Use of Passive and Wireless-Based RFID Sensors for Concrete

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Acknowledgements

- Oklahoma Transportation Center
- Oklahoma Center for Advancement of Science and Technology

Summary

- Barriers to sensor use in infrastructure
- Corrosion sensors
- Cracking sensors
- Conclusion

Why are sensors not widely used in infrastructure?

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- An average car uses 120 sensors and costs $16,000
- An average bridge uses **no sensors** and costs $1 M

Which knife would you choose?

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Which knife would you choose to outfit an army?

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Cost - $20

$90

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- The average cost per sensor is $15!!!
- The sensors provide simple feedback

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An inexpensive sensor that will last as long as the structure and doesn't require wires or batteries while providing the user with useful information.

Overview of a corrosion sensor

RFID Sensor

RFID Sensor

Handheld Reader

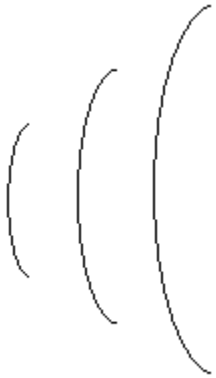
RFID Sensor

Copper Coil

Magnetic Field

Handheld Reader

RFID Sensor



Signal out

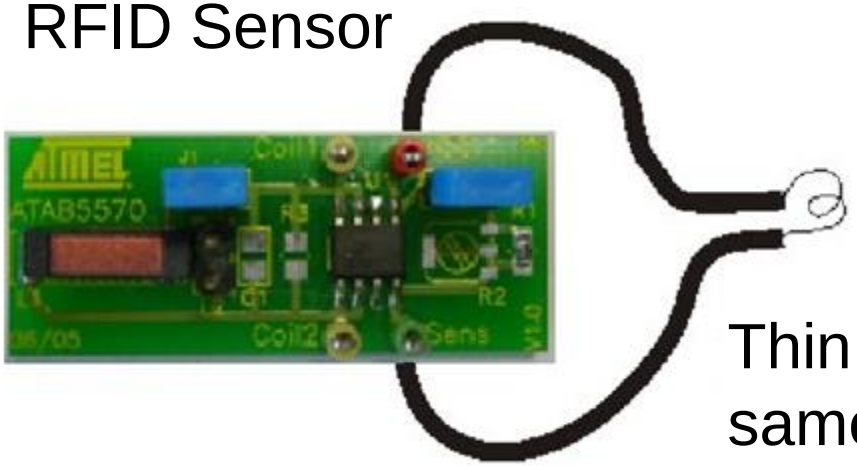
Handheld Reader

No Wires!

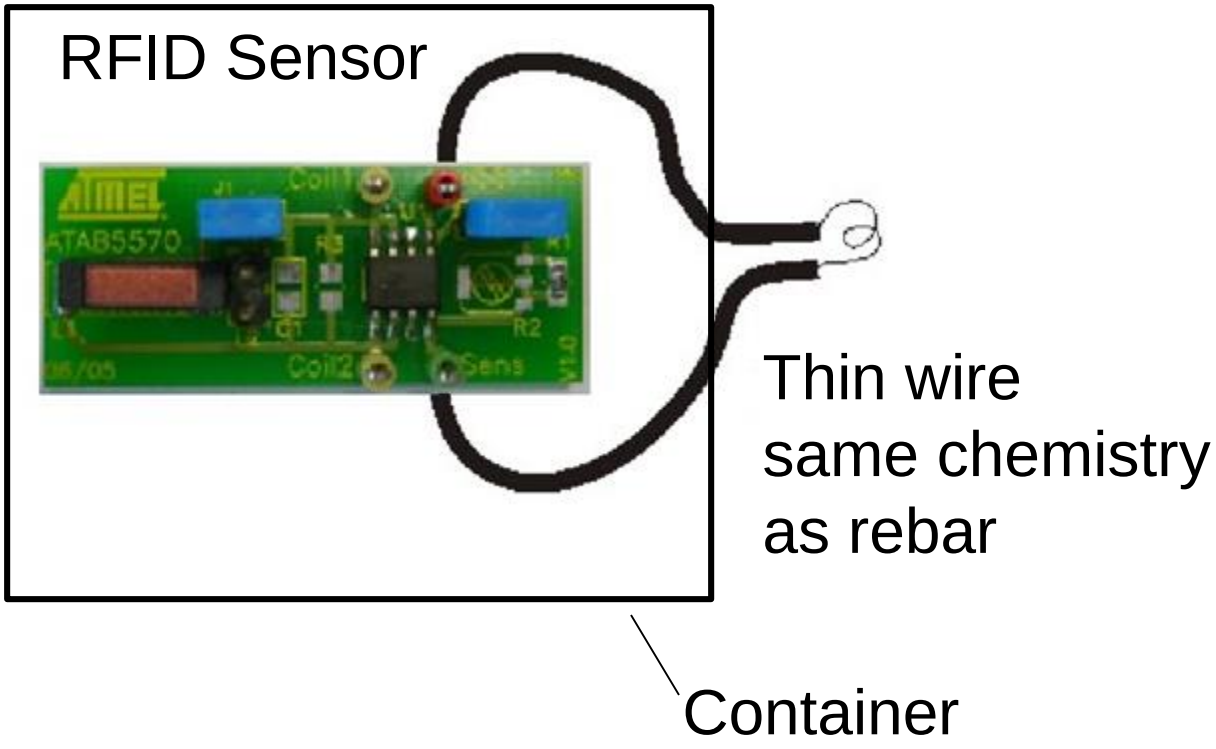
No Batteries!

Cheap! ($.01 - $5)

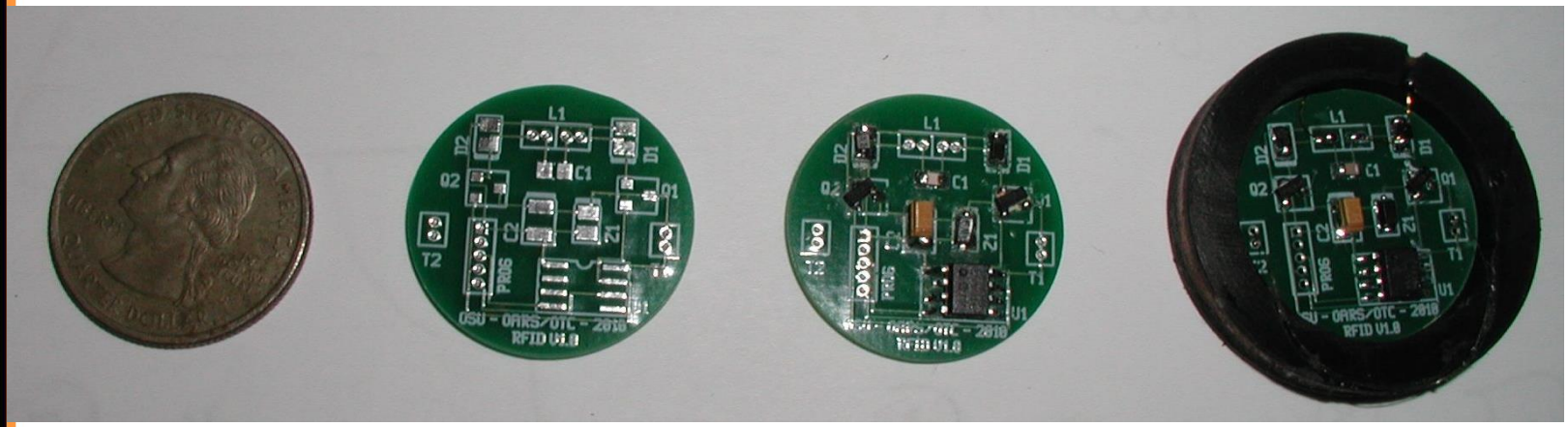
RFID Sensor



Thin wire
same chemistry
as rebar


RFID Sensor
ATAB5570
Coil1
Coil2
Sens
R2
Thin wire
same chemistry
as rebar
Container

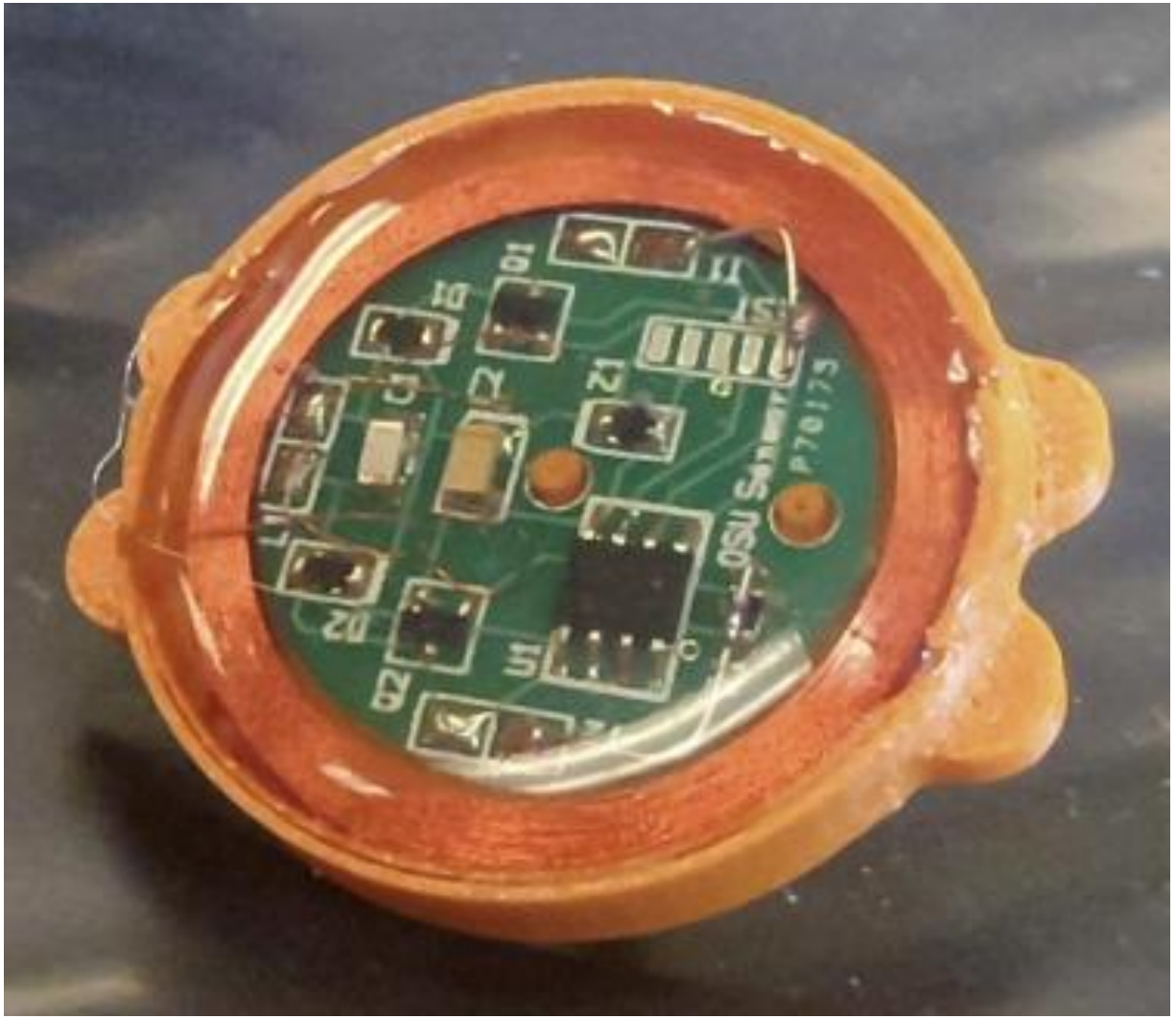
Final Prototype

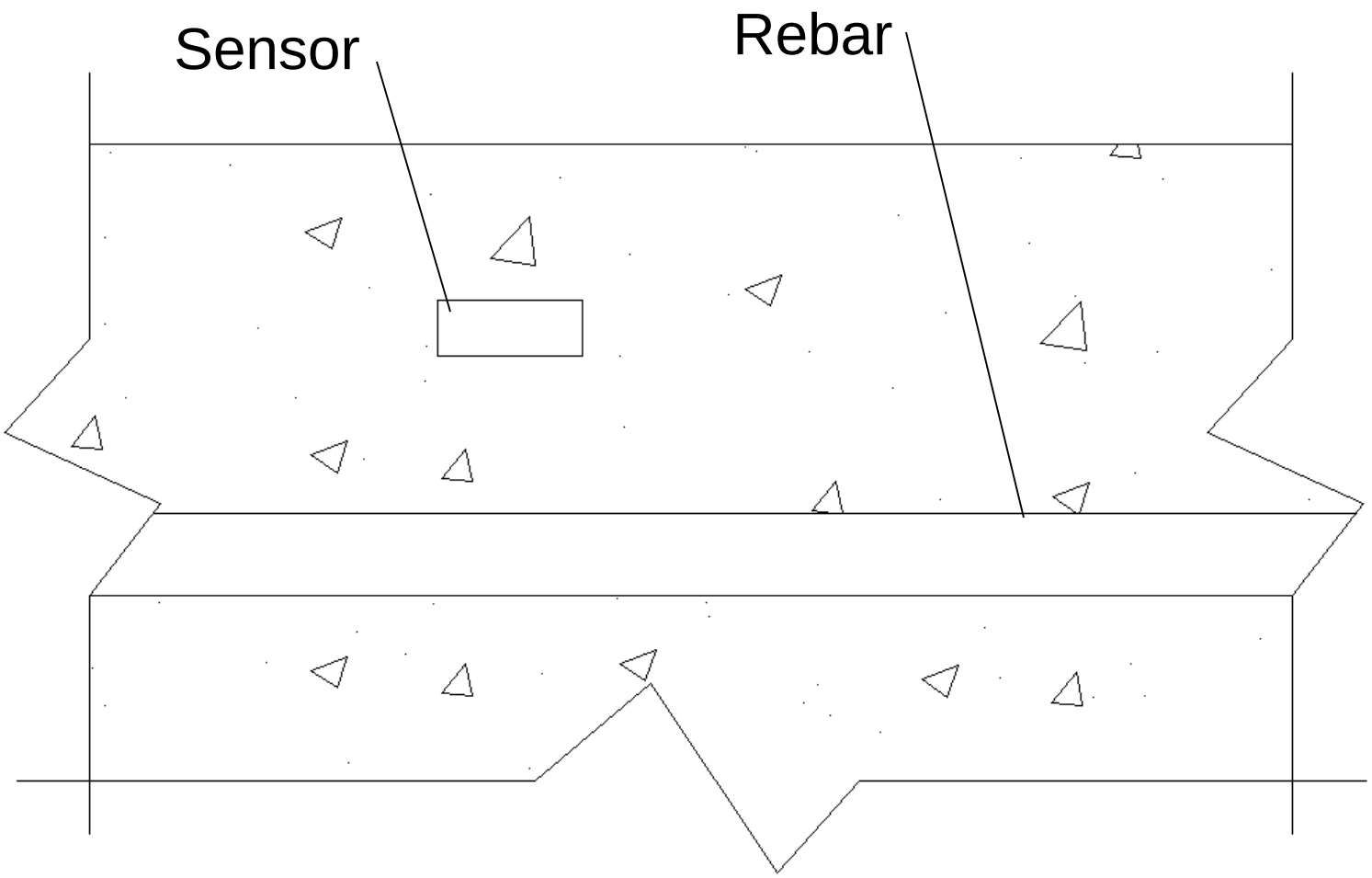


Sensing Wire

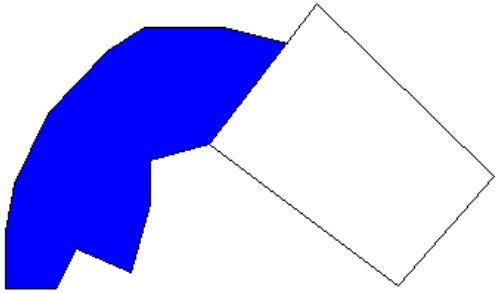
Copper Coil

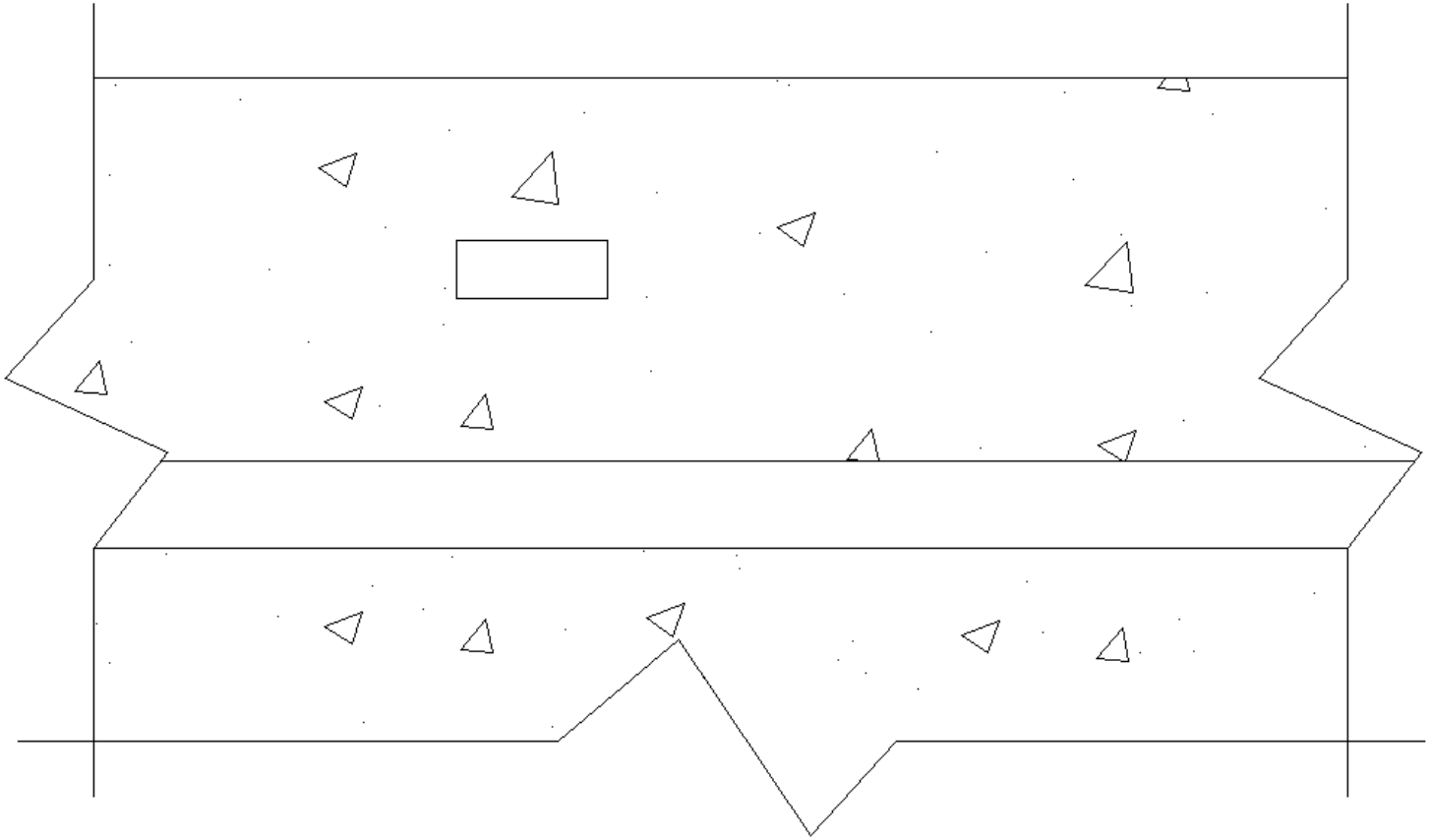
Production of Sensors



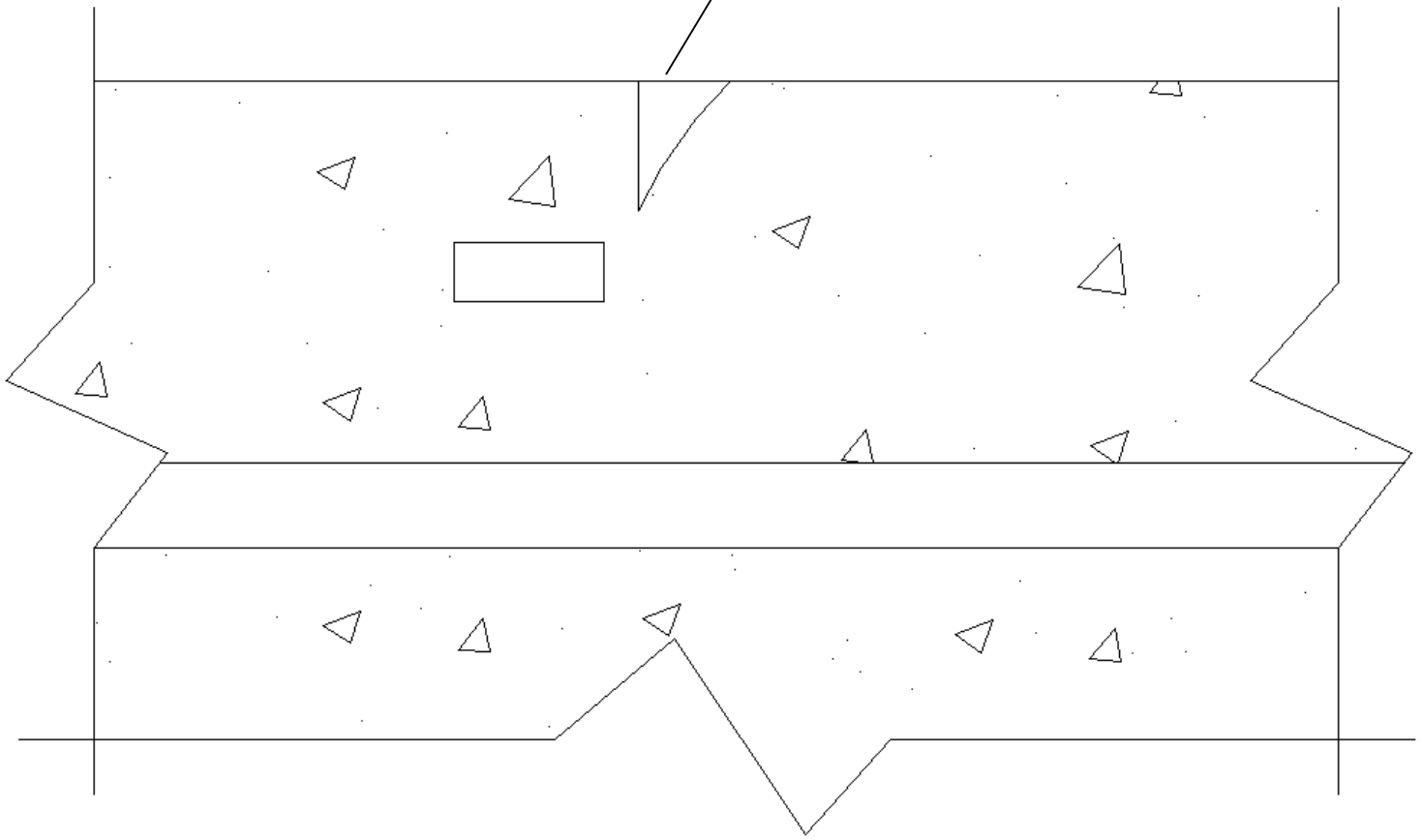

Sensor
Rebar

Chlorides

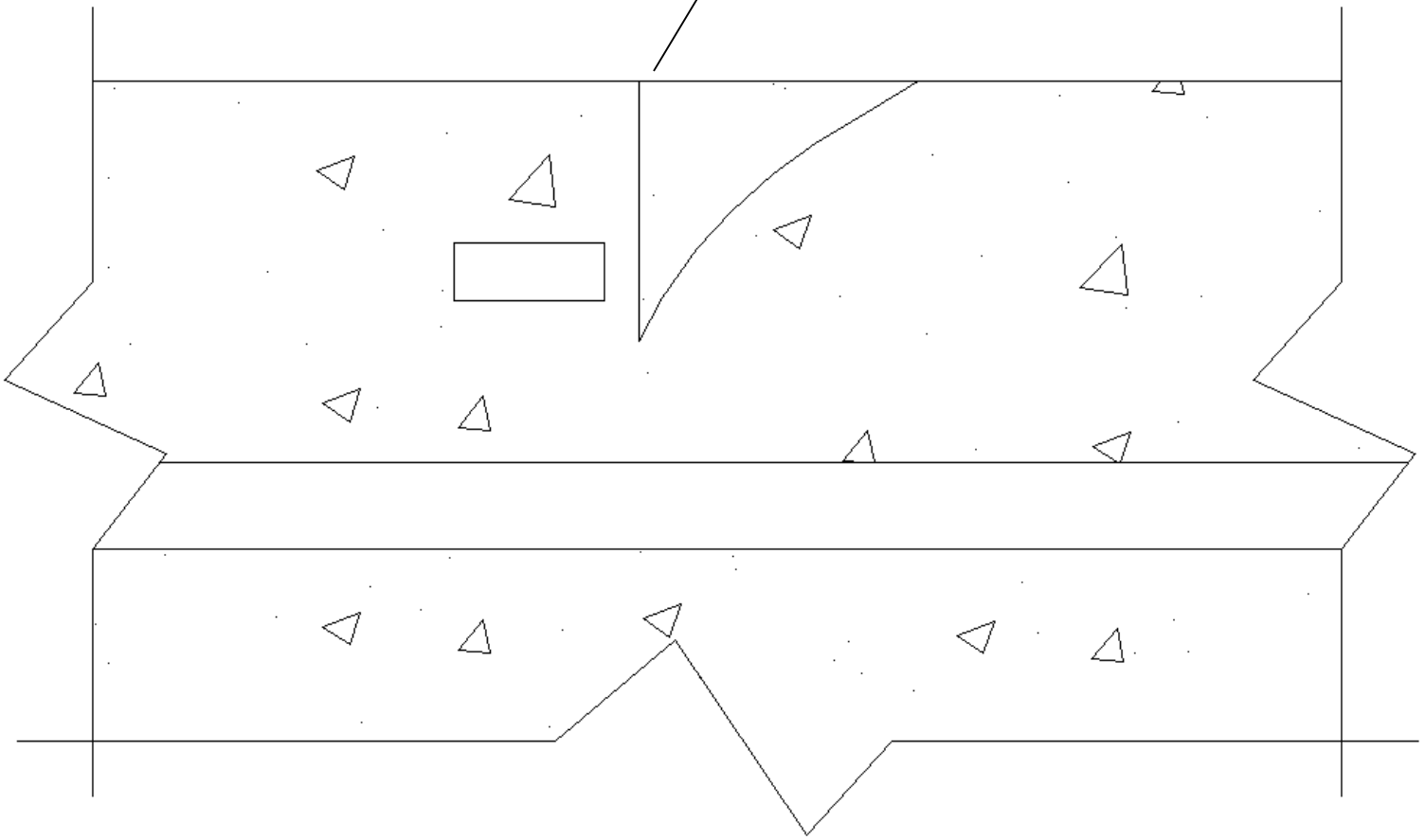




Chloride Profile

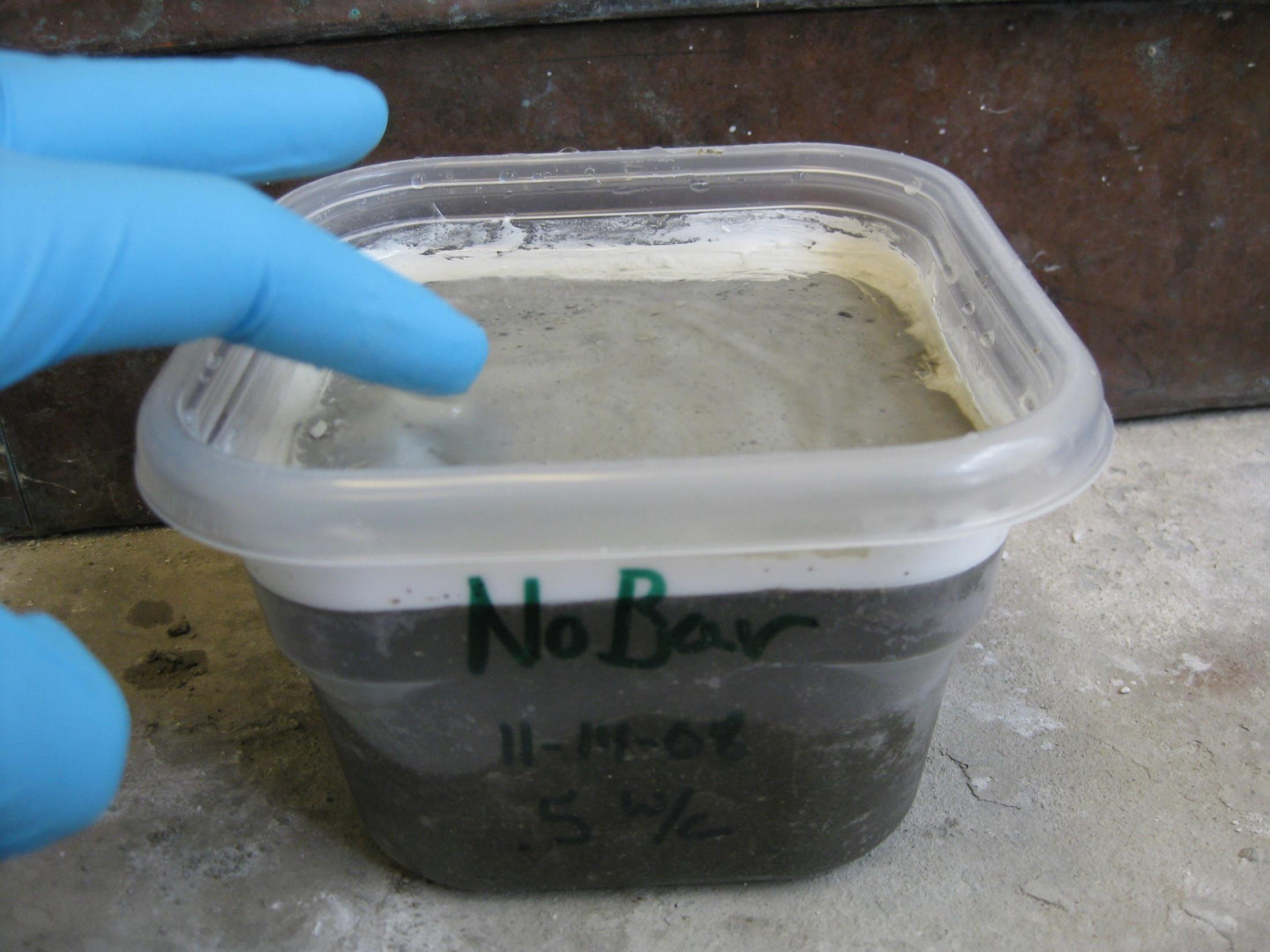


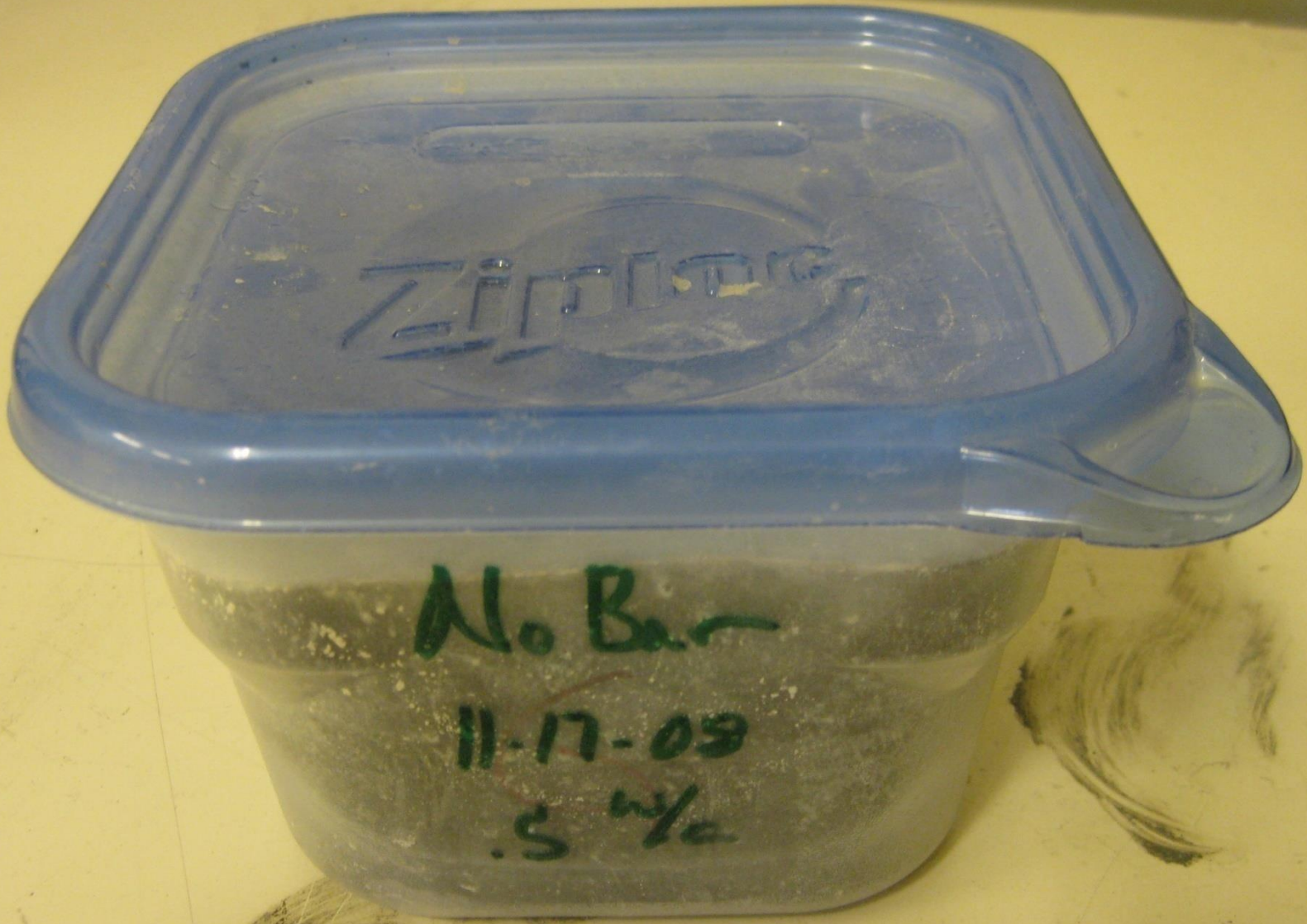
Chloride Profile



Sensor Benchmarks

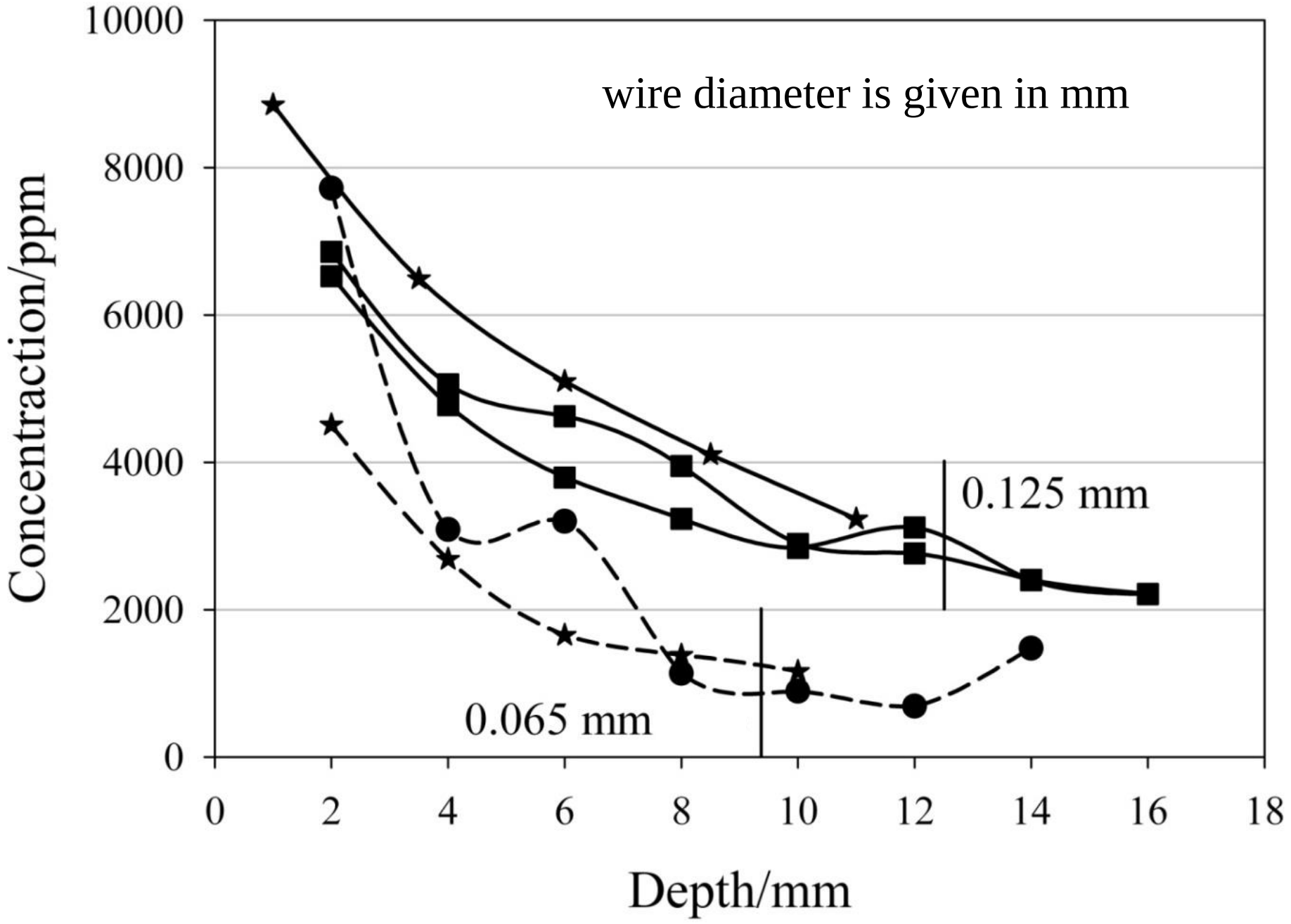

No Bar
.7 WC
10-1-08


No Bar
11-14-08
5 w/c


Ziploc
No Bar
11-17-03
.5 w/a


CENTRAL MACHINERY
DRILL PRESS
ON
OFF
Mo Bar
11-17-09
.5 %c


Al. Bar
11-17-09
.5 4/c


wire diameter is given in mm
0.125 mm
0.065 mm
Concentration/ppm
Depth/mm
10000
8000
6000
4000
2000
0
0
2
4
6
8
10
12
14
16
18

Environmental Testing

- All DOD grade electronics, plastics, and epoxies were used
- Sensors in concrete were subjected to 40 cycles from -20^{o}C to 120^{o}C
- Concrete containing the sensors were tested in compression and flexure to investigate the impact on strength

  (~8% reduction worst case)

Applications of These Sensors

- Mount an antenna on a truck and measure the sensors at highway speed
- Measure the sensors with dataloggers and an antenna
- Use of multiple sensors or sensing elements at different depths to determine chloride intrusion over time

Implementation

- We have used the sensors in six bridges in Oklahoma, Missouri, and Iowa
- Sensors are performing well
- We are looking for people interested in implementing these sensors
- Estimated price = $25 each

RFID Based Sensors for Cracking

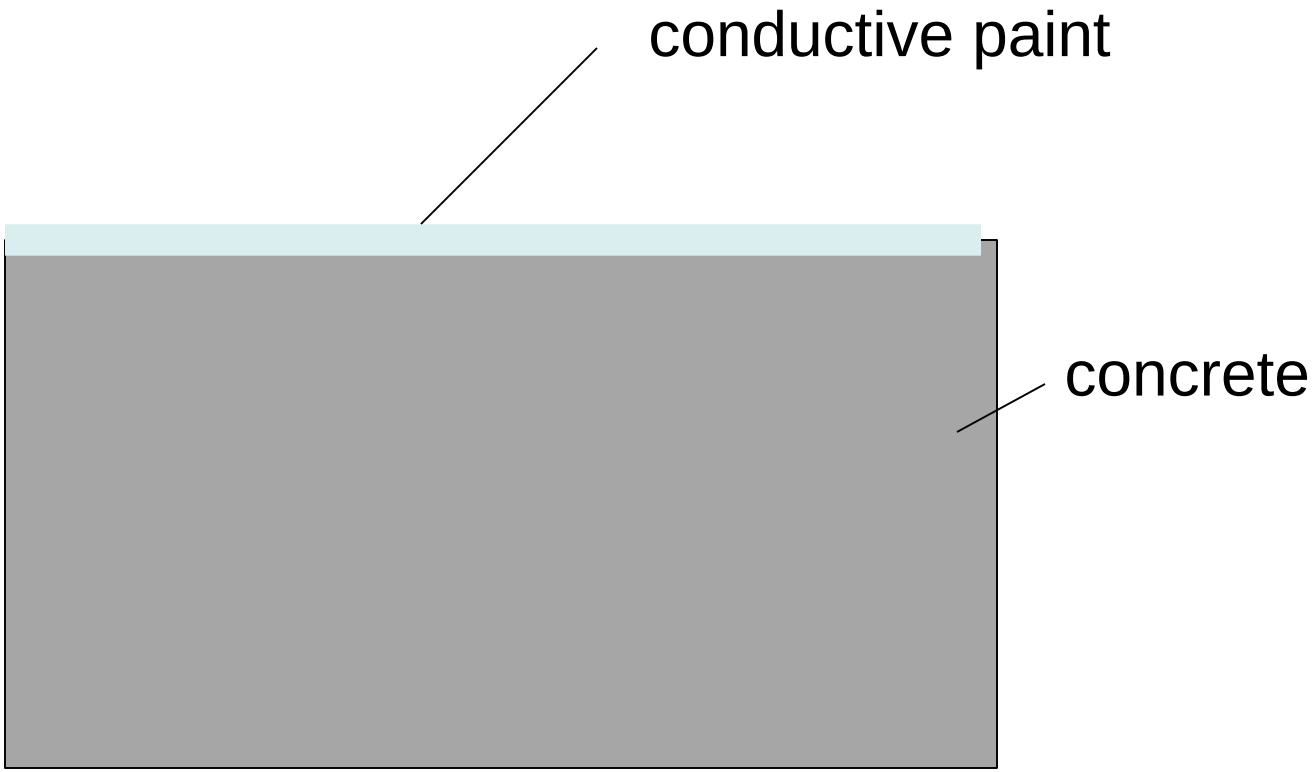
Nicholas Materer, Tyler Ley, Allen Apblett

Jason Weiss
Tim Barrett

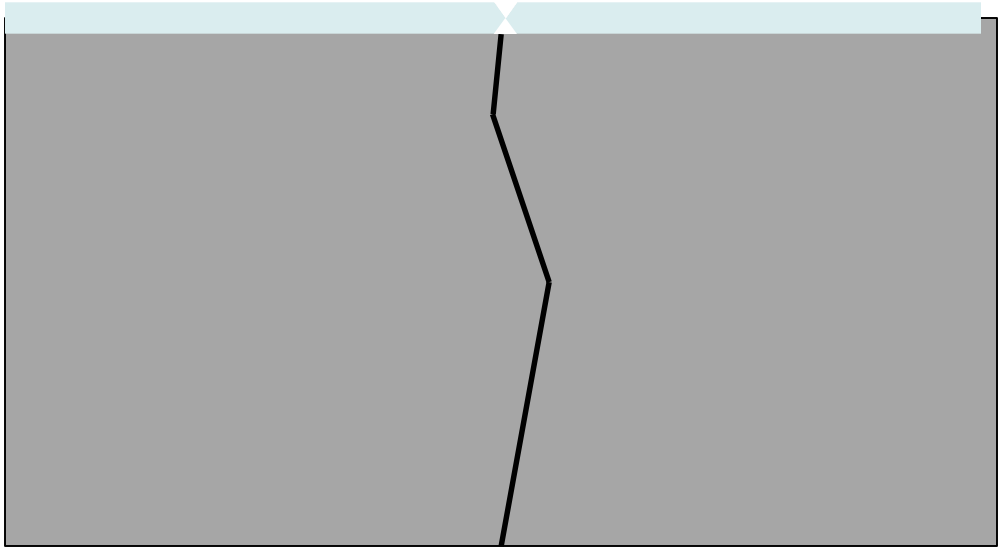
Mohammad Pour-Ghaz

Measuring Cracking

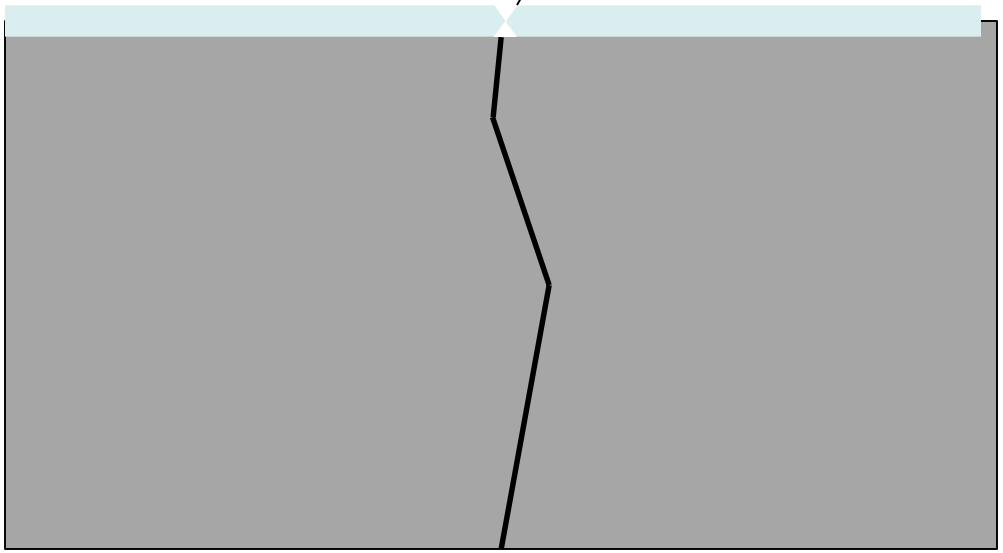
- Purdue has developed a new electrical crack gage
- They place a thin layer of conductive paint on the surface of concrete
- When the concrete cracks the paint necks and the resistance changes
- The resistance can be correlated to the crack size

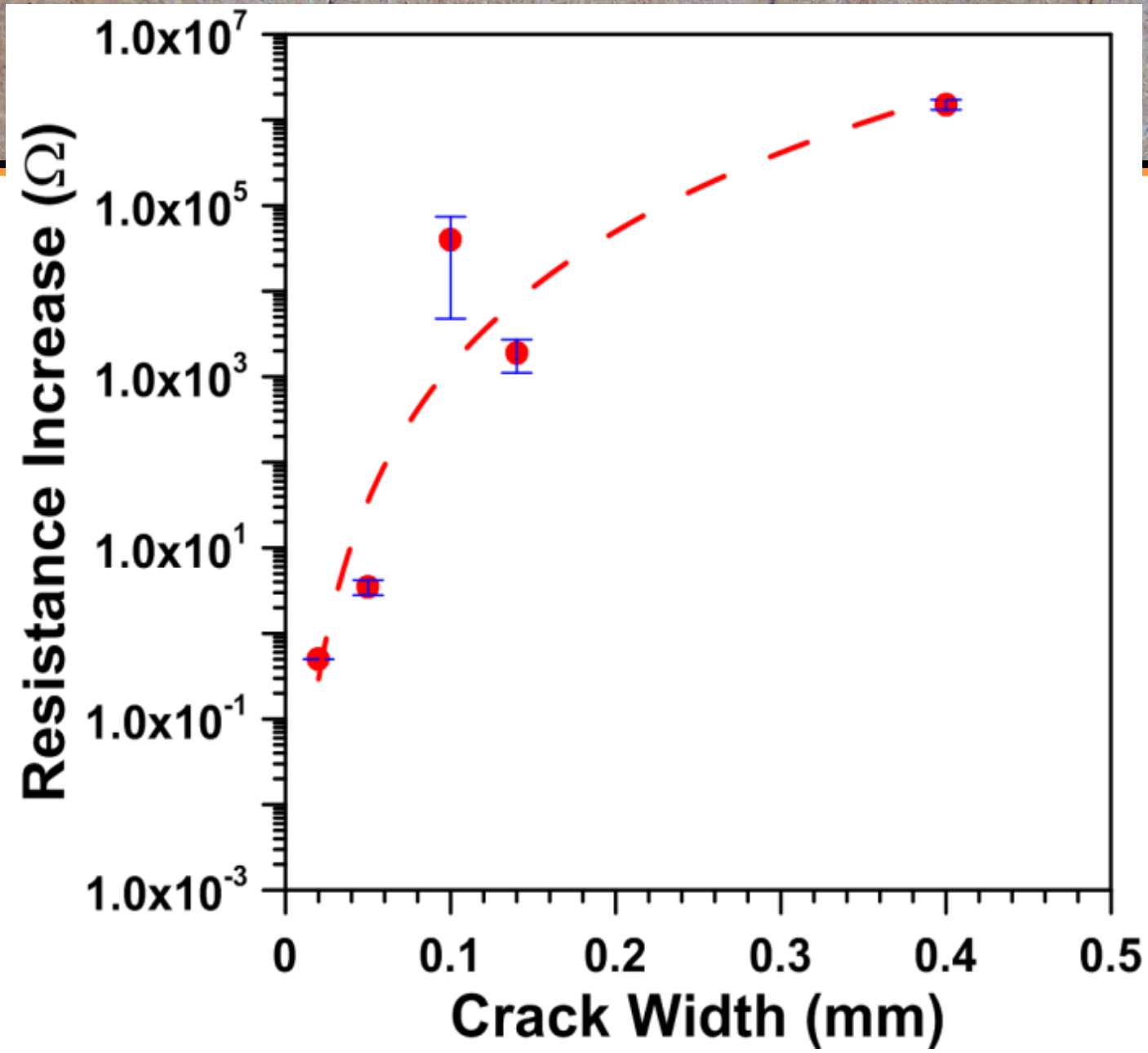

conductive paint
concrete

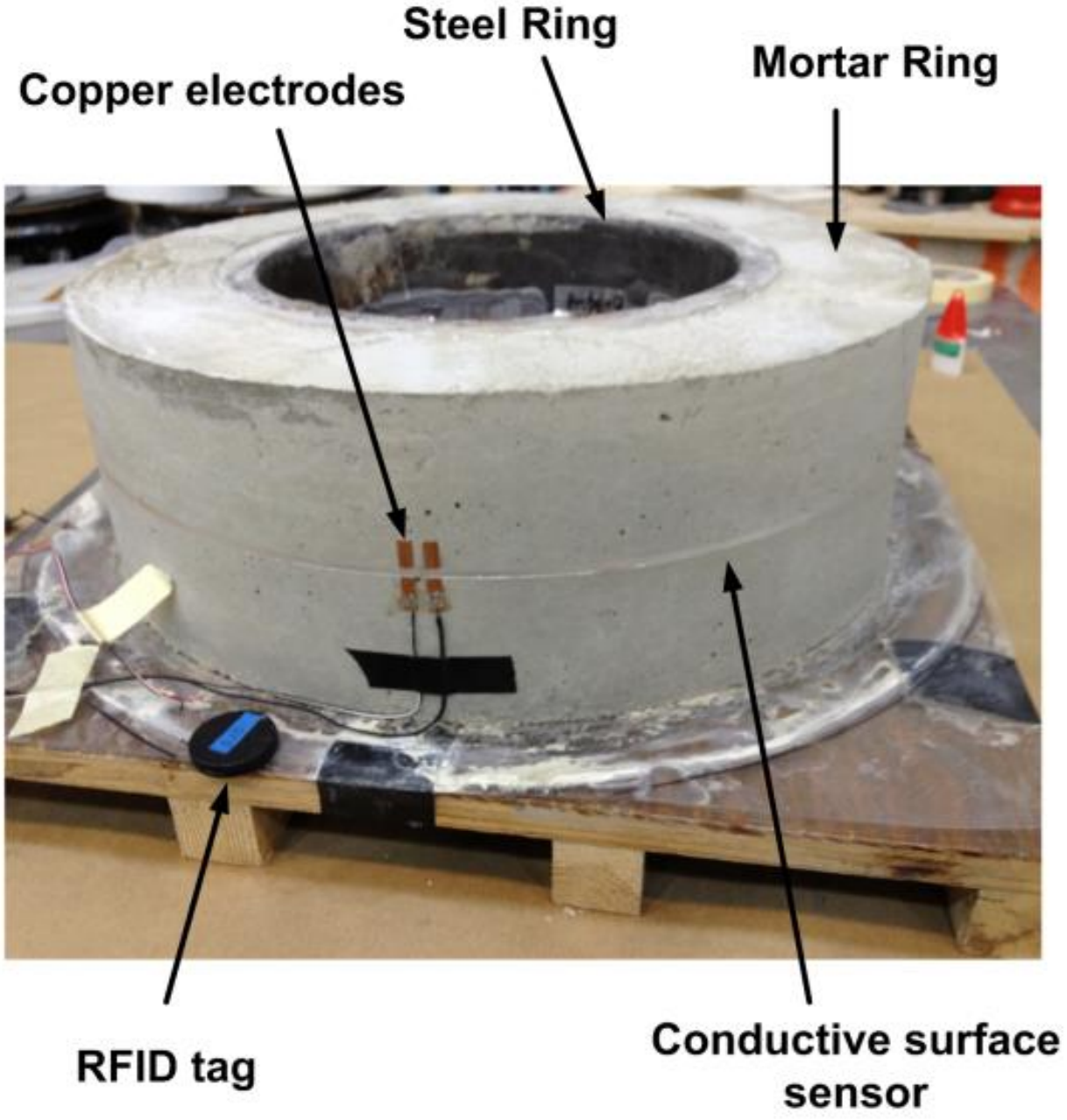

strain

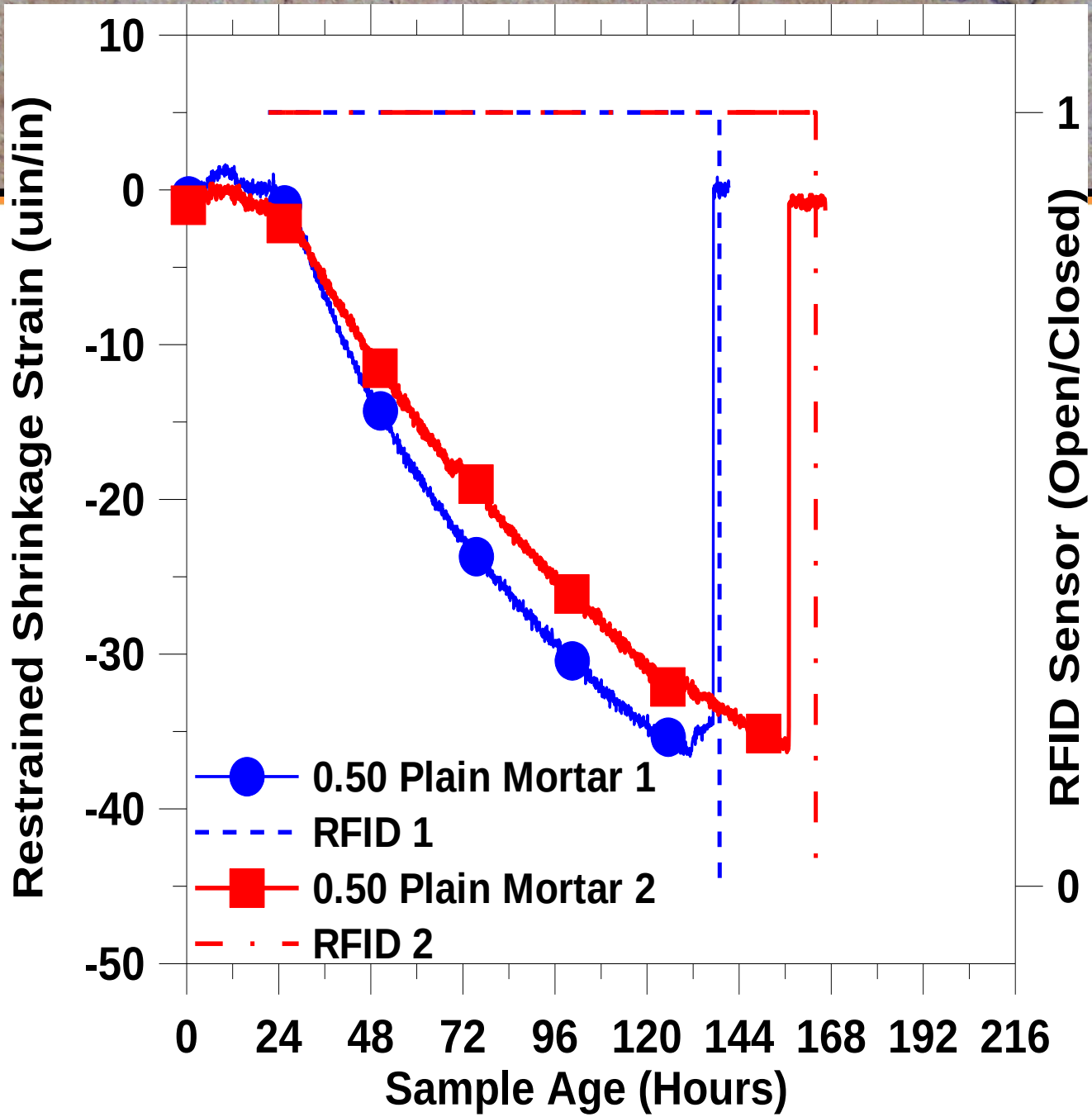


As the conductive paint necks the resistivity increases




Resistance Increase (Ω)
1.0x10^7
1.0x10^5
1.0x10^3
1.0x10^1
1.0x10^-1
1.0x10^-3
0
0.1
0.2
0.3
0.4
0.5
Crack Width (mm)


Steel Ring
Mortar Ring
Copper electrodes
RFID tag
Conductive surface sensor


Restrained Shrinkage Strain (uin/in)
RFID Sensor (Open/Closed)
Sample Age (Hours)
10
0
-10
-20
-30
-40
-50
1
0
0
24
48
72
96
120
144
168
192
216
0.50 Plain Mortar 1
RFID 1
0.50 Plain Mortar 2
RFID 2

Future Applications

- We are just getting started…
- This technology can be extended to measure moisture, resistivity, temperature, and CO_2?

Conclusions

- Passive and Wireless Corrosion sensors using RFID based technology has been developed and patented
- Validation and environmental testing is complete
- Implementation is underway

Conclusions

- Modifications to these sensors have been used to wirelessly measure time and size of cracks at comparable times to wired sensors

Questions?

www.tylerley.com