Innovative Approaches for Monitoring Concrete Strength in Transportation Infrastructure

Presented at the 2026 APWA Illinois Chapter Conference

On November 5th, 2026

Presented By

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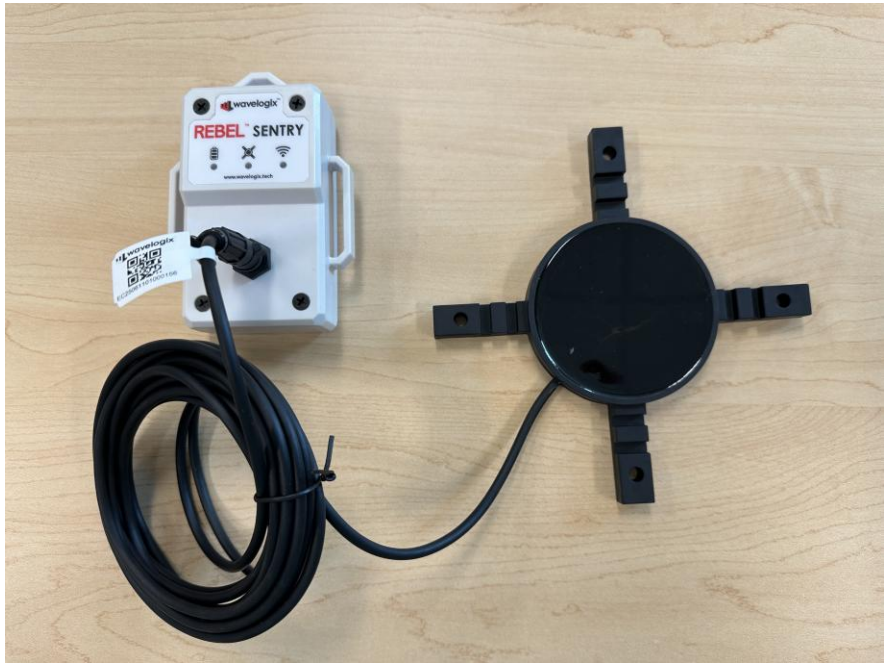
BRADLEY University

Acknowledgement

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    1. Charles Wienrank, TRP Chair
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2. Illinois Center for Transportation (ICT)
3. Bradley University's research assistants
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    2. Benjamin Poulos
4. Project Co-PI Dr. Matthew Soltani, Associate Professor, Department of Civil Engineering and Construction
5. Wavelogix for technical support

REBEL Sensor:

Piezoelectric and Resonance-Based Sensor



REBEL sensor connected to a data logger ($200 pc)



Data logger and charger



Cylinder with sensor: $250 pc

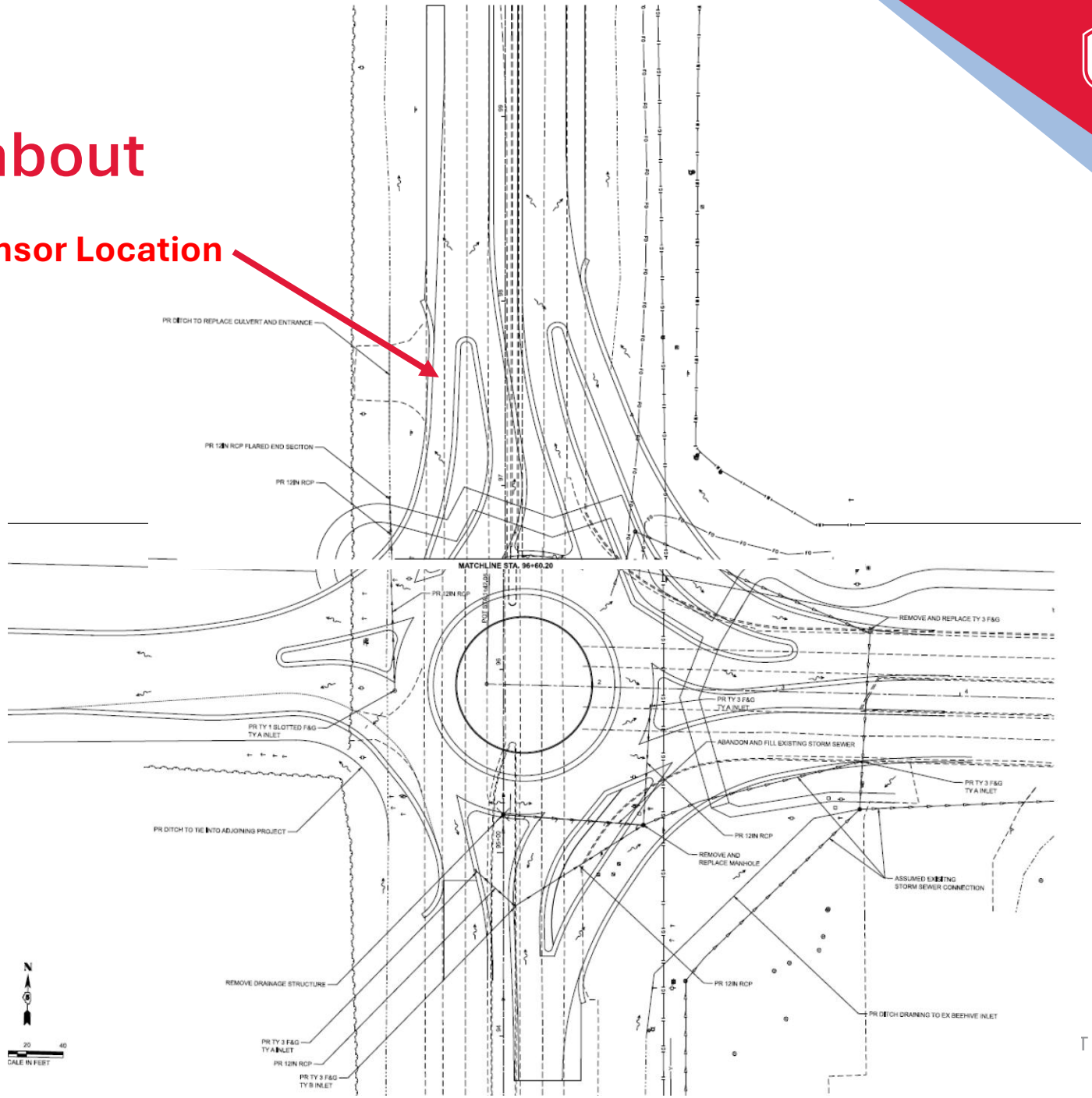
Six Construction Projects

1. Rivian Motorway Roundabout: New Pavement, District 5 (Project 1)
2. I-74 and I-57 Interchange Bridge: New Bridge Deck, District 5 (Project 2)
3. I-74 and Spoon River: New Bridge Deck, District 4 (Project 3)
4. I-74 in Carlock: Concrete Patch, District 5 (Project 4)
5. I-39 in Paw Paw: Concrete Patch, District 2 (Project 5)
6. N. University Road: New Pavement, District 4 (Project 6)

Rivian Motorway Roundabout



Sensor Location



Rivian Motorway Roundabout

1. Concrete was poured on 11/24/2025
2. 3 sensors were deployed inside the pavement
3. 2, 6-by-12 cylinders with sensors were cast
    A. 1 cylinder was cast to half-depth, and another was cast to full-depth
4. 1, 6-by-6-by-21 beam with a sensor was cast
5. 10, 6-by-12 cylinders were cast for laboratory compression tests
    A. 1-day, 3-day, 7-day, 14-day, and 28-day tests was performed
6. 1, 6-by-6-by-21 beam was cast for laboratory flexural test

Rivian Motorway Roundabout

Concrete Mix Design Summary

Ingredient/Characteristic	Value	Unit	Notes
Cement	475	lb/cy	Type IL
Water	32	gal/cy	
Coarse Aggregate	1,742	lb/cy	
Fine Aggregate	1,200	lb/cy	
Fly Ash	160	lb/cy	
Slump	4	in.	
Air Content	6.1%		
Target w/c Ratio	0.42		
Certification Strength	3,500	psi	At 14 days (336 hr)

Rivian Motorway Roundabout







Rivian Motorway Roundabout







Rivian Motorway Roundabout

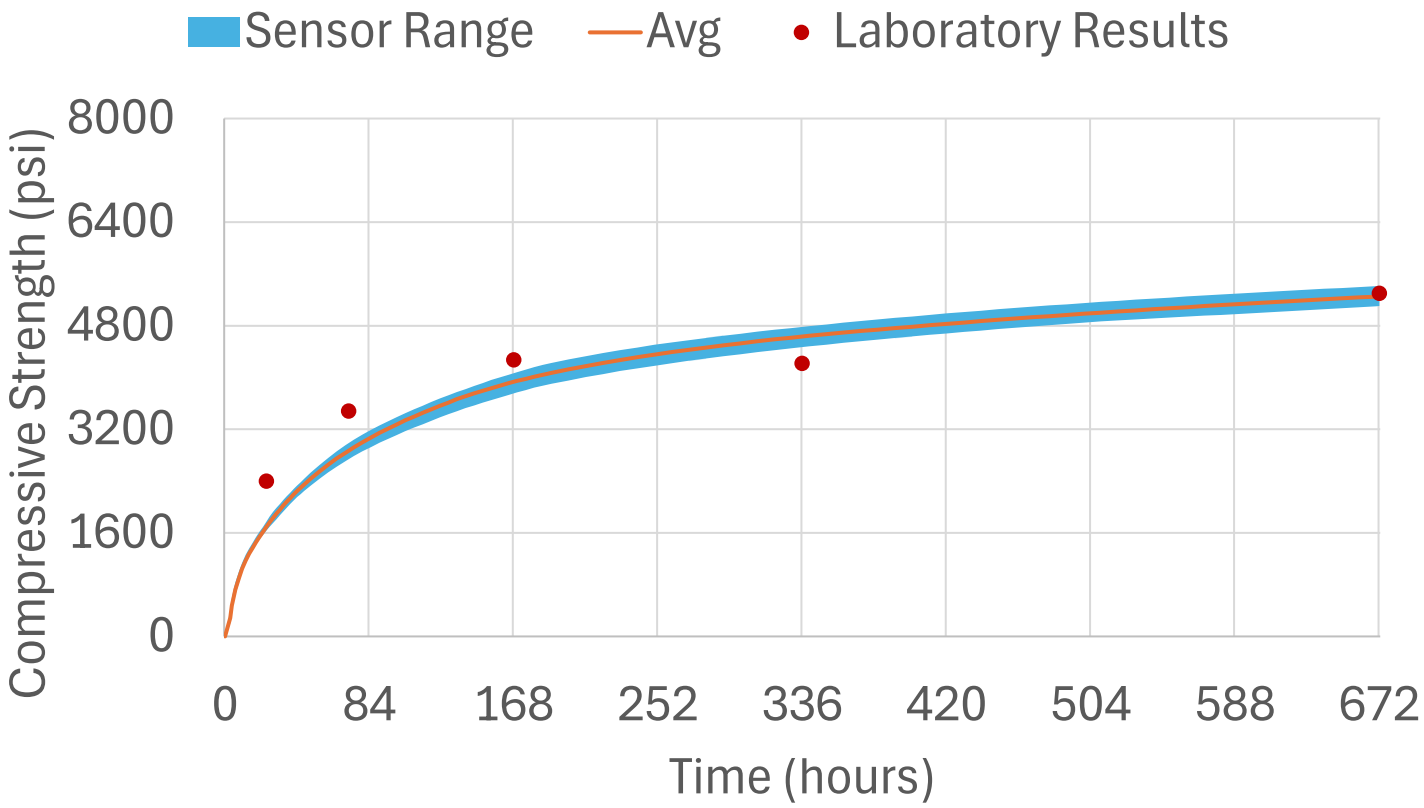
Compressive Strength in psi

Age (hr)	LT 1	LT 2	LT Avg	Embed Sensor 1	Embed Sensor 2	Embed Sensor 3	Cylinder Full Cast	Cylinder Half Cast	Beam Sensor
24	2359	2437	2398	1766	1640	1655	1770	1680	1633
72	3513	3451	3482	2856	2867	2872	2984	2879	2735
168	4327	4224	4276	3888	3987	4073	3967	3914	3763
336	4259	4179	4219	4649	4738	4764	4626	4607	4471
672	4828	5778	5303	5272	5342	5418	5269	5110	5132

Flexural Strength in psi

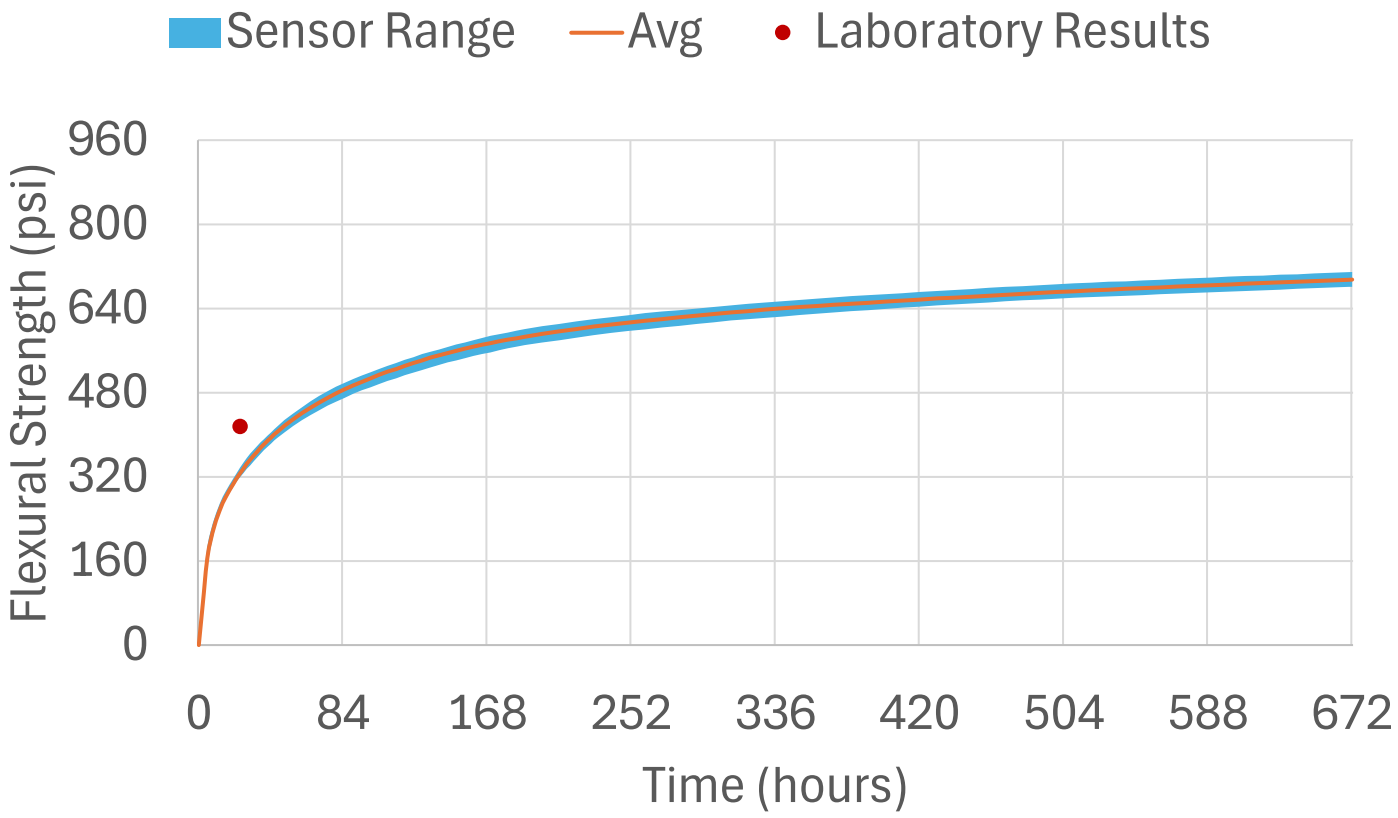
Age (hr)	LT	Embed Sensor 1	Embed Sensor 2	Embed Sensor 3	Cylinder Full Cast	Cylinder Half Cast	Beam Sensor
24	416	336	320	322	337	325	319

Rivian Motorway Roundabout





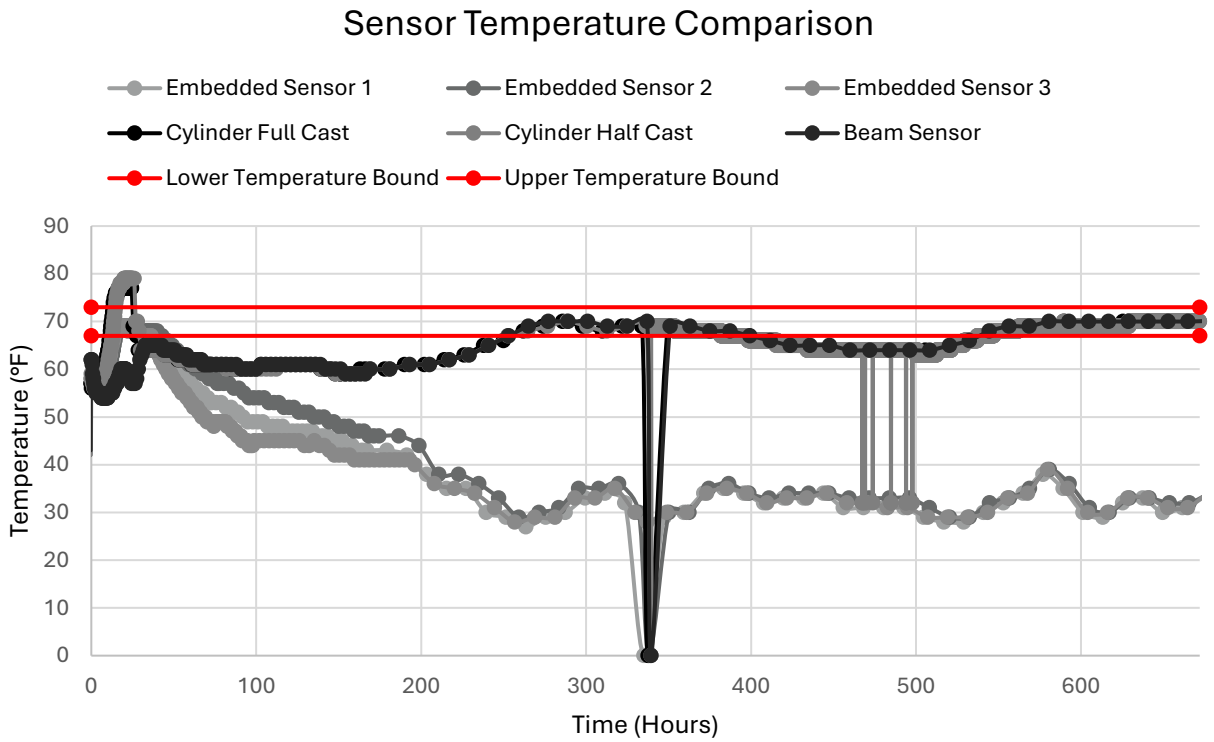
Rivian Motorway Roundabout

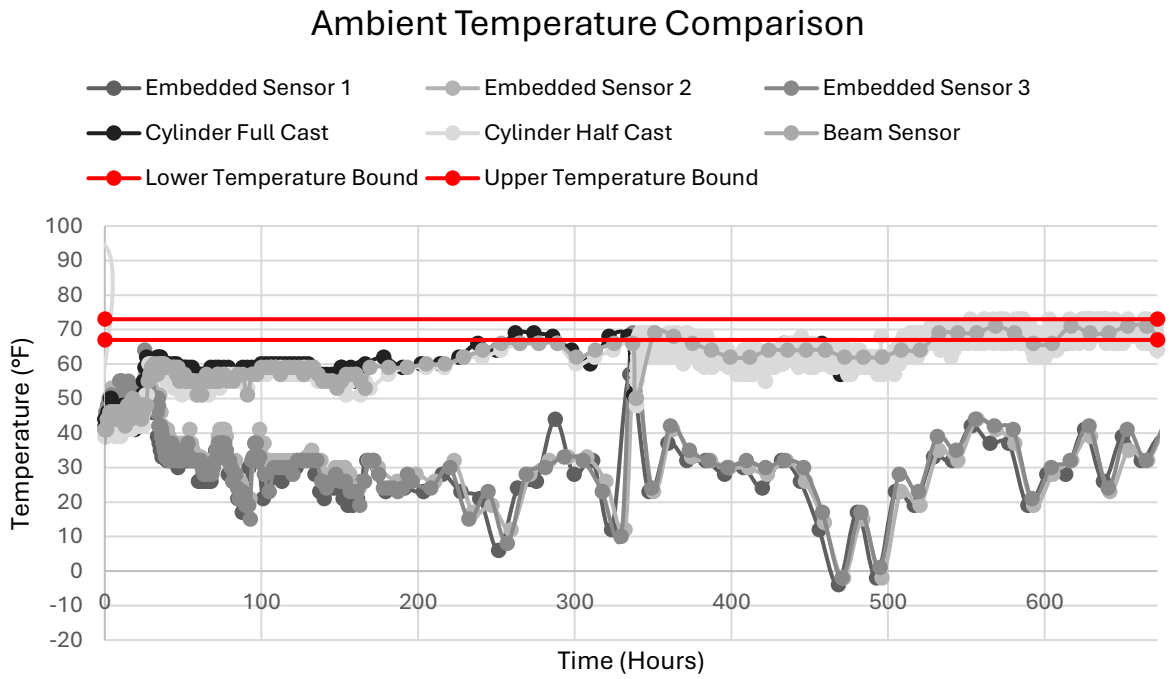




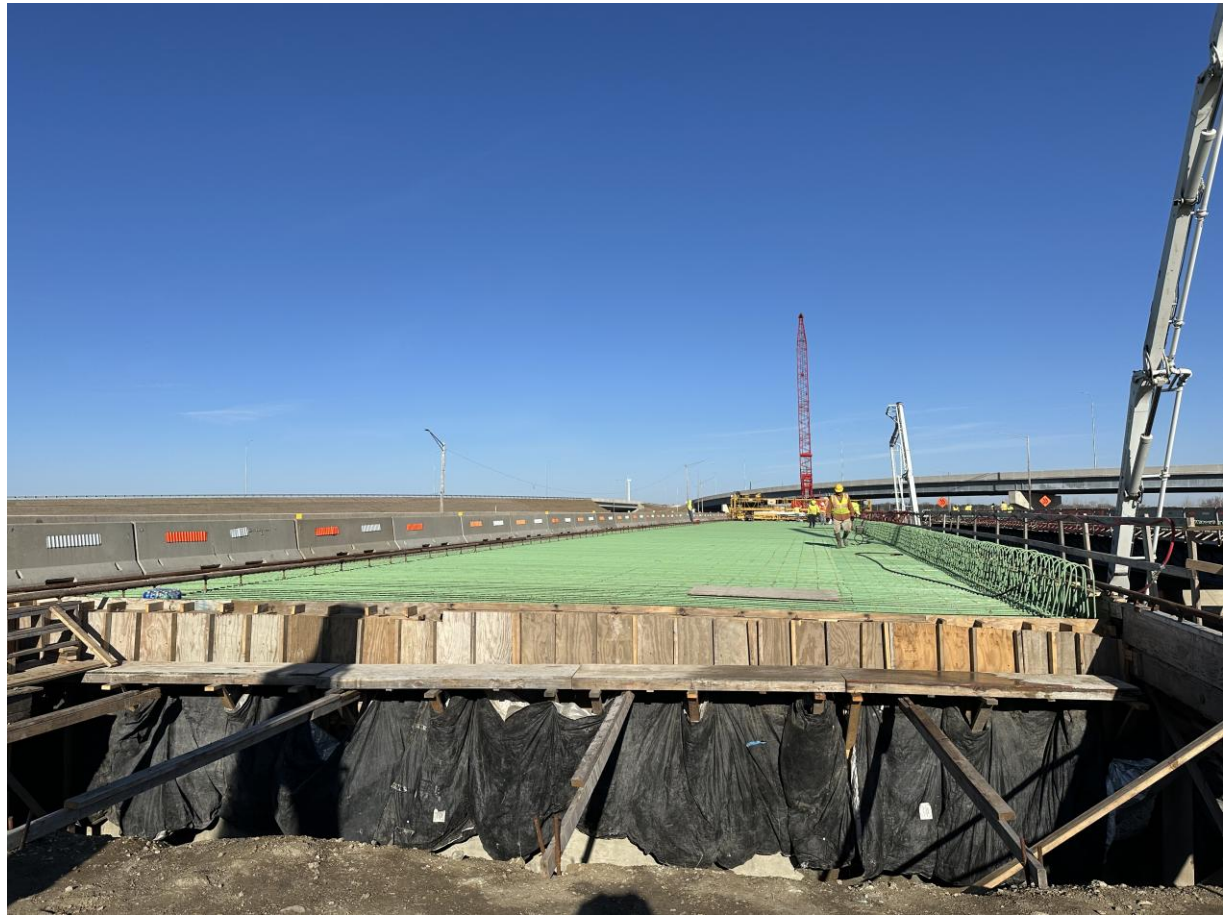


Rivian Motorway Roundabout





I-74 and I-57 Interchange (Eastbound I-74 Bridge)





I-74 and I-57 Interchange (Eastbound I-74 Bridge)

1. Concrete was poured on 2/27/2026
2. 3 sensors were deployed inside the bridge deck
3. 2, 6-by-12 cylinders with sensors were cast
    A. 1 cylinder was cast to half-depth, and another was cast to full-depth
4. 10, 6-by-12 cylinders were cast for laboratory compression tests
    A. 1-day, 3-day, 7-day, 14-day, and 28-day tests will be performed
5. 2, 6-by-6-by-21 beams were cast for laboratory flexural test

I-74 and I-57 Interchange (Eastbound I-74 Bridge)

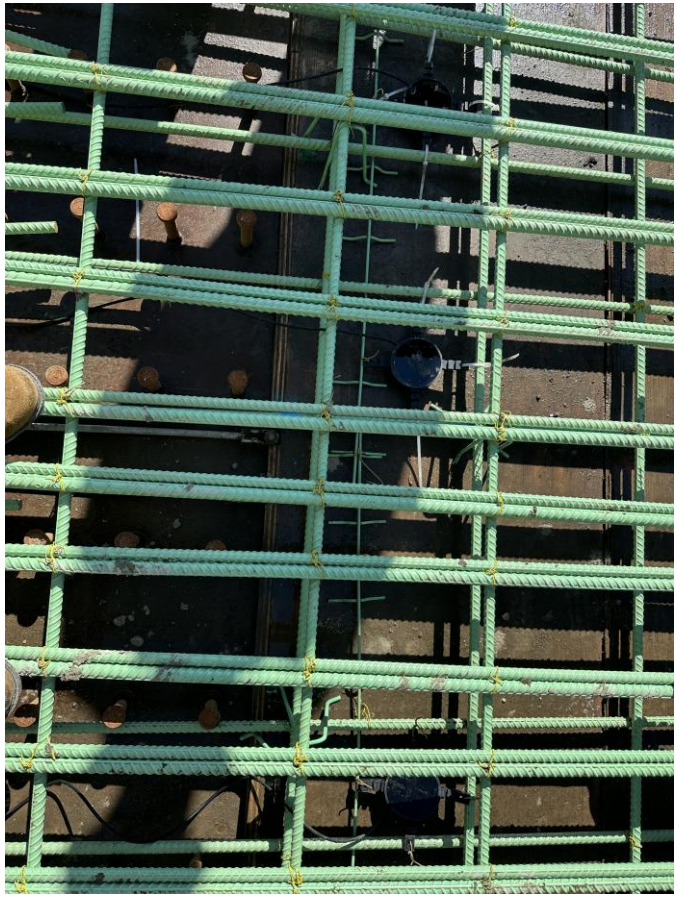
Mix Design Summary

Ingredient/Characteristic	Value	Unit	Notes
Cement	463.3	lb/cy	Type IL
Water	30.2	gal/cy	
Coarse Aggregate	1,422.2	lb/cy	CA-16
Fine Aggregate	1,233.3	lb/cy	FA-01
Slag	154.4	lb/cy	
Air Entrainer	2.8	oz/cy	
Water Reducer	28.3	oz/cy	High-Range
Retarder	24.4	oz/cy	
Slump	5	in.	
Air Content	6.7%		
Target w/c Ratio	0.4		
Certification Strength	4,000	psi	At 14 days (336 hr)

I-74 and I-57 Interchange (Eastbound I-74 Bridge)







I-74 and I-57 Interchange (Eastbound I-74 Bridge)









I-74 and I-57 Interchange (Eastbound I-74 Bridge)

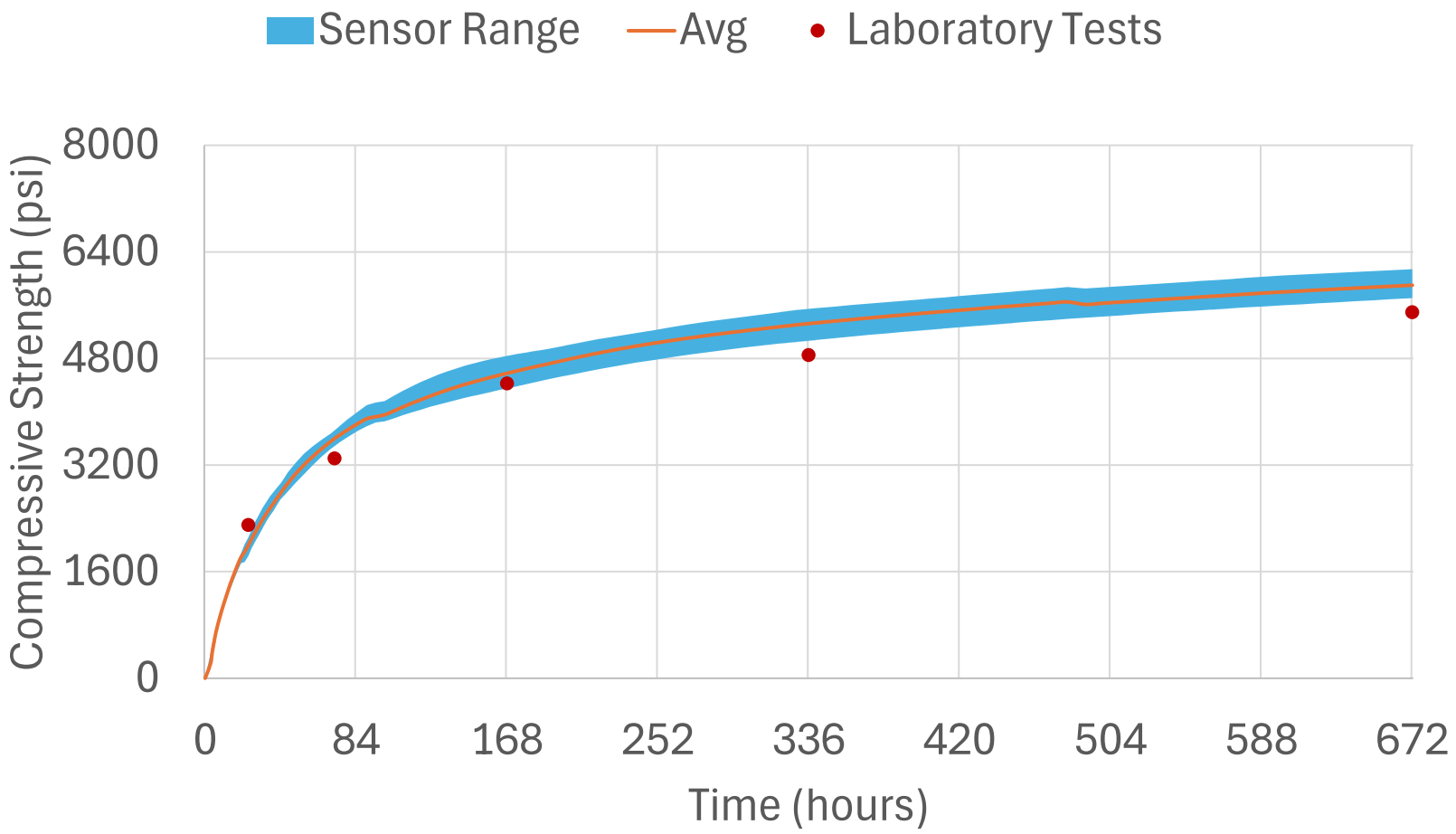
Compressive Strength in psi

Age (hr)	LT 1	LT 2	LT Avg	Embed Sensor 1	Embed Sensor 2	Embed Sensor 3	Cylinder Full Cast	Cylinder Half Cast
24	2311	2289	2300	2131	2070	1856	1967	2000
72	3174	3425	3300	3728	3711	3592	3501	3513
168	4219	4635	4427	4854	4440	4347	4647	4590
336	5095	4606	4851	5516	5153	5096	5386	5540
672	5184	5808	5496	6141	5755	5713	6014	-

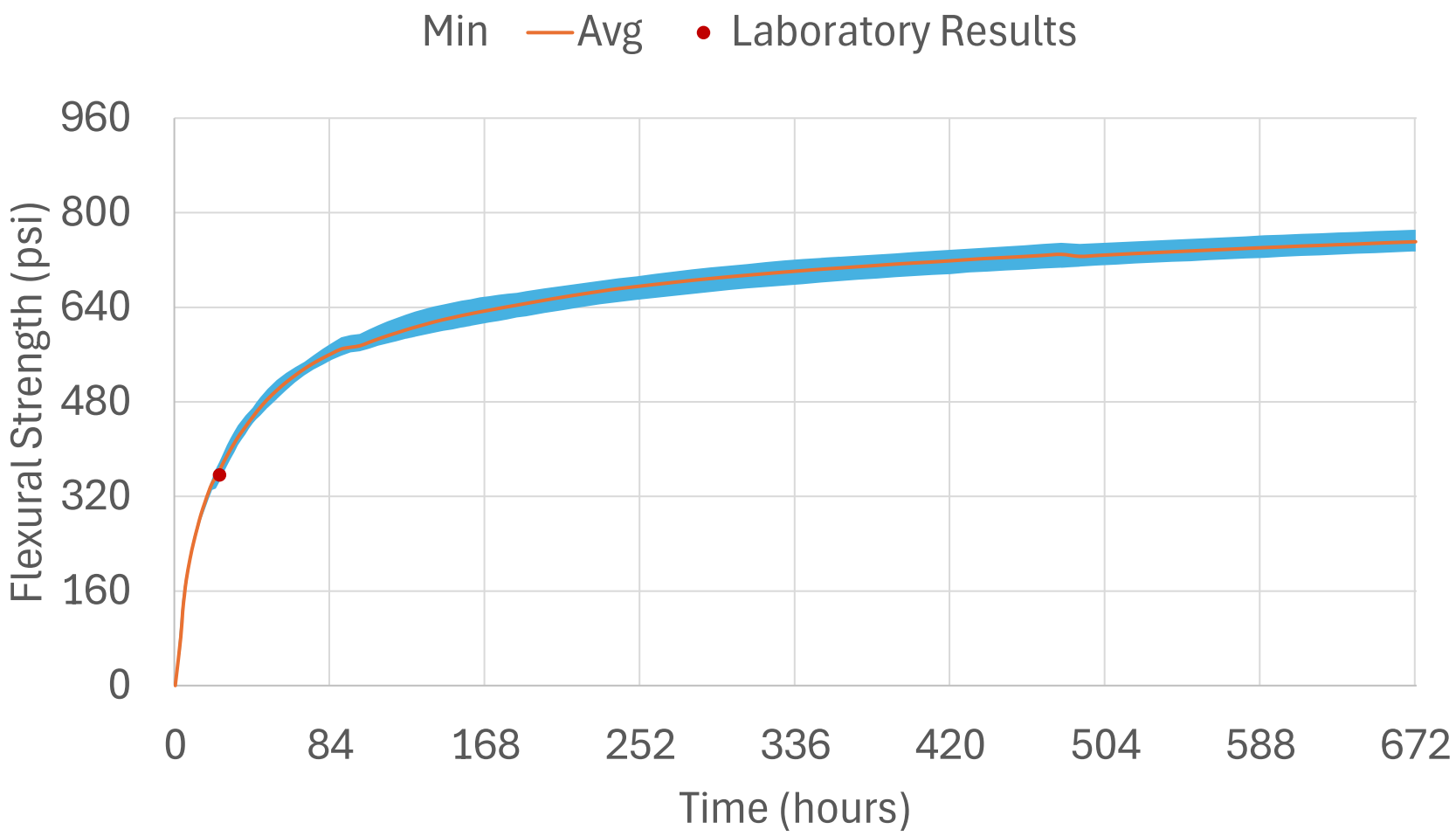
Flexural Strength in psi

Age (hr)	LT 1	LT 2	LT Avg	Embed Sensor 1	Embed Sensor 2	Embed Sensor 3	Cylinder Full Cast	Cylinder Half Cast
24	389	324	357	381	374	347	361	365

I-74 and I-57 Interchange (Eastbound I-74 Bridge)

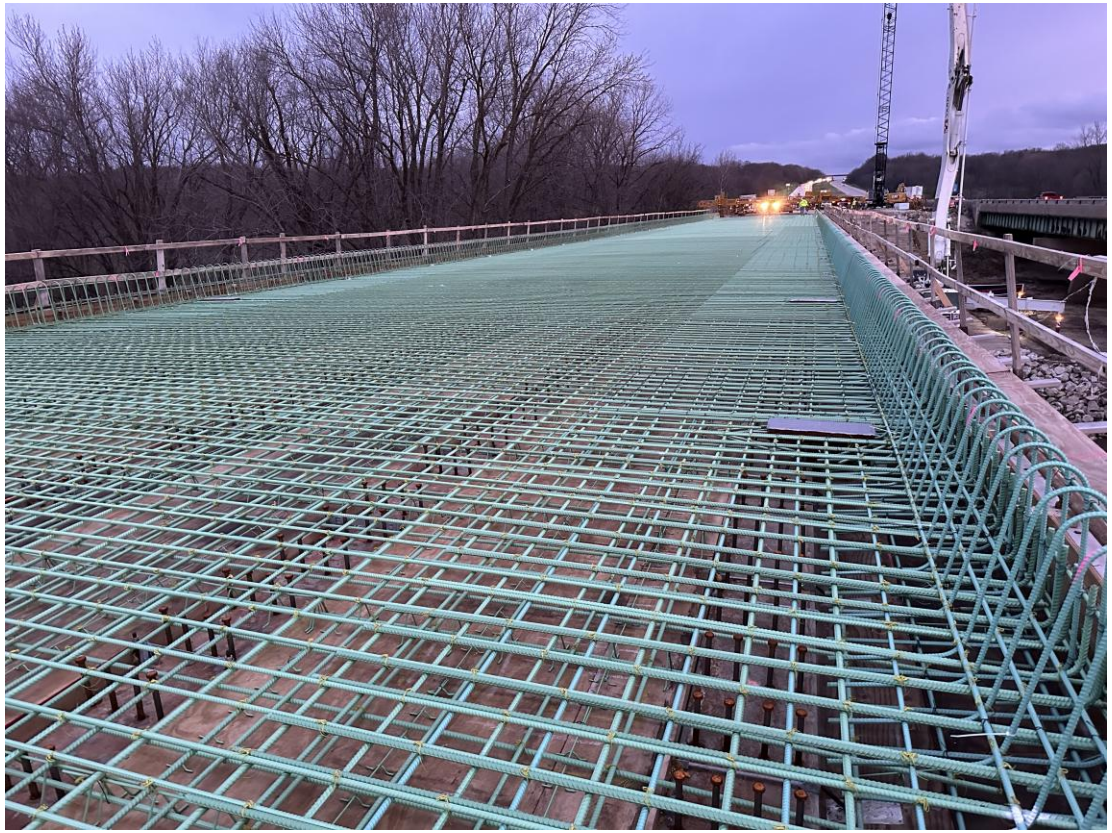


I-74 and I-57 Interchange (Eastbound I-74 Bridge)



I-74 and Spoon River (Eastbound Bridge Deck)





I-74 and Spoon River (Eastbound Bridge Deck)

1. Concrete was poured on 4/7/2026
2. 3 sensors were deployed inside the bridge deck
3. 2, 6-by-12 cylinders with sensors were cast
    A. 1 cylinder was cast to half-depth, and another was cast to full-depth
4. 15, 4-by-8 cylinders were cast for laboratory compression tests
    A. 1-day, 3-day, 7-day, 14-day, and 28-day tests will be performed
5. 2, 6-by-6-by-21 beams were cast for laboratory flexural test

I-74 and Spoon River (Eastbound Bridge Deck)

Ingredient/Characteristic	Value	Unit	Notes
Cement	490	lb/cy	Type IL
Water	30.3	gal/cy	
Coarse Aggregate	1,328	lb/cy	CA-111
Coarse Aggregate	493	lb/cy	CA-161
Fine Aggregate	1,245	lb/cy	FA-01
Fly Ash	125	lb/cy	Class C
Air Entrainer	0.85	oz/cy	DRAVAIR140
Water Reducer	4.5	oz/cy	Mid-range; MIRA 95
Slump	5.5	in.	
Air Content	6.1%		
Target w/c Ratio	0.41		
Certification Strength	4,000	psi	14 days (336 hr)

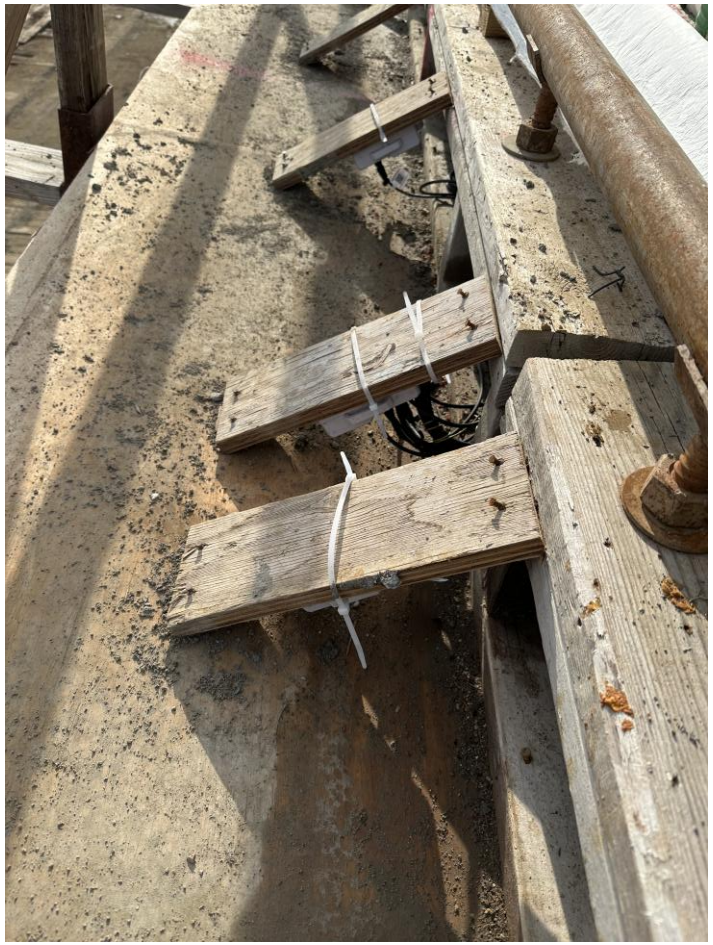
I-74 and Spoon River (Eastbound Bridge Deck)







I-74 and Spoon River (Eastbound Bridge Deck)







I-74 and Spoon River (East Bound Bridge Deck)

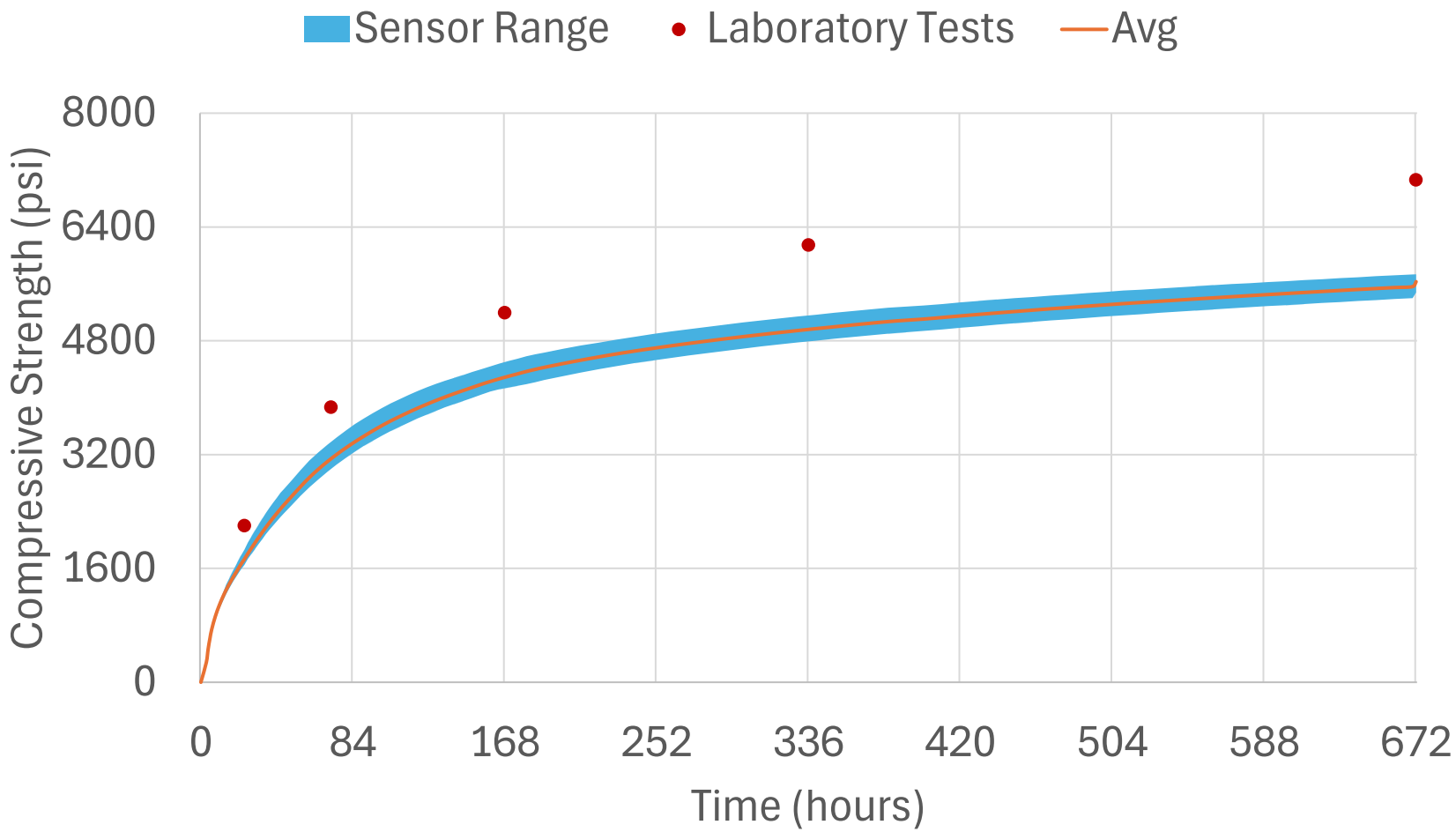
Compressive Strength in psi

Age (hr)	LT 1	LT 2	LT 3	LT Avg	Embed Sensor 1	Embed Sensor 2	Embed Sensor 3	Cylinder Full Cast	Cylinder Half Cast
24	2139	2191	2282	2204	1705	1871	1754	1672	1701
72	3866	3746	4002	3871	3043	3382	3264	3070	3062
168	5072	5451	5069	5198	4170	4511	4432	4137	4231
336	6194	6012	6247	6151	5158	5158	5092	4792	4910
672	7121	7132	6943	7065	5500	5736	5681	5402	5523

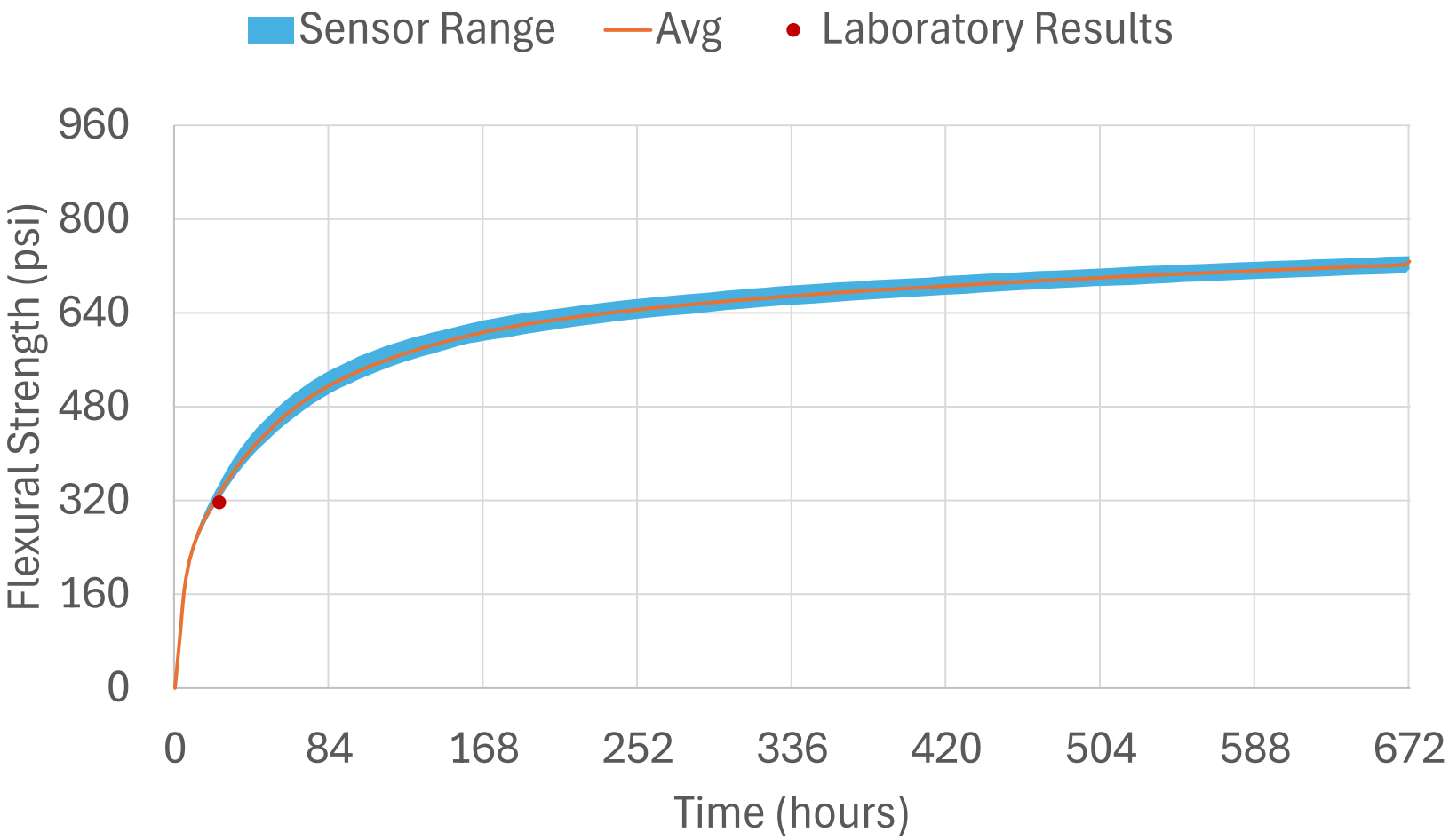
Flexural Strength in psi

Age (hr)	LT 1	LT 2	LT Avg	Embed Sensor 1	Embed Sensor 2	Embed Sensor 3	Cylinder Full Cast	Cylinder Half Cast
24	349	285	317	328	349	335	324	328

I-74 and Spoon River (Eastbound Bridge Deck)



I-74 and Spoon River (Eastbound Bridge Deck)



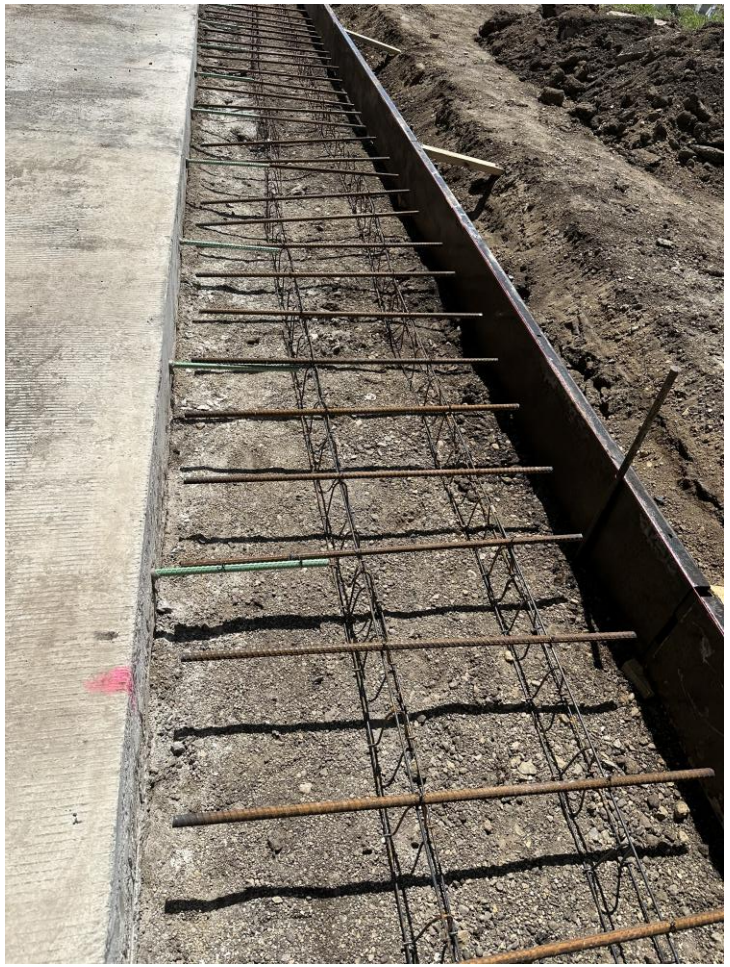
I-74 and Carlock (Westbound Shoulder Patch under E1800 Bridge)

1. Concrete was poured on 5/4/2026
2. 3 sensors were deployed inside the concrete patch
3. 2, 6-by-12 cylinders with sensors were cast
    A. 1 cylinder was cast to half-depth, and another was cast to full-depth
4. 15, 4-by-8 cylinders were cast for laboratory compression tests
    A. 1-day, 3-day, 7-day, 14-day, and 28-day tests will be performed
5. 2, 6-by-6-by-21 beams were cast for laboratory flexural test

I-74 and Carlock (Westbound Shoulder Patch under E1800 Bridge)

Ingredient/Characteristic	Value	Unit	Notes
Cement	535	lb/cy	Type IL
Water	32.6	gal/cy	
Coarse Aggregate	1,791	lb/cy	
Fine Aggregate	1,121	lb/cy	
Fly Ash	180	lb/cy	
Air Entrainer	0.85	oz/cy	DRAVAIR140
Water Reducer	225	oz/cy	Low-range; ZYLA360
Water Reducer	153	oz/cy	High-Range; Superplasticizer
Slump	4	in.	
Air Content	5.5%		
Target w/c Ratio	0.33		
Certification Strength	3,200	psi	2 days (48 hr)

I-74 and Carlock (Westbound Shoulder Patch under E1800 Bridge)

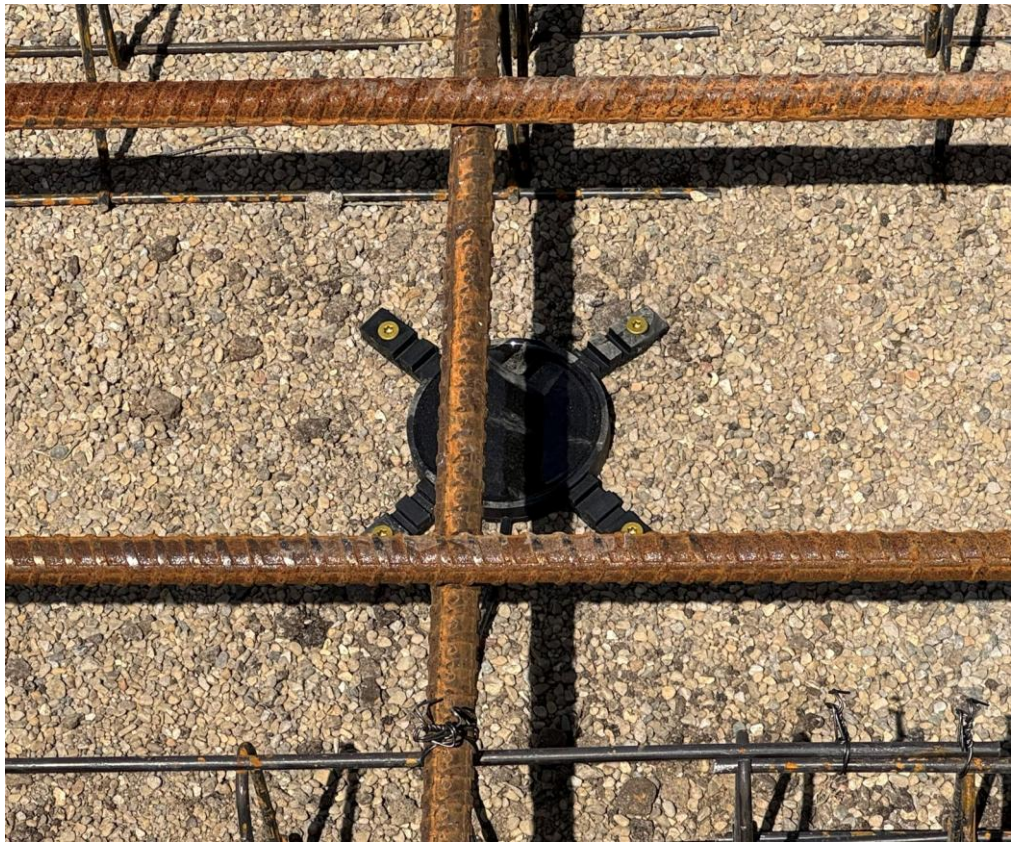






I-74 and Carlock (Westbound Shoulder Patch under E1800 Bridge)





I-74 and Carlock (Westbound Shoulder Patch under E1800 Bridge)







I-74 and Carlock (Westbound Shoulder Patch under E1800 Bridge)

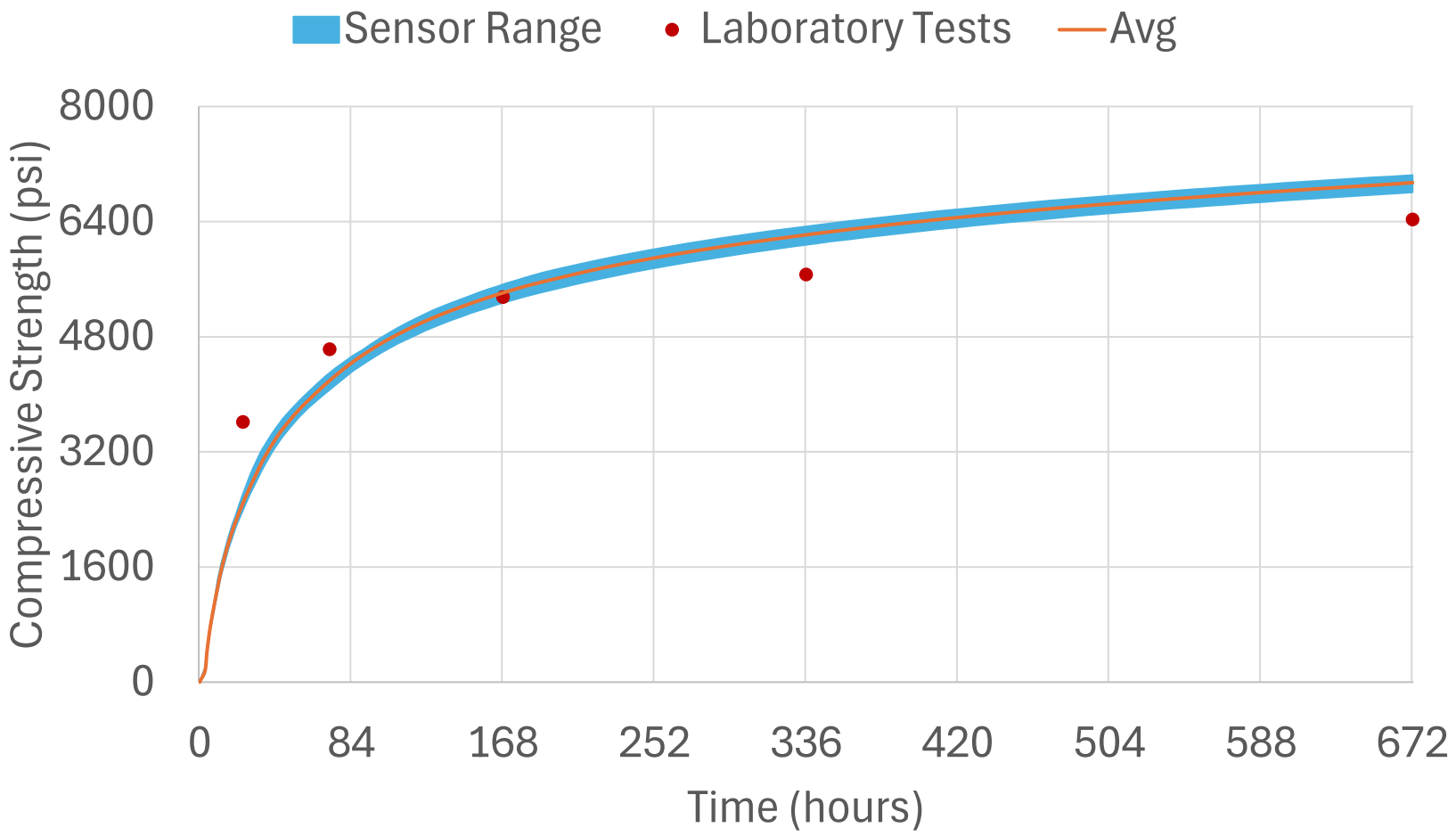
Compressive Strength in psi

Age (hr)	LT 1	LT 2	LT 3	LT Avg	Embed Sensor 1	Embed Sensor 2	Embed Sensor 3	Cylinder Full Cast	Cylinder Half Cast
24	3596	3591	3669	3619	2628	2390	2410	2565	2482
72	4549	4970	4359	4626	4314	4068	4101	4261	4267
168	5456	5242	5364	5354	5401	5285	5366	5510	5532
336	5155	6181	5668	5668	6199	6084	6213	6306	6361
672	5997	6696	6604	6432	6910	6810	6898	7020	7056

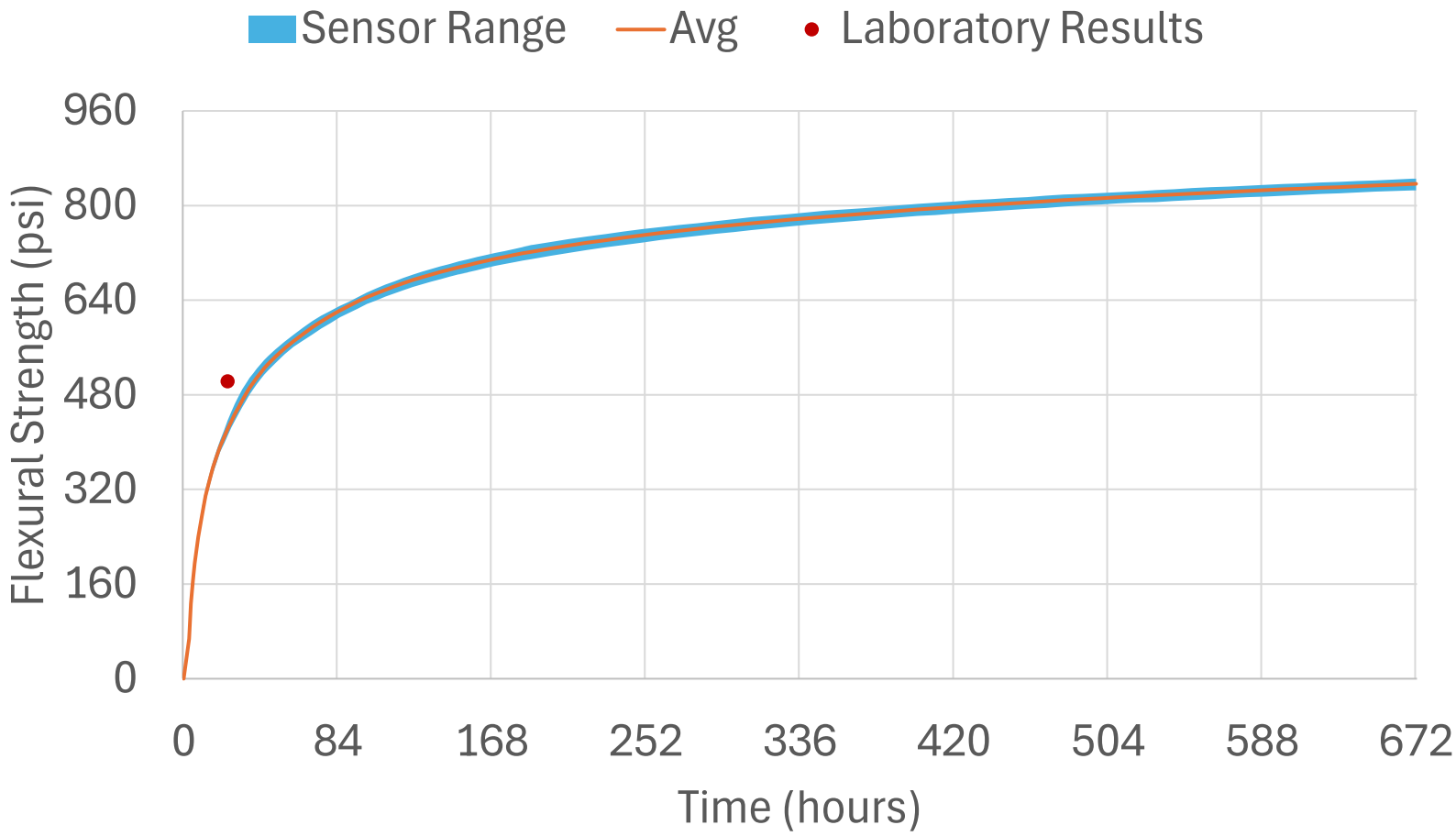
Flexural Strength in psi

Age (hr)	LT 1	LT 2	LT Avg	Embed Sensor 1	Embed Sensor 2	Embed Sensor 3	Cylinder Full Cast	Cylinder Half Cast
24	500	506	503	438	411	413	431	422

I-74 and Carlock (Westbound Shoulder Patch under E1800 Bridge)



I-74 and Carlock (Westbound Shoulder Patch under E1800 Bridge)



I-39 and Paw Paw (Northbound Willow Creek Rest Area

1. Concrete was poured on 5/14/2026
2. 3 sensors were deployed inside the concrete patch
3. 2, 6-by-12 cylinders with sensors were cast
    A. 1 cylinder was cast to half-depth, and another was cast to full-depth
4. 15, 4-by-8 cylinders were cast for laboratory compression tests
    A. 1-day, 3-day, 7-day, 14-day, and 28-day tests will be performed
5. 2, 6-by-6-by-21 beam was cast for laboratory flexural test

I-39 and Paw Paw (Northbound Willow Creek Rest Area

Ingredient/Characteristic	Value	Unit	Notes
Cement	625	lb/cy	Type IL
Water	31	gal/cy	
Coarse Aggregate	1,782	lb/cy	CM11 R-T
Fine Aggregate	1,116	lb/cy	FM02 F-S
Slag	110	lb/cy	
Air Entrainer	0.6	oz/cwt	
Water Reducer	5	oz/cwt	High-range
Retarder	1	oz/cwt	SikaTard 10
Slump	4	in.	
Air Content	6%		
Target w/c Ratio	0.352		
Certification Strength	3,200	psi	2 days (48 hr)

I-39 and Paw Paw (Northbound Willow Creek Rest Area







I-39 and Paw Paw (Northbound Willow Creek Rest Area







I-39 and Paw Paw (Northbound Willow Creek Rest Area

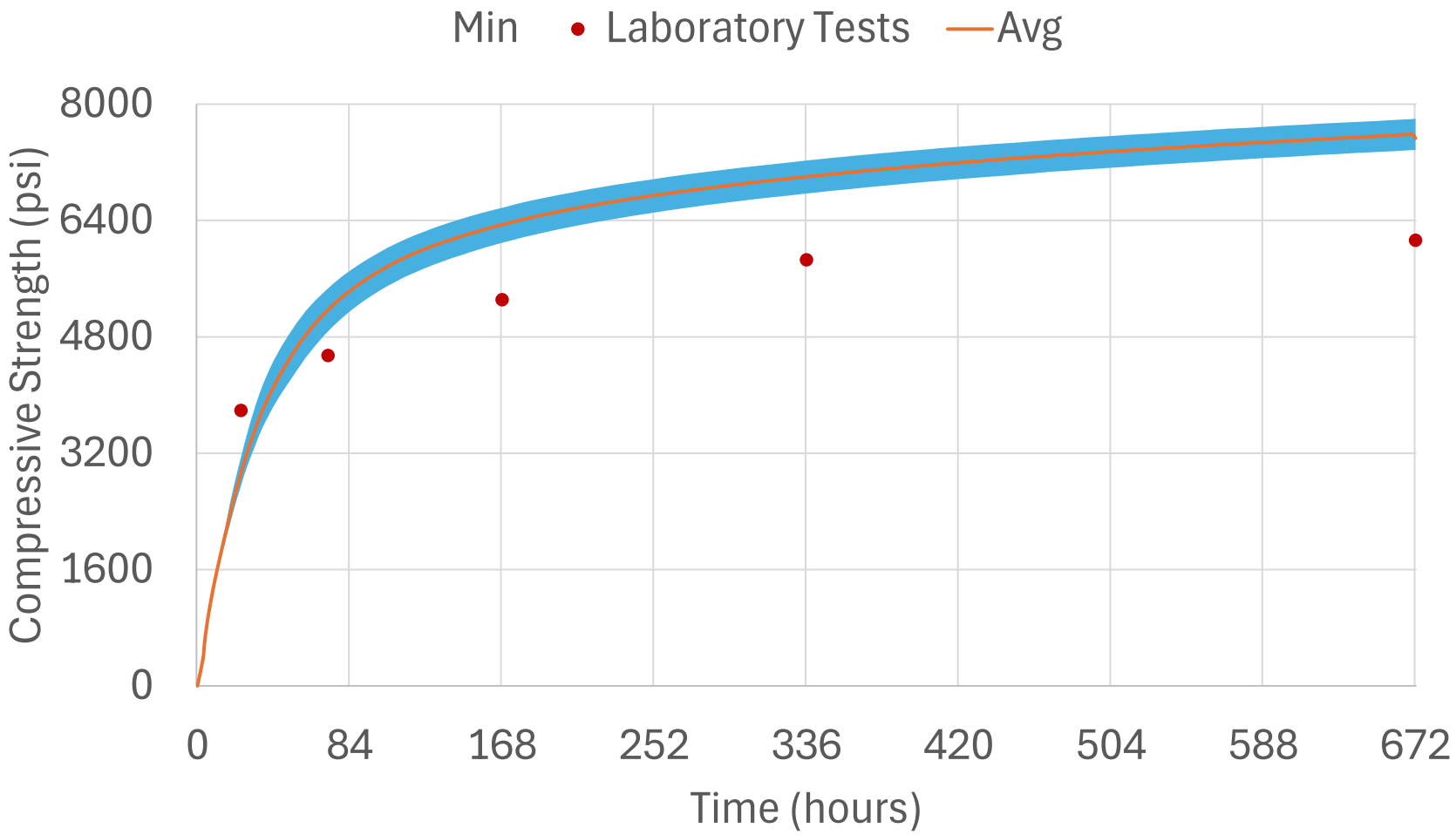
Compressive Strength in psi

Age (hr)	LT 1	LT 2	LT 3	LT Avg	Embed Sensor 1	Embed Sensor 2	Embed Sensor 3	Cylinder Full Cast	Cylinder Half Cast
24	3375	3981	4011	3789	2782	2836	3158	2949	2997
72	4649	4403	4579	4544	4879	5091	5524	5215	5231
168	5282	5350	5305	5312	6102	6176	6645	6418	6458
336	5836	5851	5898	5862	6776	6831	7221	7070	7129
672	5851	6653	5880	6128	7372	7415	7792	7648	7684

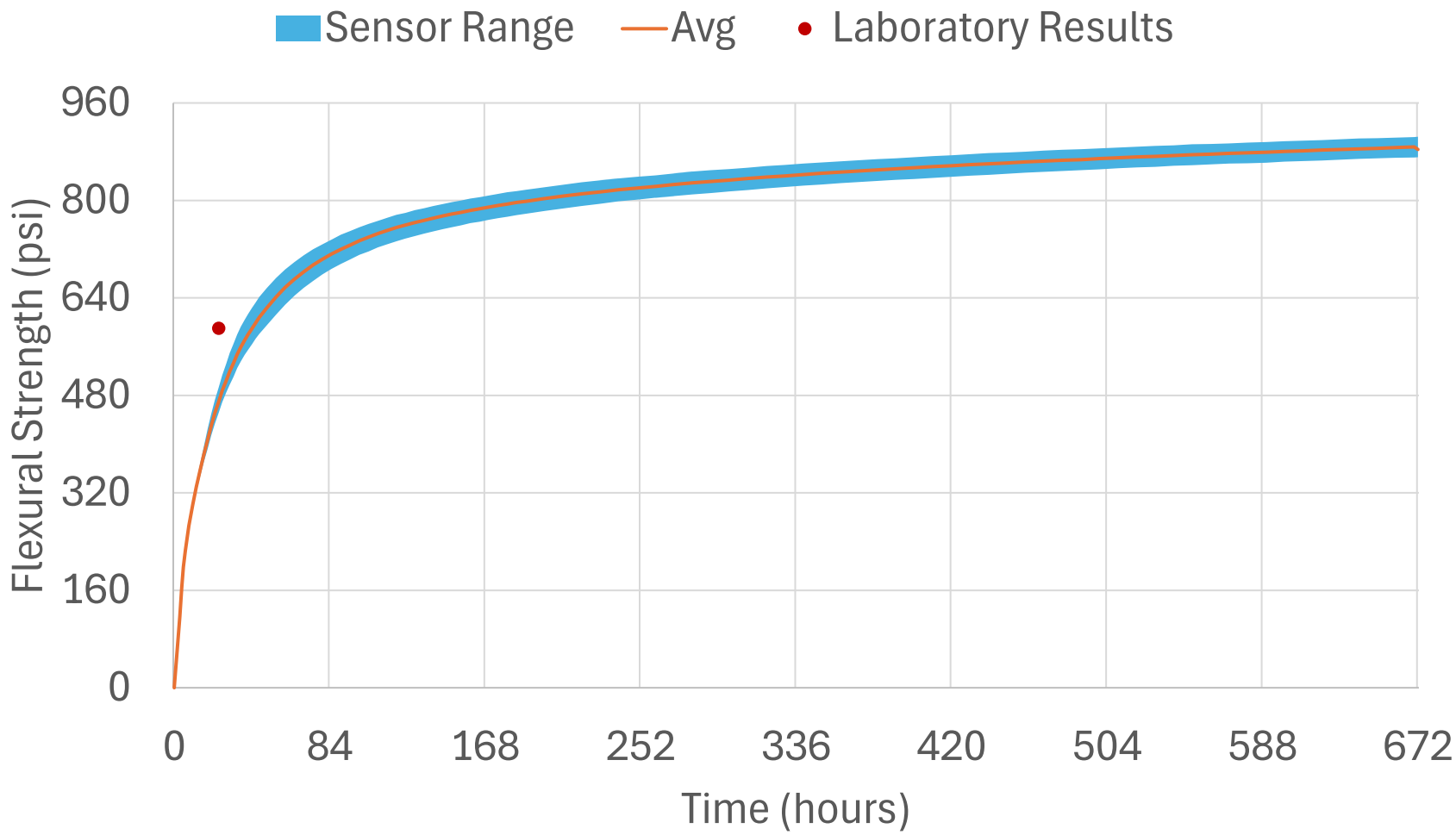
Flexural Strength in psi

Age (hr)	LT 1	LT 2	LT Avg	Embed Sensor 1	Embed Sensor 2	Embed Sensor 3	Cylinder Full Cast	Cylinder Half Cast
24	593	587	590	455	461	495	473	478

I-39 and Paw Paw (Northbound Willow Creek Rest Area



I-39 and Paw Paw (Northbound Willow Creek Rest Area



N University Road (Southbound; at the intersection of N. University Rd. and W Northmoor Rd.)

1. Concrete was poured on 5/27/2026
2. 3 sensors were deployed inside the concrete patch
3. 1, 6-by-12 cylinders with sensors were cast
    A. The cylinder was cast to half-depth
4. 15, 4-by-8 cylinders were cast for laboratory compression tests
    A. 1-day, 3-day, 7-day, 14-day, and 28-day tests will be performed
5. 2, 6-by-6-by-21 beams were cast for laboratory flexural test

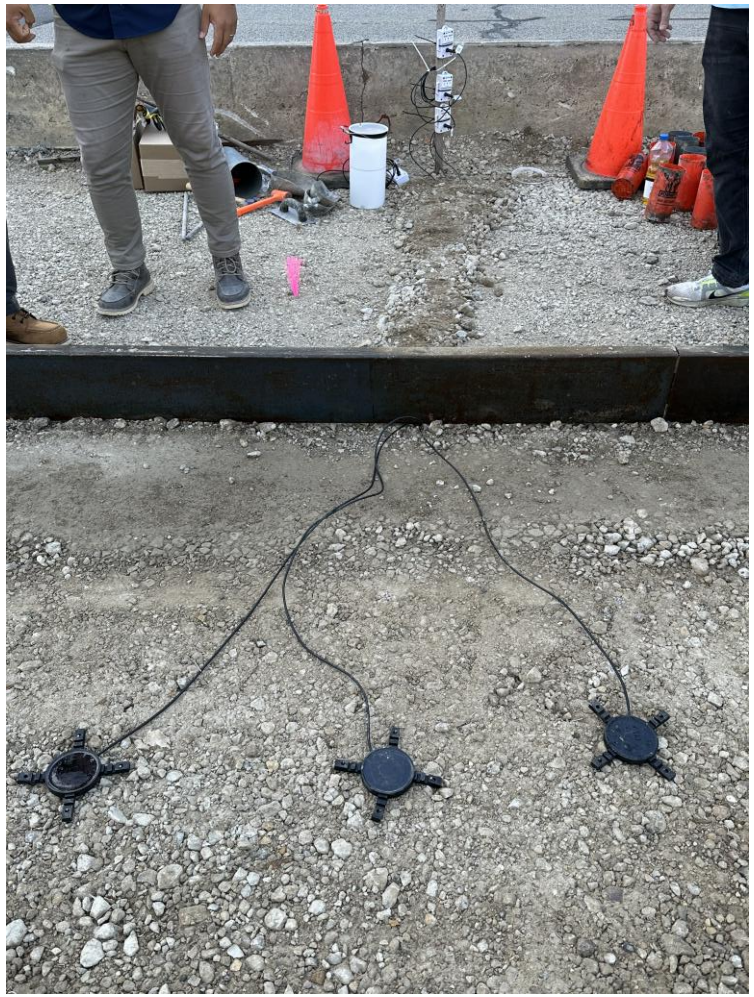
N University Road (Southbound; at the intersection of N. University Rd. and W Northmoor Rd.)

Ingredient/Characteristic	Value	Unit*	Notes
Cement	435	lb/cy	Type IL
Water	29.2	gal/cy	
Coarse Aggregate	1,821	lb/cy	CA-11
Fine Aggregate	1,271	lb/cy	FA-01
Fly Ash	145	lb/cy	Class C
Air Entrainer	1.1	oz/cy	AEA 14 Sika
Water Reducer	4	oz/cy	Low-range
Retarder	2	oz/cy	SikaTard 440
Slump	5.5	in.	
Air Content	6%		
Target w/c Ratio	0.419		
Certification Strength	3,500	psi	14 days (336 hr)

N University Road (Southbound; at the intersection of N. University Rd. and W Northmoor Rd.)







N University Road (Southbound; at the intersection of N. University Rd. and W Northmoor Rd.)







N University Road (Southbound; at the intersection of N. University Rd. and W Northmoor Rd.)

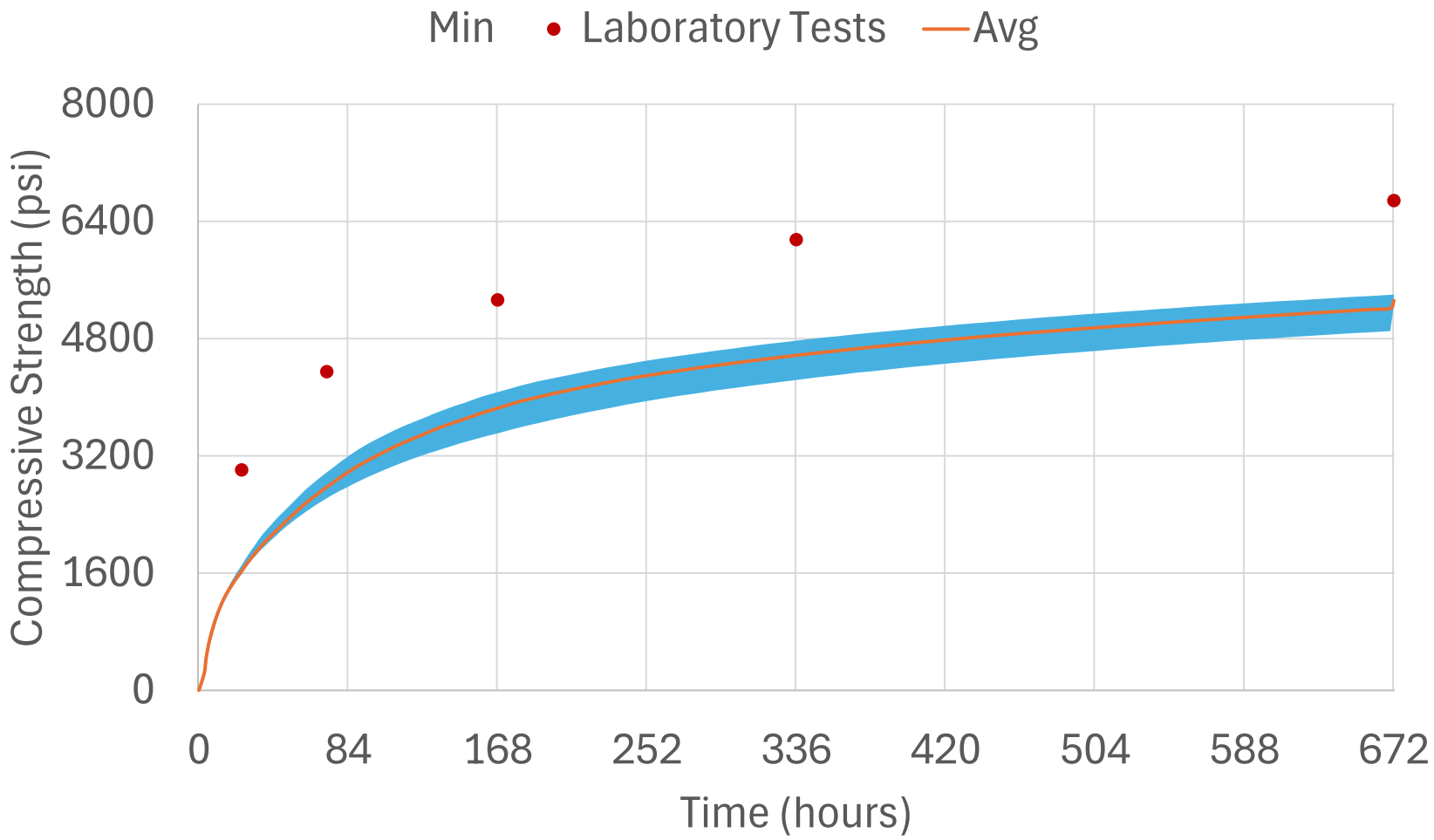
Compressive Strength in psi

Age (hr)	LT 1	LT 2	LT 3	LT Avg	Embed Sensor 1	Embed Sensor 2	Embed Sensor 3	Cylinder Half Cast
24	3027	3061	2940	3009	1601	1625	1716	1612
72	4337	4257	4456	4350	2782	2748	2988	2637
168	5342	5232	5417	5330	3893	3946	4075	3517
336	6206	6229	6022	6152	4617	4666	4783	4242
672	6684	6781	6591	6685	5260	5295	5405	4909

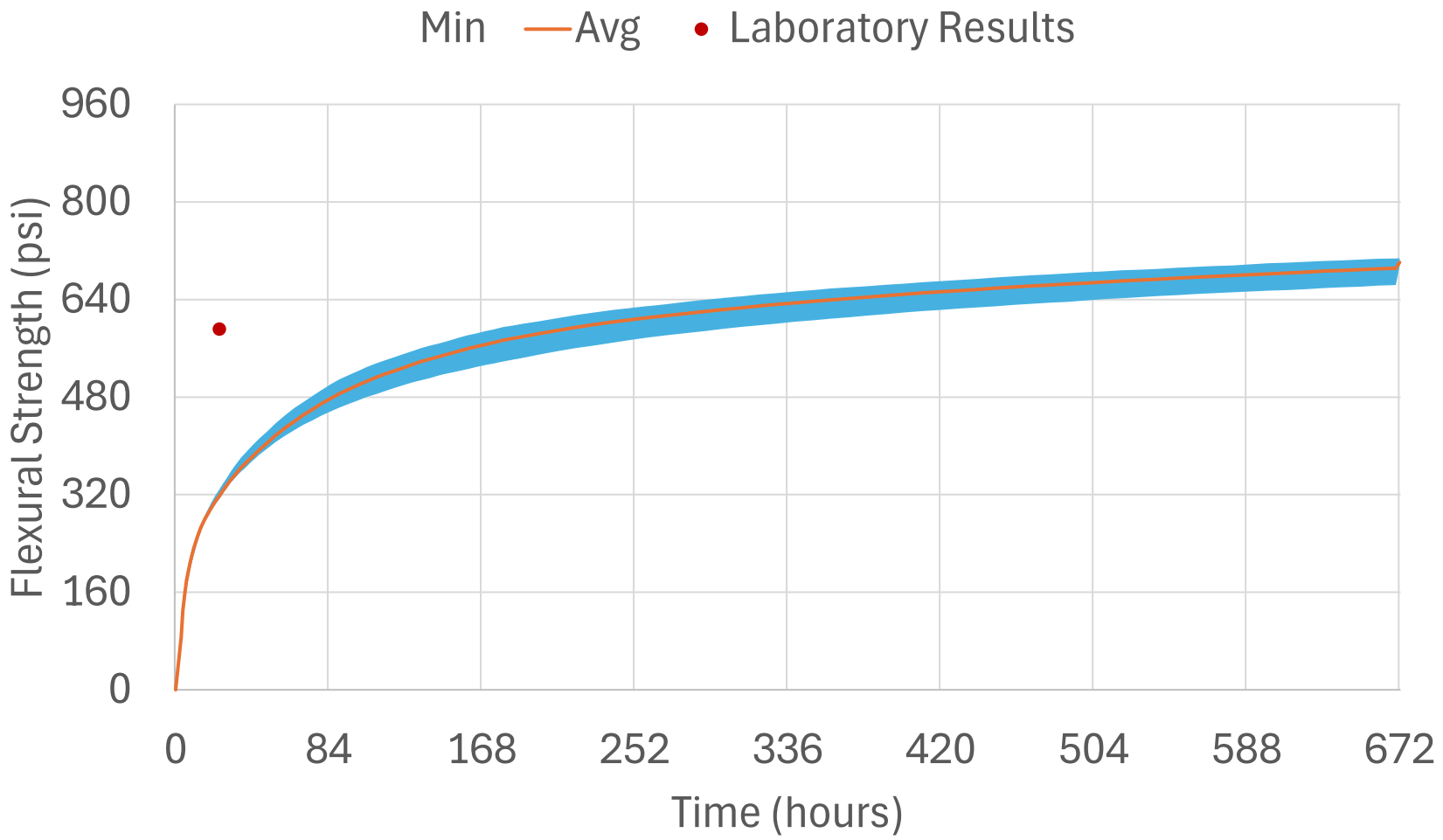
Flexural Strength in psi

Age (hr)	LT 1	LT 2	LT Avg	Embed Sensor 1	Embed Sensor 2	Embed Sensor 3	Cylinder Half Cast
24	628	556	592	315	318	330	316

N University Road (Southbound; at the intersection of N. University Rd. and W Northmoor Rd.)



N University Road (Southbound; at the intersection of N. University Rd. and W Northmoor Rd.)



Mix Design Comparison and Variation

- Six projects with six different mix designs
- Cement type, Type IL, remains the same for all six mixes, but varying quantities
    - Four mixes used Fly Ash (Projects 1, 3, 4, 6)
- Varying CA and FA types and quantities
    - Two mixes used Slag (Projects 2 and 5)
- Widely varying admixture types and quantities
    - Five mixes (Projects 2, 3, 4, 5, 6) used Air Entrainer (different types and quantities)
    - All mixes used Water Reducer (different types and quantities)
    - Three mixes (Projects 2, 5, 6) used Retarders (different types and quantities)

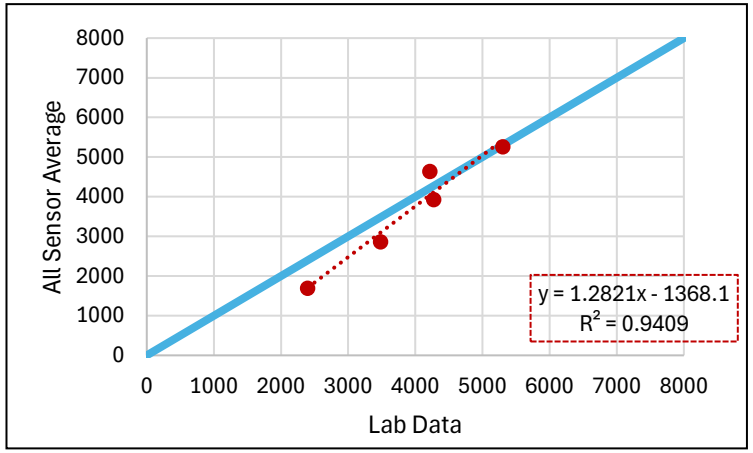
Laboratory Samples Comparison and Variation

- 6 by 12-size cylinders (10 counts) were tested (Compression tests) in Projects 1 and 2
- 4 by 8-size cylinders (15 counts) were tested (Compression tests) in the rest of the four projects
- 6 by 6 by 21-size beams (2 counts) were tested (flexural tests) in all projects
- 6 by 12-size cylinders with sensors were cast for all projects
    - Two 6 by 12-size cylinders with sensors were cast for five projects
    - One 6 by 12-size cylinder with a sensor was cast for project 6
- Except for Project 6, all cylindrical samples were placed in a cooler box for 24-hours
    - Project 6 samples were cured using the field curing agent
- All cylindrical samples were covered with a wet towel except for Project 6

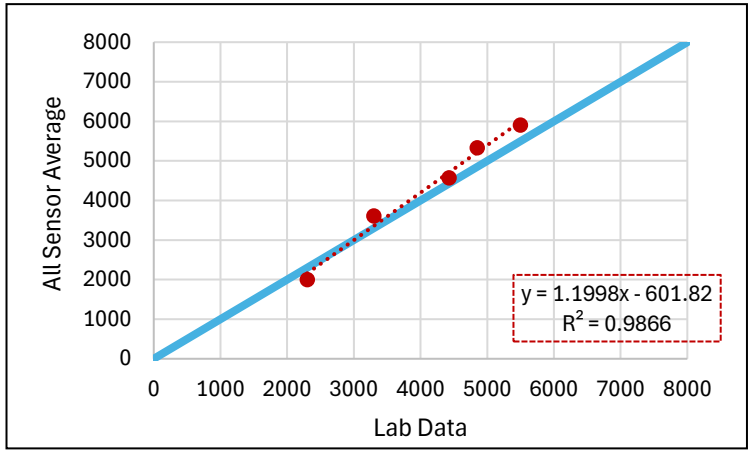
Embedded Sensors Recorded Average Ambient Temperature

Project No.	Sensor Deployment Date	Temperature (^{0}F)				
		24 Hr.	72 Hr.	168 Hr.	336 Hr.	672 Hr.
1	11/24/2025	51	38	32	61	41
2	2/27/2026	54	35	69	49	42
3	4/7/2026	52	48	78	74	53
4	5/4/2026	51	56	65	64	80
5	5/14/2026	65	75	63	80	72
6	5/27/2026	69	70	56	77	81

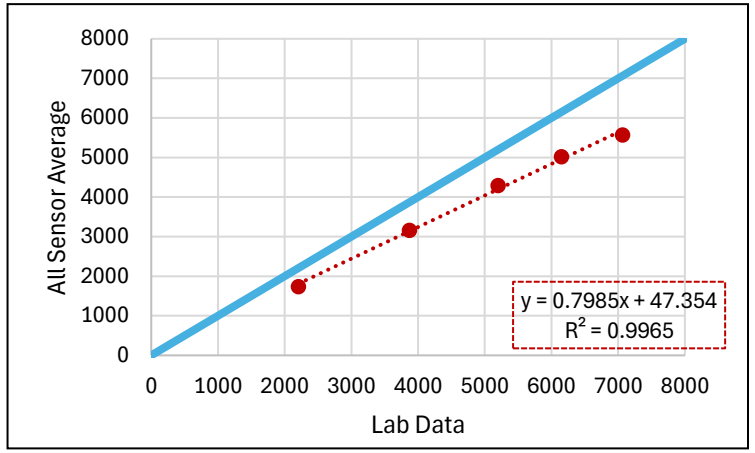
Correlation of Lab Data Average vs. Sensor Average



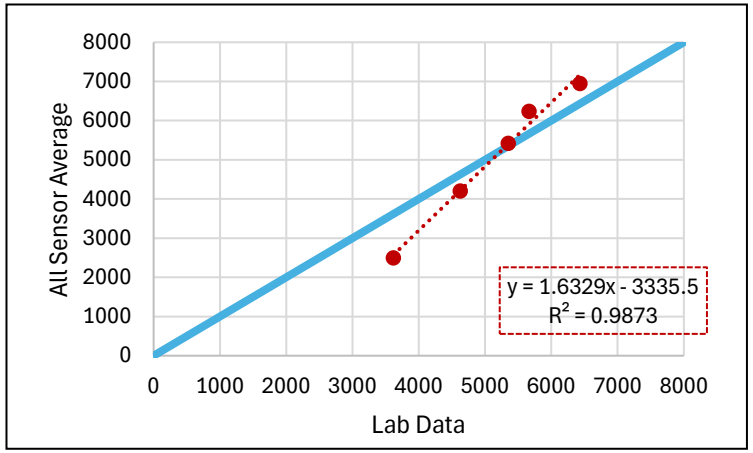
Project 1



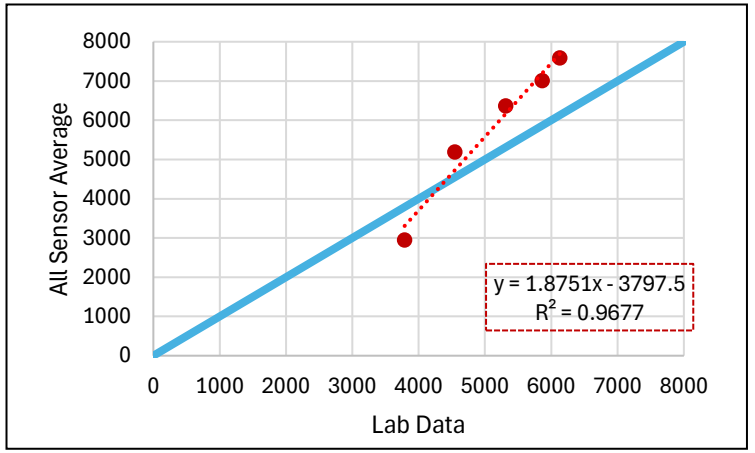
Project 2



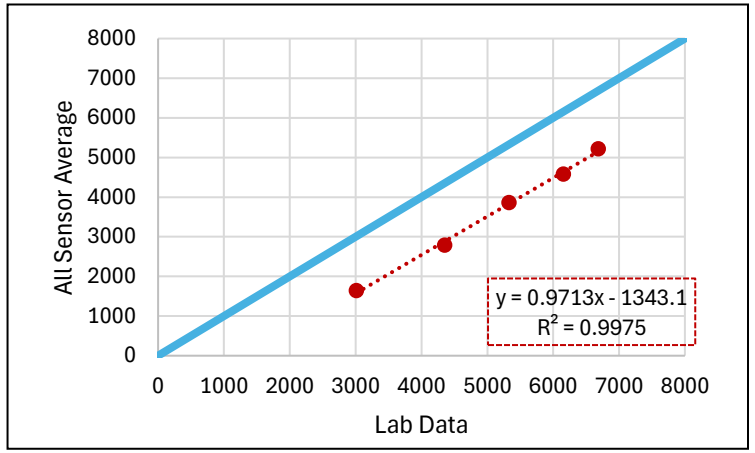
Project 3



Project 4



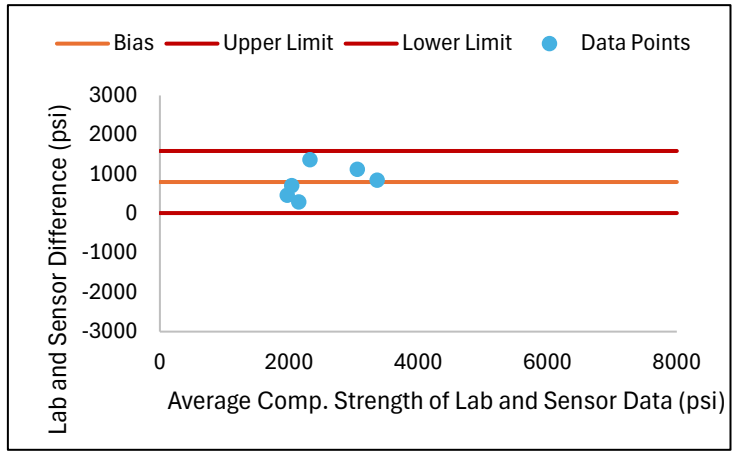
Project 5



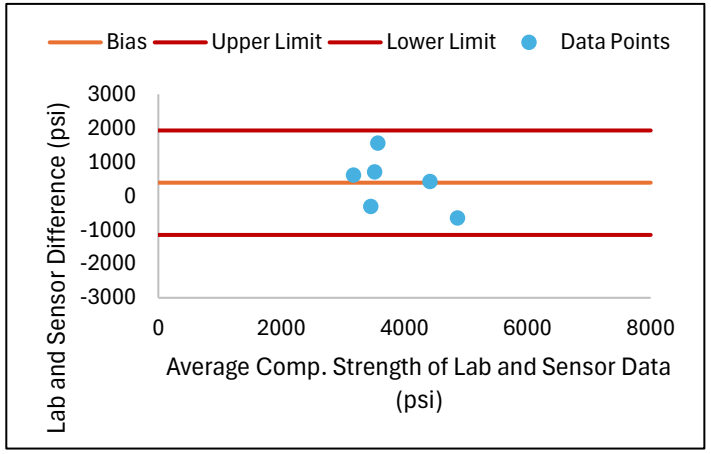
Project 6

Difference between Lab Data Average vs. Sensor Average

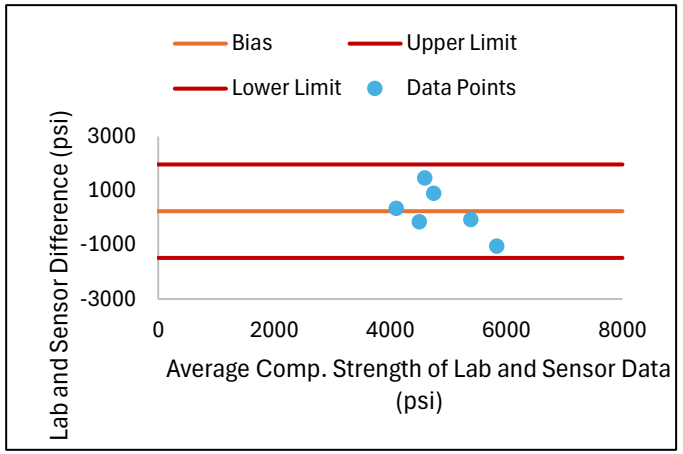
- Bland-Altman test to check the difference between the lab test and sensor test data



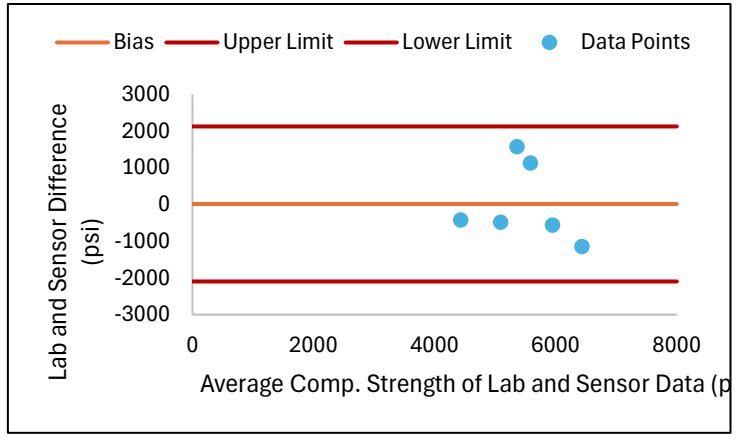
Day 1



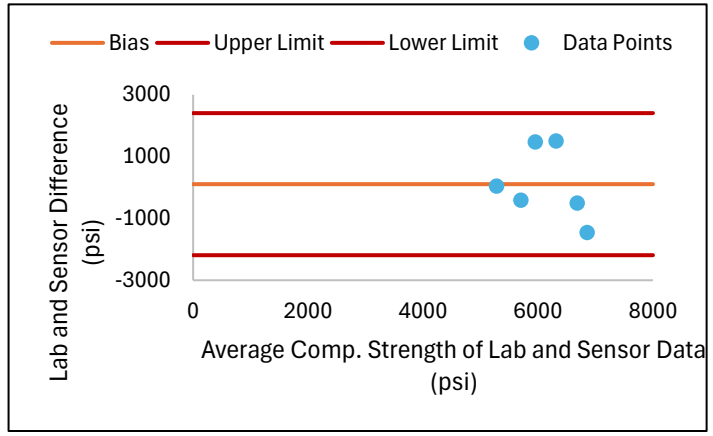
Day 3



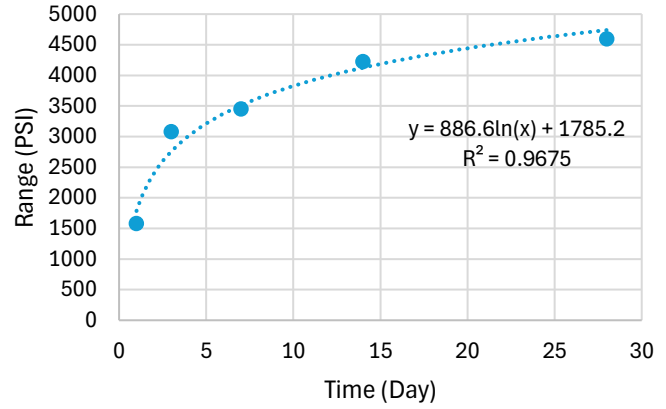
Day 7



Day 14



Day 28



Data Analysis Conclusion

- The results demonstrated that REBEL sensors were able to predict concrete strength development during curing.
- According to the regression analysis, the increase in strength in laboratory-cured samples
- However, the Bland-Altman analysis showed that the difference between laboratory-cured samples and field concrete increases logarithmically as the concrete ages.
- The findings indicate that REBEL sensors provide a practical means of continuously monitoring in-place concrete strength, though a strong correlation between sensor-measured data and laboratory test data could not be established, suggesting the need for more rigorous investigation.

Future Study Recommendation

- It is expected that each project will have a unique mix, so a cross-check of laboratory data with the consultant or contractor is needed



Thank You

BRADLEY University