University of Pittsburgh

Swanson School of Engineering

PITT | IRISE

IRISE Implementation Workshop

Julie Vandenbossche

IRISE Annual Meeting

May 23rd, 2024

Early Opening of Concrete Pavements to Traffic

- PI: Dr. Lev Khazanovich
- Constructor: Chuck Niederriter
- Owner: Jason Molinero
- Owner: Ed Skorpinski
- Owner: Jimmy Hontz (D11)

Technology: Early Opening of PCC Pavements

- The current empirical methods for determining traffic-opening criteria encourage the use of concrete with high early strength, but do not consider long-term effects
- Pub 408 permits estimating concrete strength by the maturity according to PTM 640, but it is not common
- An innovative strength determination method and mechanistic-based procedure for quantifying the risk of premature failure and long-term damage caused by traffic opening will facilitate reduction of unnecessary construction delays, construction and user costs.

PennDOT Strength Criteria (2021)

Slab Thick, inches	Strength for Opening to Traffic, psi			
	Slab Length < 10 ft		Slab Length ≥ 10 ft	
	f'c	MR (3rd)	f'c	MR (3rd)
6.0	3000	490	3600	540
7.0	2400	370	2700	410
8.0	2150	340	2150	340
9.0	2000	275	2000	300
10.0 +	2000	250	2000	300

Golden Triangle Parking Lot Testing

	High Early Strength Mix	Long-Life Conventional Paving Mix
Cement (lbs)	600	477
Pozzolan 1 (lbs)	150	134
Total Cementitious (lbs)	**750**	**611**
Coarse Aggregate 1 (lbs)	1309	1357
Coarse aggregate 2 (lbs)	396	410
Total Coarse Aggregate (lbs)	**1705**	**1767**
Fine Aggregate (lbs)	**1158**	**1161**
Total Water (lbs)	**236**	**249**
W/C Ratio	**0.315**	**0.408**
Unit Weight (lbs/cu.ft)	142.93	141.03

Table 3: Average and standard deviation for compressive strength testing in psi

	High Early Strength Mix		Long-Life Conventional Mix	
Test Time	Avg. f'c	SD f'c	Avg. f'c	SD f'c
3 hr	125	16	-	-
5 hr	951	43	-	-
7 hr	2484	73	-	-
1 day	3658	128	3311	145
3 days	-	-	4329	115
5 days	-	-	4426	106
7 days	-	-	5040	217
14 days	-	-	5237	440
28 days	-	-	6219	111

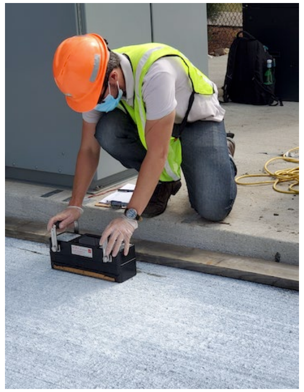
Table 4: Average and standard deviation for flexural strength testing in psi

	High Early Strength Mix		Long-Life Conventional Mix	
Test Time	Avg. MOR	SD MOR	Avg. MOR	SD MOR
7 hr	360.9	12.8	-	-
1 day	-	-	597.2	57.9
3 days	-	-	741.2	18.0
5 days	-	-	719.0	19.2
7 days	-	-	819.3	88.6
14 days	-	-	824.0	86.9
28 days	-	-	804.4	25.5

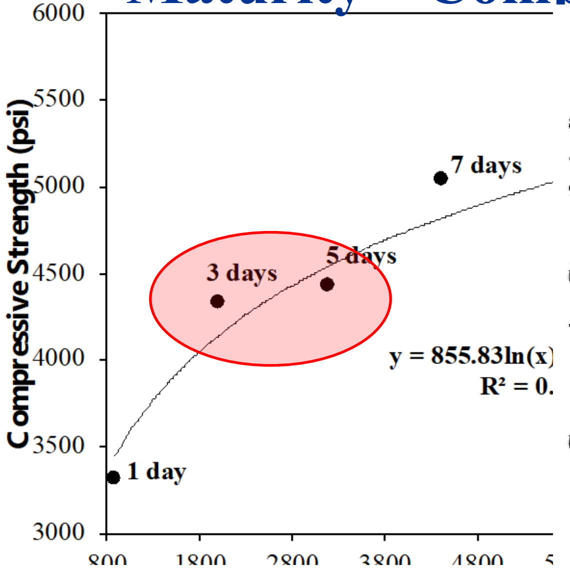
Non-Destructive Strength Determination

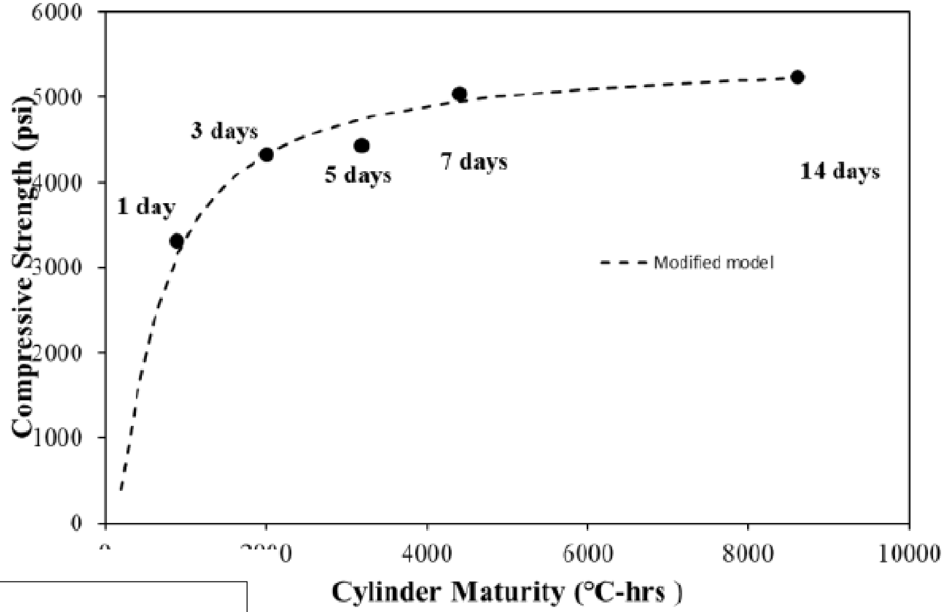
Maturity method

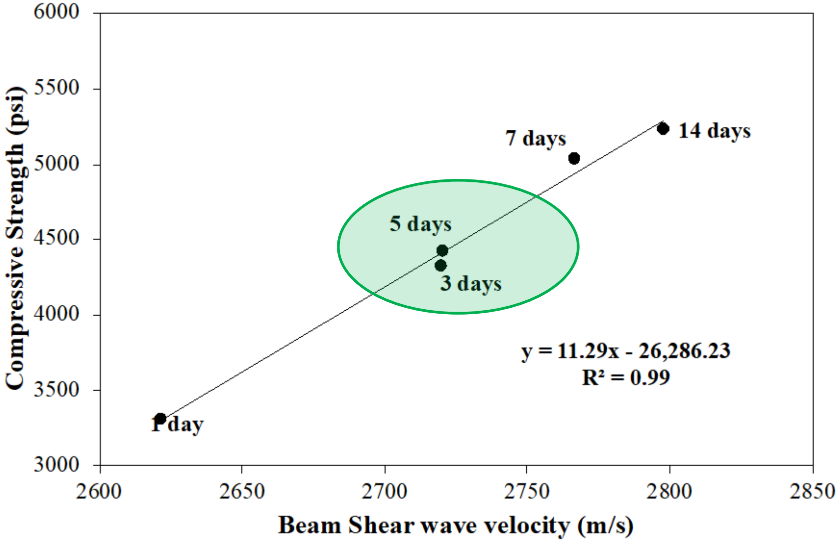
Ultrasound velocity method



Maturity – Compressive Strength







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Web-Based Tool for Risk Assessment

Access to technology:

Early Opening: Constructor - Chuck Niederriter

- Maturity testing is already approved for use by PennDOT and other agencies.
- A barrier to implementation is the large amount of technical work needed to develop a maturity curve although industry is beginning to overcome this barrier.
- New sensors that measure strength based on a mechanical aspect which work with any mix and do not require calibration are a breakthrough improvement over the temperature sensors.
- High early strength concrete pavement project requirements are often specified that may be unnecessary.

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Early Opening: Constructor - Chuck Niederriter

- Current practice of utilizing test cylinders to represent pavement characteristics is often inaccurate.
- What is the actual strength needed to open pavement to traffic?
- High early strength often is over emphasized at the peril to long term durability.
- In conclusion, tools are now available for implementation. Training is key.

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Early Opening: Owner – Jason Molinero

Needs or Potential Challenges to Implementation

- Development of a roadmap or workflow.
- Assignment of responsibility between Agency/Contractor and Design/Construction.
- Changes to the Publication 408 Specifications (Section 501.3(q)).
- Guidelines for Design
- Implications for traffic control (opening a roadway to passenger vehicles only)
- Prevalence and Acceptance of non-destructive testing methods (maturity and ultrasonic tomography).

Early Opening: Owner – Ed Skorpinski

NDT evaluation method: Shear wave velocity

Compressive PCC strength @ opening, psi: 1000

Opening PCC SWV, m/s: 2336

PCC Flexural Strength @ opening, psi: 346

PCC Strength - Shear Wave Velocity Models

Long-term MR, psi: 850

Long-term f'c, psi: 5500

ultimate strength

A_s: 0.00193462

B_s: -5.417

MR = MR_u exp(-A/Mat)^b)

A_m: 273.44

B_m: 1.017

$M_r = M_{ru} \exp(-(A/Maturity)^B)$

C_m: 508.09

D_m: 1.039

$f'_c = f'_{cu} \exp(-(C/Maturity)^D)$

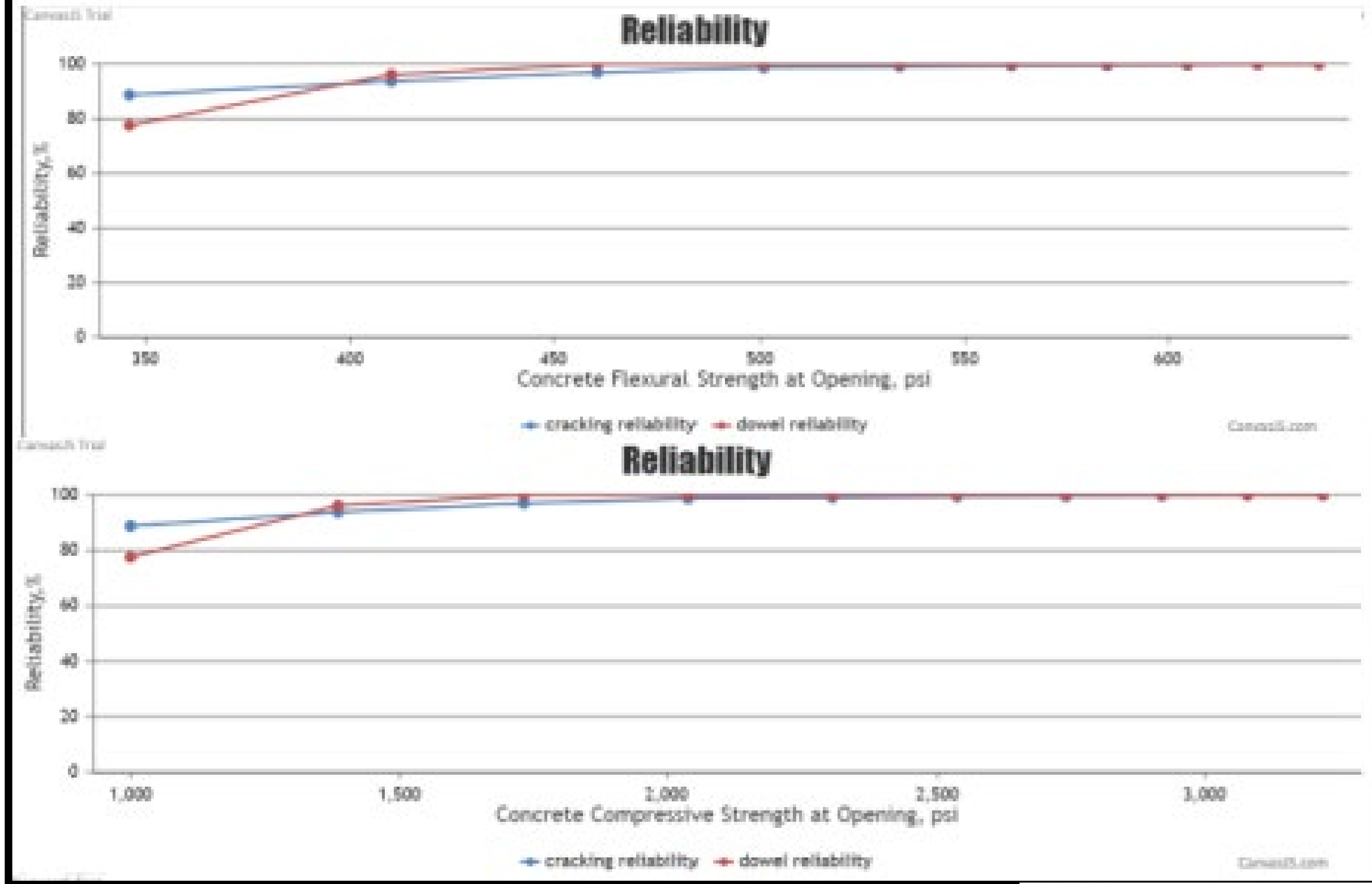
Submit | Settings

Results

Cracking performance reliability, %: 88.7

Dowel performance reliability, %: 77.5

ESALs repetitions to design strength: 997.7



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Early Opening: Owner – Ed Skorpinski

Pub 408

Section 501.3(q)

PCCP

Table 1: Strength criteria from PennDOT 408 (2021)

Slab Thickness, in	Strength for Opening to Traffic, psi			
	Slab Length < 10 ft		Slab Length ≥ 10 ft	
	f'_c	MR (3rd point loading)	f'_c	MR (3rd point loading)
6.0	3000	490	3600	540
7.0	2400	370	2700	410
8.0	2150	340	2150	340
9.0	2000	275	2000	300
10.0 +	2000	250	2000	300

Pub 242

TABLE 6.5
RELIABILITY BY FUNCTIONAL CLASSIFICATION

FUNCTIONAL CLASSIFICATION	RANGE (%)
Interstates and Other Expressways	95
Arterials	90 - 95
Collectors	85 - 90
Locals	70 - 85

Early Opening: Owner - Jimmy Hontz (D11)

- Currently permitted in Pub 408 per PTM 640
- Requires 28 day maturity curves for each step down and mix design
- Used on two district 11 projects by modifying PTM 640
- Identifying more accurate early strength gain and proper opening strength
- Implementing for use with accelerated structure repairs

Material Compatible Repair for Partial Depth Repairs

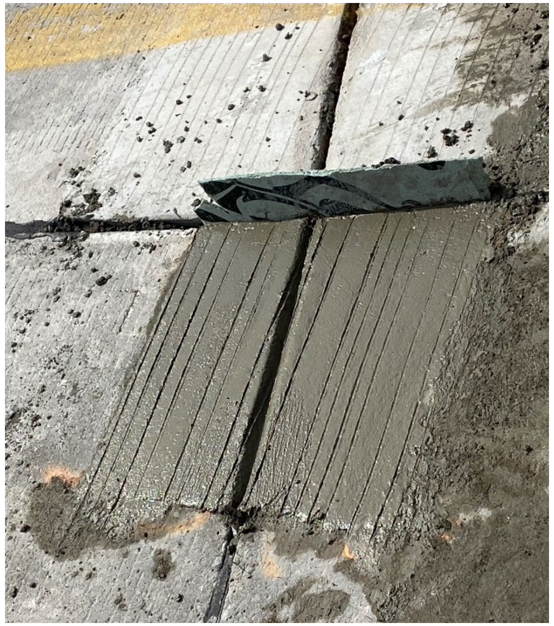
- PI: Dr. Steve Sachs
- Constructor: Chuck Niederriter
- Designer: CDR Maguire
- Owner: Ed Skorpinski
- Owner: Rachel's staff (D12)

Technology: Material Compatible Repair (MCR)

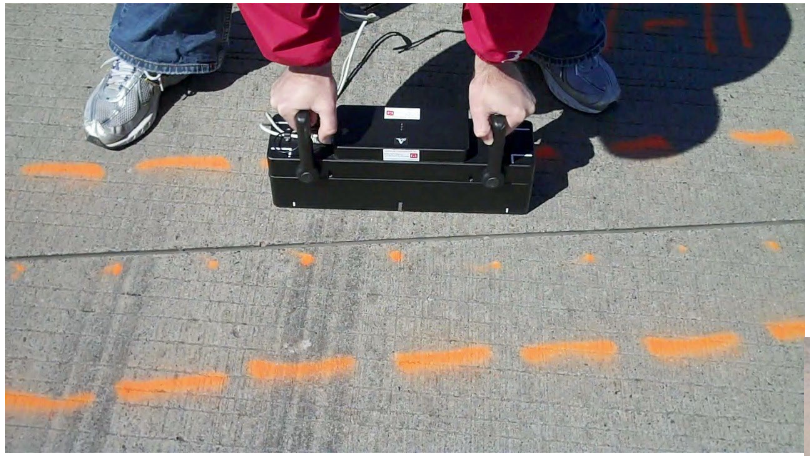
1. Assess distressed area so correct repair is being performed (MIRA)

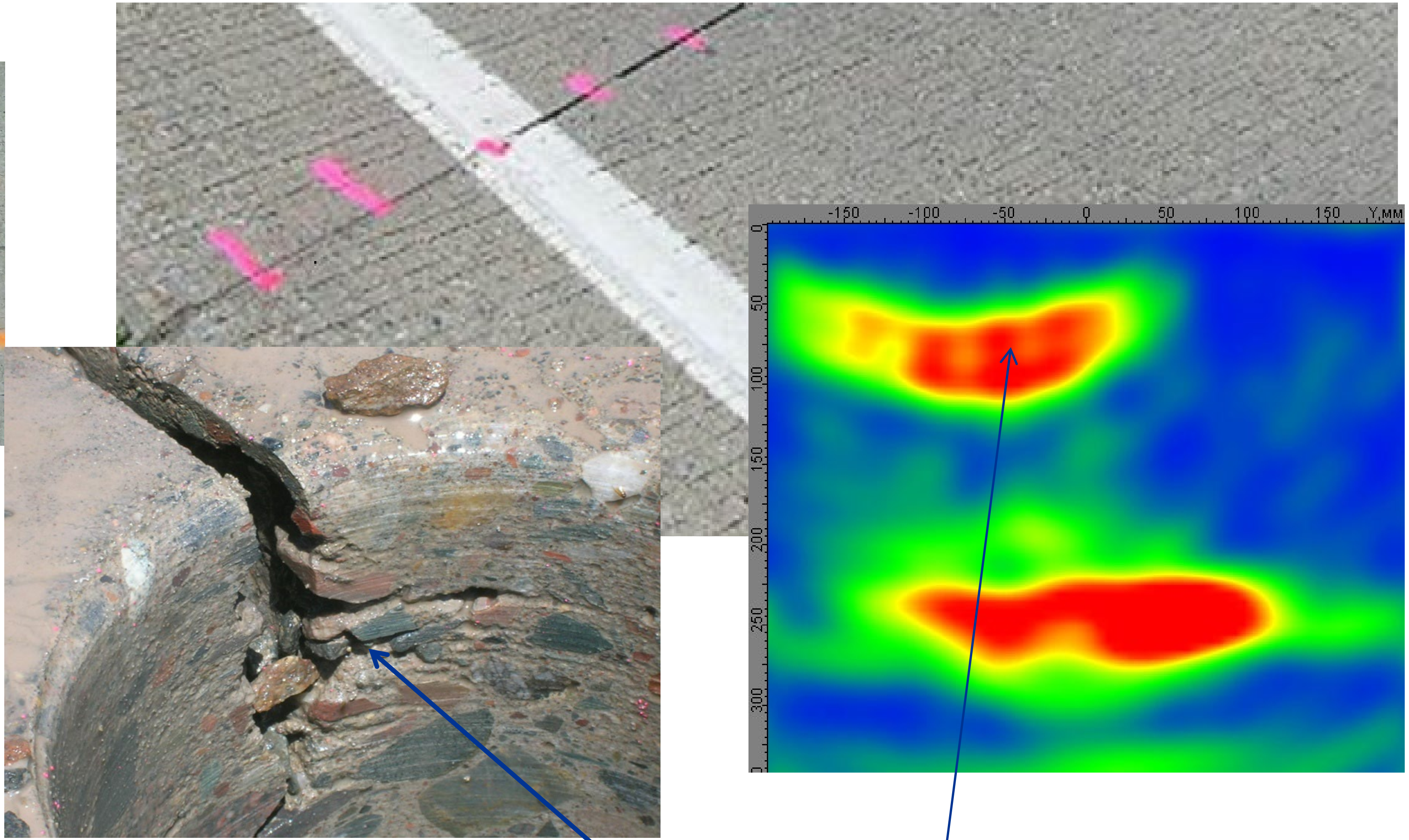
2. Use a repair material that is compatible with the existing material (PERM)

3. Ensure repair is bonded



Identify correct repair type: full or partial depth





damage

Performance Engineered Repair Mixture (PERM)

Traditional Repair » Material Compatible Repair

- Applied load » Elastic modulus, $E_{repair} = E_{existing}$
- Change in temperature » Thermal coefficient, $\alpha_{repair} = \alpha_{existing}$
- Drying shrinkage » ε_{repair} reduced

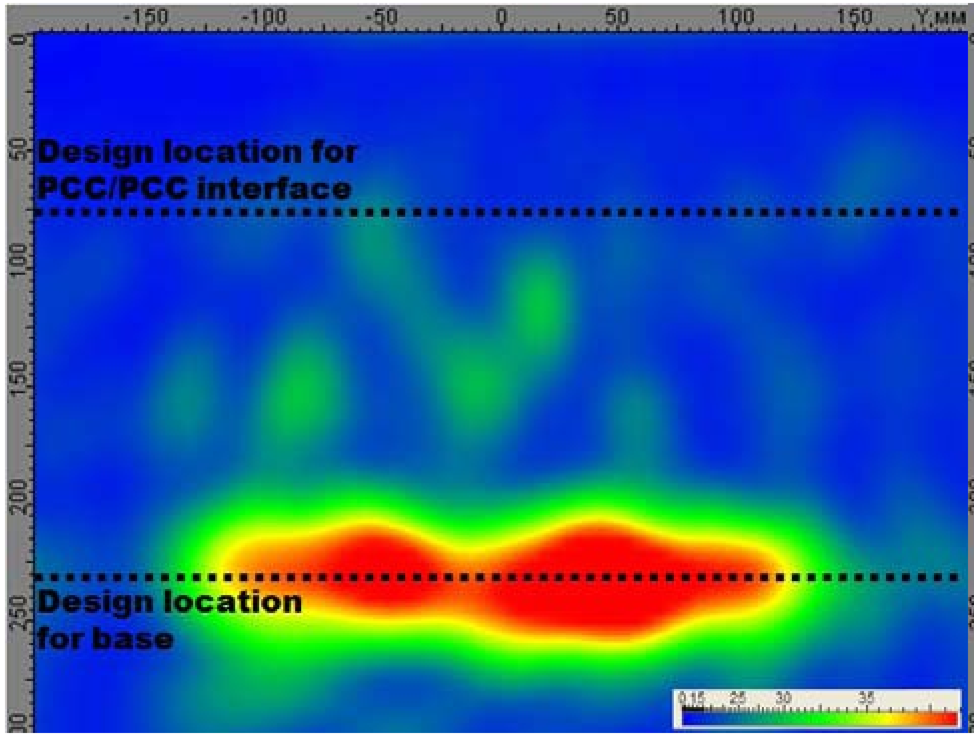
Performance Engineering Repair Mixture (PERM)

Two main steps toward developing a PERM:

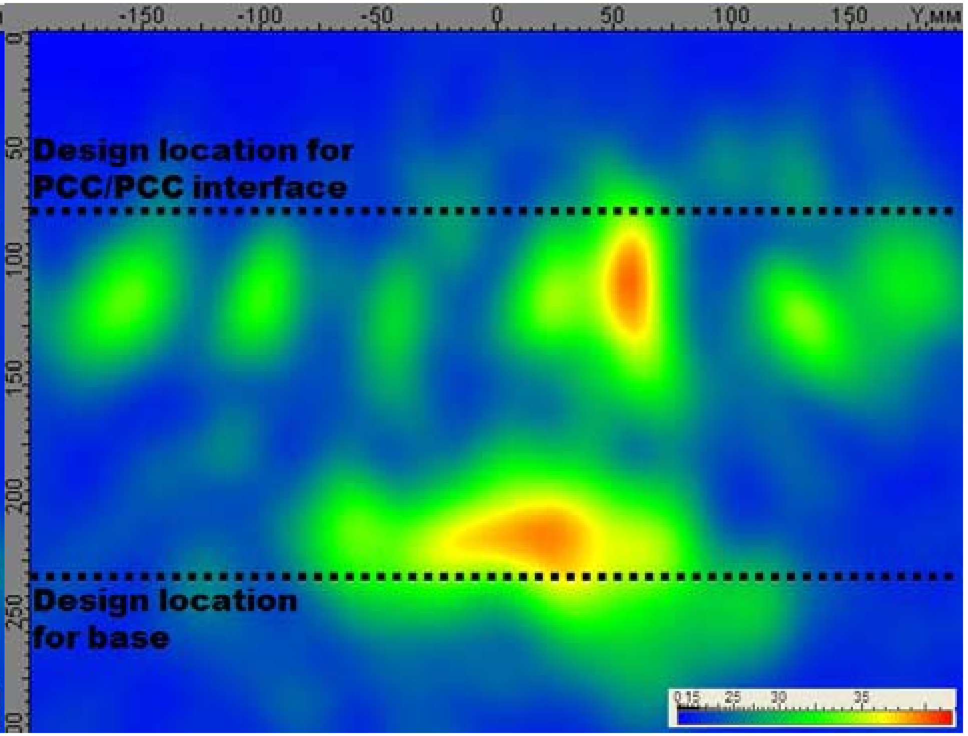
1. Identifying the CTE of the in-situ concrete;

2. Using appropriate materials and proportioning so:
   - ❑ CTE of the PERM and the in-situ concrete are comparable,
   - ❑ Drying shrinkage of the PERM is minimized (internal curing can be beneficial),
   - ❑ Strength and durability requirements are met.

Ensure bond between new and old concrete



Partial depth repair indicating full bond with old pavement.



Partial depth repair indicating debonding with old pavement.

MCR: Constructor - Chuck Niederriter

- Current methodology for repairing concrete is not providing long term results.
- Choice of material must be chosen job specific based on existing concrete composition.
- Requires each project to have proper analysis. One size does not fit all.
- Specifications will need to be updated.
- Materials may be more costly although not a severe impact to a project. Labor costs drive the cost.
- Implementation is easily within reach with proper training.

MCR: Designer – Dave Snively

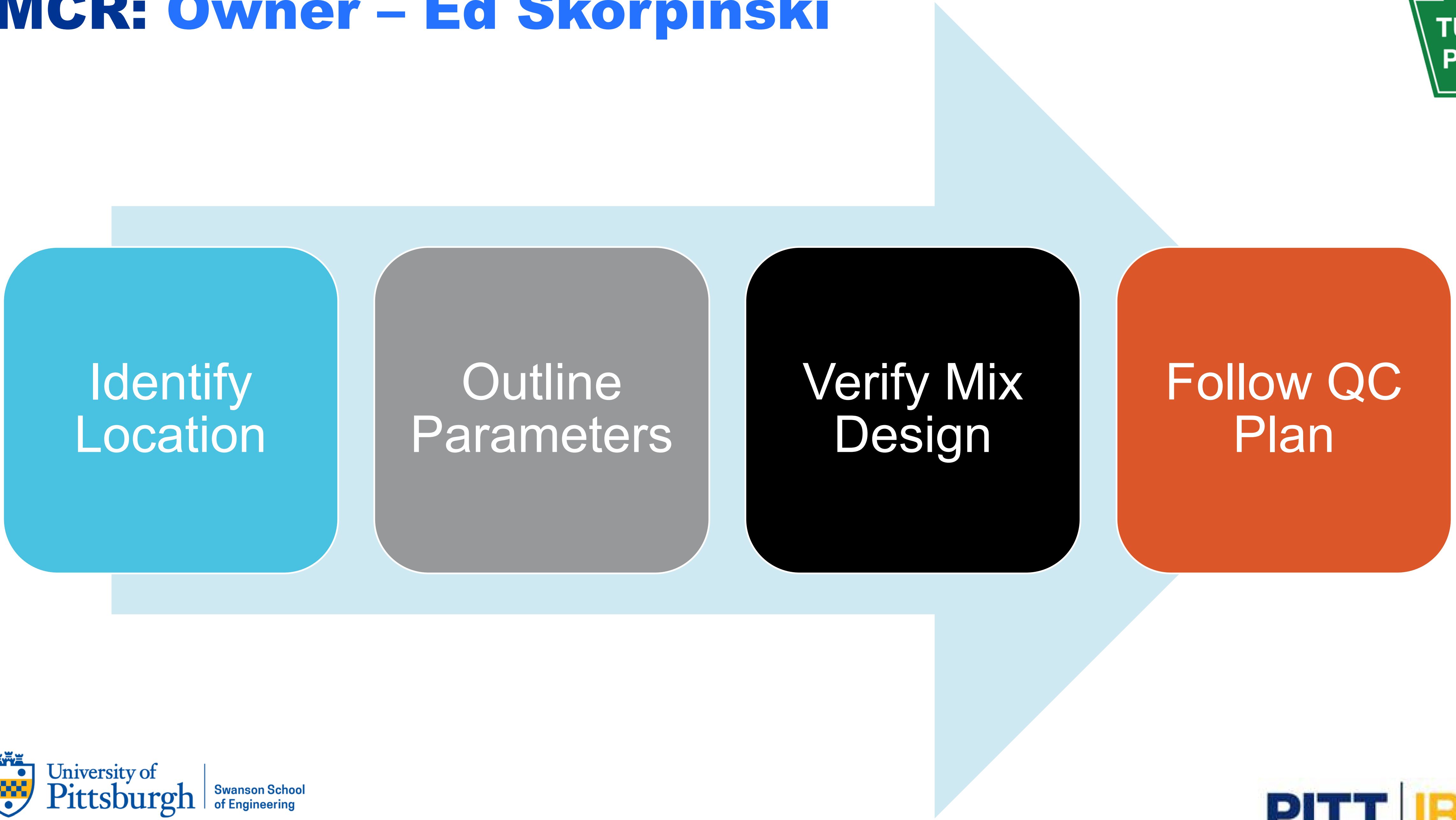
- Repairing concrete pavement defects, with concrete partial depth repairs is preferred to a bituminous repair. However, with limited-service life of the patch, sometimes 2-5 years before the patch fails, creates recurring maintenance issues. This is a cost issue for owners, but also a perception issue for the public, that highways are failing and unsafe with potholes.
- The new Material Compatible Repair (MCR) method can significantly reduce long-term maintenance costs, improve ride quality for motorists, reduce risk of tire blowouts and other vehicle damage from hitting large potholes, etc. These benefits far outweigh the initial repair costs increases over traditional methods.
- There is a significant inventory of concrete pavement, which most owners prefer to manage in "like-new" condition, meaning pothole free and with an acceptable ride quality. The MCR method has an opportunity to significantly enhance the operational performance of concrete pavements, making concrete a more desirable alternative for pavement selection.

MCR: Owner – Ed Skorpinski

Table 11. Summary of mixture requirements for developing PERM

Mix Parameter	Property	Specified test(s)	Acceptance
Cement	-	-	ASTM C150
Aggregate properties	Coarse aggregate	-	ASTM C33
	Fine aggregate	-	ASTM C136 / ASTM C778
	Lightweight aggregate	-	ASTM C330
Mixture design specifications	w/c	-	Pub 408-Section 704
	Cement factor	-	Pub 408-Section 704
	Coarse aggregate content	-	Pub 408-Section 704
Fresh concrete	Slump	ASTM C143	ASTM C928
	Air content	ASTM C231/ASTM C173	ASTM C928
	Setting time	ASTM C191	ASTM C928
	Mixing room condition	-	ASTM C511
Hardened concrete	Compressive strength	ASTM C39	Pub 408-Section 704/ASTM C928
	Flexural strength	ASTM C78	-
	Rapid chloride permeability	AASHTO T277	-
Bond strength	Slant shear	ASTM C882	ASTM C928
	Splitting tensile	ASTM C496	-
Compatibility	Coefficient of thermal expansion	AASHTO T 336	Material compatible repairs
	Internal curing	ASTM C1761	Material compatible repairs
	Shrinkage	ASTM C596	Material compatible repairs

MCR: Owner – Ed Skorpinski



MCR: Owner – Rachel's staff (D12)

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DEPARTMENT OF TRANSPORTATION

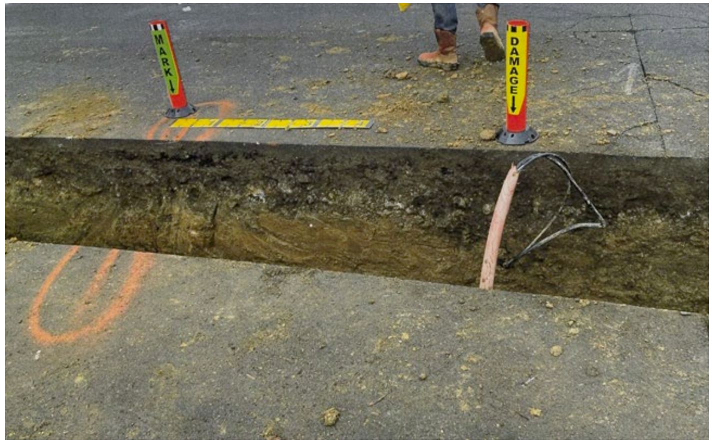
To do list:

Investigating New Underground Utility Location Technologies and Novel Methods to Improve Safety a Efficiency of Highway Construction

- PI: Dr. Lev Khazanovich
- Constructor: Chuck Niederriter
- Designer: MBI
- Owner: Jason Molinero

Technology: Investigating Underground Utility Location Technologies

- In many instances, the position of the utilities is unknown or incompatible with existing records.
- Current practices are highly dependent on tracer wires and pavement marks or use expensive vacuum trucks.
- Ground-penetrating radars have been shown to be a promising technology for non-destructive utility location, but old single-frequency systems did not provide sufficient resolution and required extensive data interpretation.



https://infrasense.com/gpr-scan-on-connecticut-interstate/

Results

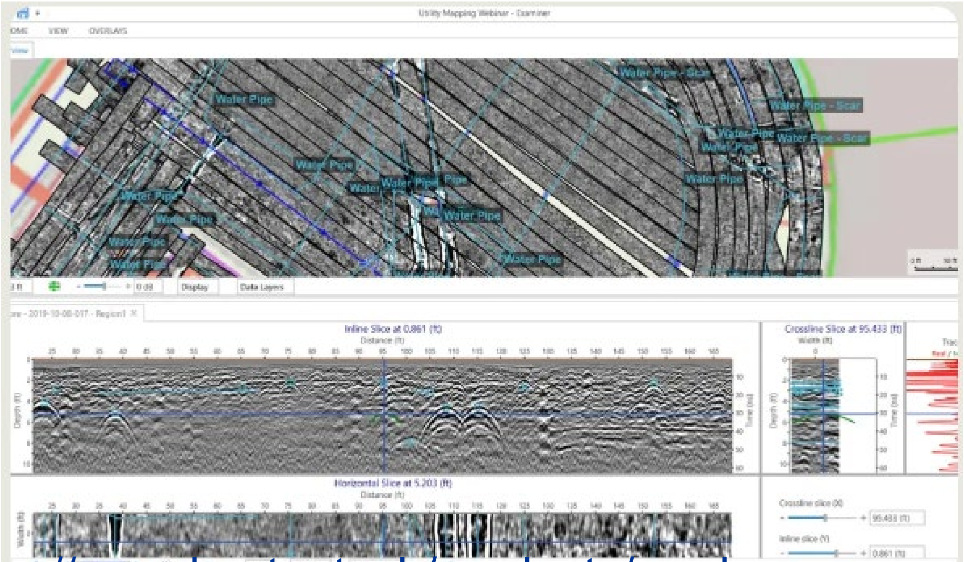
In the last several years, ground-penetrating radar (GPR) technology has improved dramatically in terms of data collection and data analysis. A wide range of systems are available on the market:

- Linear array systems (example: Kontour)
  - Pros: High resolution; High productivity; Compatible with BIM models.
  - Cons: High cost of the device; Data analysis requires significant expertise and is relatively time-consuming.
- Portable step frequency GPRs (example: Screening Eagle)
  - Pros: Relatively cheap, easy to operate.
  - Cons: Line-evaluation, resolution limitations.
- LDR Excavate: ground penetrating radar (GPR) integrated into the excavator’s digging bucket

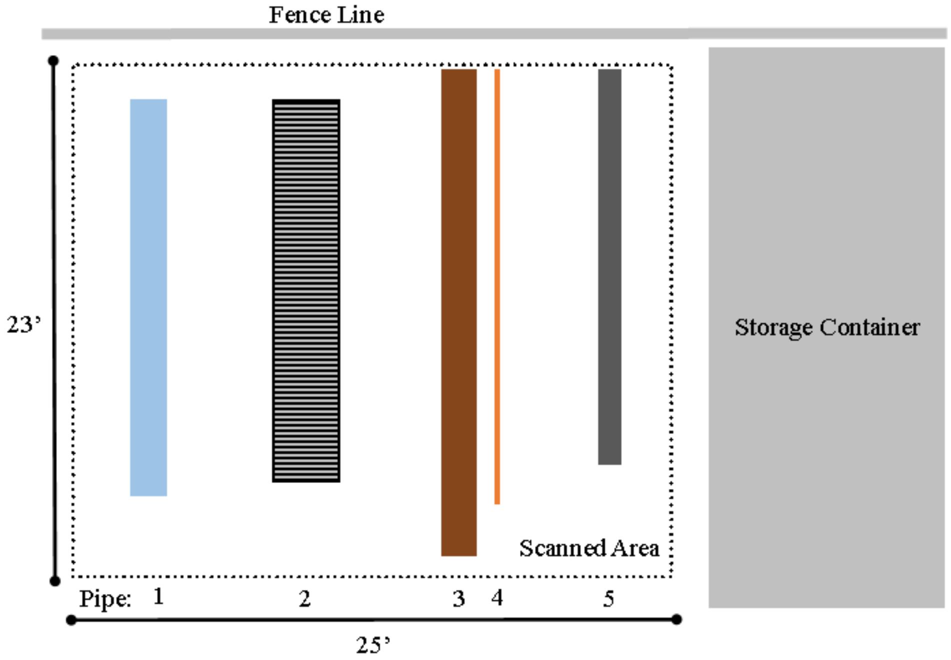
Recommendations

Underground utility location is a system problem. It is highly recommended:

- To conduct extensive screening of construction sites during the design stage.
  - Ensure high fidelity and compatibility with BIM models.
  - In addition to locating utilities, gather information on layer thicknesses and properties, condition of drainage, presence of voids, etc.
- To use portable GPR systems prior to excavation as a final check.
  - It is important to have a proper system and trained personnel.
  - Use a site with a controlled location of utilities for training and equipment testing.



https://www.kontur.tech/products/roads-pavements



Access to technology:

https://www.engineering.pitt.edu/contentassets/e9b3db3b2163488aaf2e4c50a2f6c640/undeground-utilities-final-report_mod.pdf

Utility location: Constructor - Chuck Niederriter

- Extremely pervasive, long term problem in the urban construction environment from both safety and cost perspective.
- Various technologies and tools are available. Many requiring advanced training to operate/analyze.
- Current success of available technology is “hit or miss”.
- Underground facilities vary in depth and composition causing the greatest challenge.
- New technology is needed beyond the scope of the study.

Underground investigation: Owner – Jason Molinero

Needs or Potential Challenges to Implementation

- Training and Workforce Development
- Procurement of devices for Design, Construction and Excavation
- Cost
- One Call – technicians seek and mark only the utility they are responsible for marking.
- Evolving technology – how to stay current on advancements or new technologies and devices that hit the market.

Underground investigation: Designer – MBI

Michael Baker
INTERNATIONAL

To do list: