (x_0)^{1/2}][((x_0 + h)^{1/2} + (x_0)^{1/2})]}{h} \\
  &= \lim_{h \to 0} \frac{h}{h[(x_0 + h)^{1/2} + (x_0)^{1/2}]} = \frac{1}{x_0^{1/2}}
\end{align*}
\]
About Rithm

• Concept started
• Join ASTM 1155 Committee
  • 2014 Revision – “Laser Imaging” as valid apparatus
• Adoption across industry
  • Map across US
  • List of talks, publications, etc.
  • Faro
  • Laser FF
• DPR Construction
  • Adoption in SoCal
Getting adoption with concrete contractors

99.7% of the data are within 3 standard deviations of the mean
95% within 2 standard deviations
68% within 1 standard deviation

Dipstick, Total Station, and FARO Laser Scanner comparison for FF/FL

<table>
<thead>
<tr>
<th></th>
<th>FARO</th>
<th>Total Station</th>
<th>Dipstick</th>
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<tr>
<td>FF Values</td>
<td>36.02</td>
<td>35.99</td>
<td>36.37</td>
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<tr>
<td>FARO vs. Total Station</td>
<td>0.08%</td>
<td>FARO vs. Dipstick</td>
<td>0.96%</td>
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</tbody>
</table>
Implementation

Our floor flatness journey
Concrete Laser Scanning
Implementation at DPR

CHALLENGES

• Understanding the standards
• Accuracy of new methods
• Lack of trust
• Cost vs value
Concrete Laser Scanning
Implementation at DPR

NEXT STEPS

• Study current standards
  • Laser imaging device approved in 2014
  • Same requirements for test surface:
    • Sample measurement >11ft
    • no measurement within 2ft of slab boundary, CJ, block out, penetrations, etc.
Concrete Laser Scanning
Implementation at DPR

NEXT STEPS

• Study current standards

• Compare equipment function & cost
  • Dipstick
    • Less expensive, established
    • Single purpose equipment & data
  • Laser scanner
    • Multiple uses, lots of data
    • Higher cost, learning curve
Concrete Laser Scanning
Implementation at DPR

NEXT STEPS

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Concrete Laser Scanning
Implementation at DPR

NEXT STEPS

• Study current standards
• Compare equipment function & cost
• Test software & provide feedback
Concrete Laser Scanning
Implementation at DPR

NEXT STEPS
• Study current standards
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• Test software & provide feedback
• Optimize workflows & duplicate results
Concrete Laser Scanning
Implementation at DPR

NEXT STEPS

• Study current standards
• Compare equipment function & cost
• Test software & provide feedback
• Optimize workflows & duplicate results
• Document everything
Concrete Laser Scanning
Implementation at DPR

NEXT STEPS

• Study current standards
• Compare equipment function & cost
• Test software & provide feedback
• Optimize workflows & duplicate results
• Document everything
• Roll out
Concrete Laser Scanning
Implementation at DPR
Concrete Laser Scanning
workflow

FF/FL REQUEST
• Provide general project information
• Advanced notice of concrete placement:
  • Prefer 1 week

PLACE & FINISH CONCRETE
• Real-time feedback, when will the surface be walkable?

PERFORM SCAN
• Best practices during scanning:
  • Limit foot traffic
  • Remove debris, equipment & material

CREATE FF/FL REPORT
Report includes:
• Overall FF & FL
• Minimum FF & FL
• 90% confidence intervals (req. per ASTM E1155)
• Project specification “Pass/Fail” rating
• Test run details & exaggerated profiles
Re: Norris Healthcare Center Health Sciences Campus
2204 East Alcazar Street
Los Angeles, CA 90033

Subject: Concrete F# Number Measurement / Concrete Floor Profiling

On 11-3-15, [redacted] performed F-Number measurement for the concrete floors at the project listed above. Testing was performed in accordance with ASTM E1155. The test sections, calculations, graphs and floor map are enclosed for your records.

The test data indicates the Combined F-number run values for Deck, Level1 Plaza are:

- Floor Flatness = **FF39.36**
- Floor Levelness = **FL11.50**

Thank you for choosing [redacted] to service your concrete floor flatness and levelness testing needs. Please feel free to contact me should you have any questions regarding your F-Number measurement reports.

Sincerely,
### Inspection Information

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Project</strong></td>
<td>USC NHC L1 PLAZA</td>
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<tr>
<td><strong>Location</strong></td>
<td></td>
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<tr>
<td><strong>Pour Date</strong></td>
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<tr>
<td><strong>Date Measured</strong></td>
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<tr>
<td><strong>Measured Area</strong></td>
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<tr>
<td><strong>Type of Run Selection</strong></td>
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</table>
85/6

F-Number reports to date / projects
What future does laser scanning have in the concrete industry?
Limitations of Current Process

Descriptive text and content

- Does not capture what is in between runs
  - Miss high/slows
  - 1-1/2” of shim on extra-deflecting slabs
How might this technology improve the concrete quality control process?

- Does not capture what is in between runs
  - Miss high/slows
  - 1-1/2” of shim on extra-deflecting slabs
- Not truly “repeatable” in a practical sense
  - Cannot do runs in the exact same area
  - People are only going to do so many and not fully take an average due to time constraint
Why?

- Pass Inspection
- Prevent Litigation
Code Compliance – Stairs, Ramps

UC Berkeley Lower Sproul Fire-Marshall Initiated Stair Survey
Computer Vision – AutoStair Detection
Parking Garage Compliance
What if you could calculate concrete tolerances while it’s still workable?
Building Survey

Courtesy of McCarthy Building Companies
What happens when our basic assumptions change?

“...since all of the infinite potential profiles to be seen by the traffic can not possibly be measured.”
Source of a problem?

“Measurement is the first step that leads to control and eventually to improvement.”

— H. James Harrington
What might a future standard look like?

- More repeatable
  - Basically making the 2D become 3D
- Take advantage of all the information
- Can be met reasonably by a typical contractor
- A standard score typical to FF/FL for pass/fail
- Be able to be met using current tools
- Be easily relatable to old standard, i.e. Same score
Partnering with Universities

Pingbo Tang, PhD, Arizona
Call to Action

• Fund research
• Participate in discussion for new standards
• Allow your projects to be tested and investigated
• Adopt the technology!
Questions & Discussion