Evaluating Compressive Strength of Core and In Situ Specimens of PCC Pavement

Acknowledgements: This poster is based on the results of research study ICT-R27-137, *Evaluation of PCC Pavement and Structure Coring and In Situ Testing Alternatives*, conducted in cooperation with the Illinois Center for Transportation, the Illinois Department of Transportation, and the Federal Highway Administration. The study's authors are **John Popovics** (University of Illinois at Urbana-Champaign), **Agustin Spalvier** (UIUC), and **Kerry Hall** (University of Southern Indiana).

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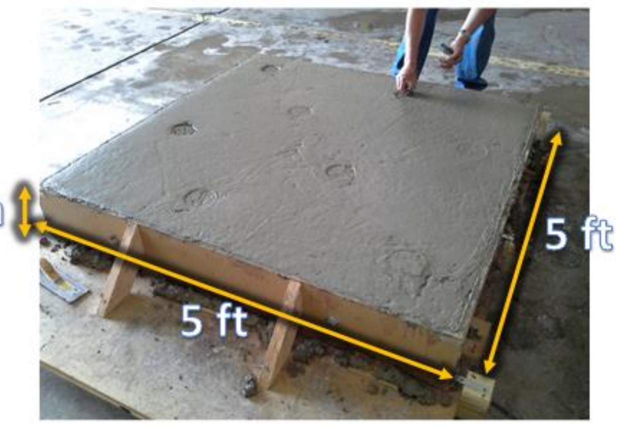
Research Objective

1. To evaluate core strength relative to in situ strength under different conditions likely to be encountered in the field.
2. To investigate core conditioning practices that provide better estimates of in situ strength.

Research Approach

- A total of sixteen 5-ft x 5-ft x 9-in slabs were cast and tested.
- Each slab accommodated 8 cores and 8 in situ specimens.
  - In situ specimens were cast using a method similar to **ASTM C 873**, Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds
- Slabs were organized in pairs; each having the same feature as follows:
  - 3 concrete mix designs,
  - 2 methods of core conditioning, and
  - Absence/presence of rebar in the core.
- In total, 8 combinations were studied.



Experimental Slab Features

Mix Design

Three mix designs, differing from each other primarily in terms of strength, were evaluated:

- a **high-strength (5,000 psi) concrete** typical for precast-prestressed IDOT bridge beams,
- a **regular-strength (3,500 psi)** IDOT paving concrete, and
- a **low-strength (<3,500 psi)** concrete, essentially the same mixture as the regular-strength paving mix but with excess water and air

	lb per yd³ of concrete		
	Regular-Strength	High-Strength	Low-Strength
Coarse Agg. 1*	364	1820	364
Coarse Agg. 2**	1450	—	1450
Fine Agg.	1227	1108	1227
Fly Ash – Class C	145	—	145
Cement – Type I	435	705	435
Water (w/c)	29.2 gal (0.42)	29.6 gal (0.35)	34.8 gal (0.50)
Air-Entraining Admixture	1.9 - 2.0 oz	1.0 oz	Variable***
Water Reducer – Type A	4.0 oz	4.0 oz	4.0 oz

* 100% passing 1-in. sieve
** 100% passing ½-in. sieve
*** To induce high air content

Core Conditioning

Two types of moisture conditioning for cores were evaluated:

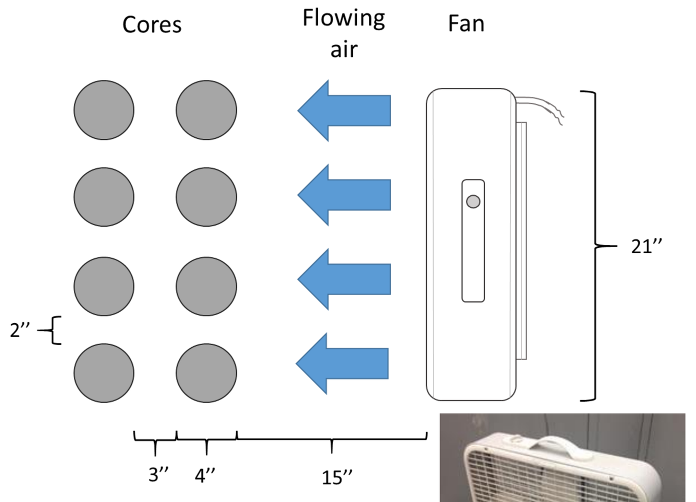
- **1-Day Dry:** placing the cores, immediately following extraction, in front of a fan at room temperature and humidity for 24 hours before testing
- **1-Day Wet:** submerging the cores in water at 73°F for 24 hours before testing

Alternative core conditioning procedures were evaluated in an effort to potentially reduce the time between extraction and testing. For example, **AASHTO T 24 specifies a 5-day waiting period** to "reduce moisture gradients introduced when the core is drilled or wetted during sawing or grinding"; this is done primarily to "provide a reproducible moisture conditions that minimize within-laboratory and between-laboratory variations."

1-Day Wet Conditioning Setup

Image Source: www.globalgilson.com

1-Day Dry Conditioning Setup



Ordinary Box-type Fan >

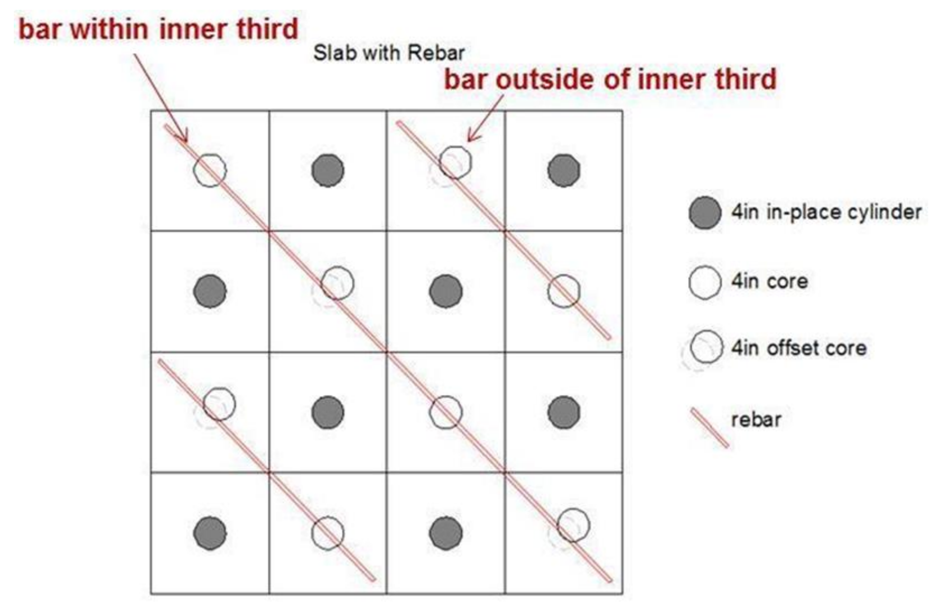
Presence of Rebar

The third feature/effect investigated was the absence vs. presence of reinforcing bar in the core. **Per AASHTO T 24, "specimens containing embedded reinforcement shall not be used for determining compressive, splitting tensile strength or flexural strength."** However, this is not always practicable in the field.

To evaluate the presence of rebar, **#5 epoxy-coated bars** were cast with **2 inches of cover**, and then cored such that two different locations were accommodated:

crossing through the inner third of the core's cross section

crossing through the outer third



Specimen Scheme for Experimental Slab with Reinforcement Bar

In Situ Strength Specimens

In situ specimens were cast using ASTM C 873 (modified). A side-study established that the specimens shared the same temperature profile as the slab and could be consolidated in such a way to produce the same density as the vibrated concrete in the slab.

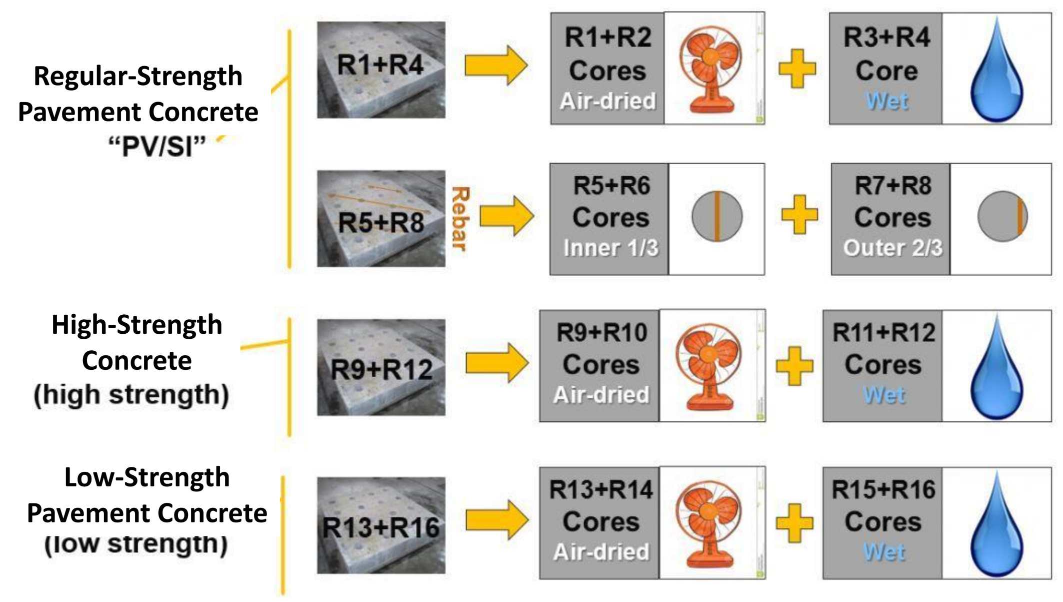
Experimental Slab Matrix

Concrete for each slab was provided by a nearby ready-mix plant using Department-approved mix designs. Each truck was batched with 4 yd³ of concrete to help ensure consistency and adequate mixing action.

A total of 16 slabs were cast and tested:

- **8 regular-strength** paving concrete slabs wet-cured with burlap and plastic sheeting for 3 days
  - 4 slabs **without** embedded rebar
  - 4 slabs **with** embedded rebar
- **4 high-strength** concrete slabs wet-cured for 1 day
- **4 low-strength** concrete slabs wet-cured for 3 days

- For each set of 4: half of the slabs had their cores conditioned with the **1-Day Dry** treatment, the other half had theirs conditioned with the **1-Day Wet** treatment.



Testing

Fresh Properties: slump, air content, and unit weight

Hardened Properties: Compressive strength & longitudinal dynamic modulus of elasticity

For each compressive strength specimen, the following applied:

- Perpendicularity and cross-sectional area were measured and verified.
- All cores and in situ specimens were **tested 16 days after casting.**
- All cores were cut from the slab 15 days after casting and then conditioned for 24 hours (i.e., 1-Day Wet or 1-Day Dry conditioning).
- All in situ specimens were removed from the slab on day 16 and then tested.

Statistical Analysis of Strength Results

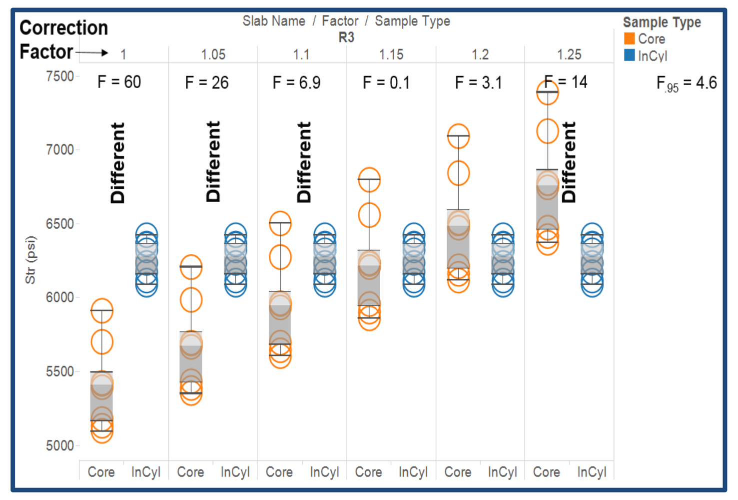
An **analysis of variance (ANOVA)** was used to statistically evaluate the strength results of each slab and each pair of related slabs.

The **null hypothesis** for the analysis was: **"Population samples for a particular type of core condition […] have the same mean value as that from the molded in-place cylinder samples for a given concrete mixture and condition."**

Thus, the **alternative hypothesis** was: **"Population samples have different mean values."** In which case, correction factors were then applied to the average strength a slab's cores such that the null hypothesis would be made true.

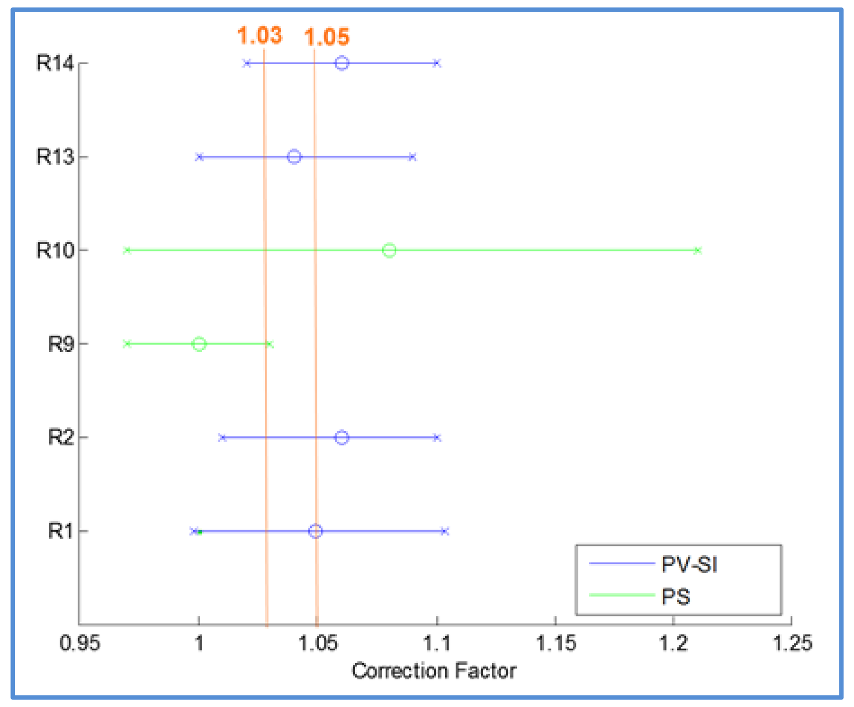
That is, if the core strengths and in situ specimen strengths for a slab were determined to be statistically different (i.e., null hypothesis is false), correction factors were applied to the cores' results to make them statistically similar to in situ results within a 95% confidence level.

The example at right is for 1-Day-Wet conditioning R3 cores; the optimal correction value results in an F-score nearest to 0.

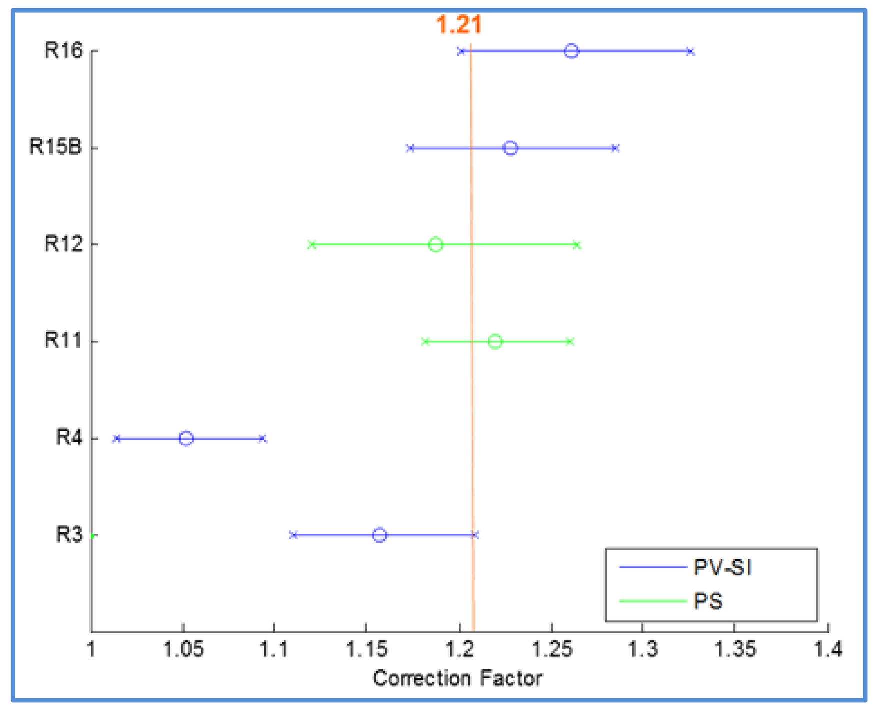


Correction Factors

For **regular- and low-strength paving concrete**, a factor of **1.05** provided a **"good prediction of in-place strength"** for cores subjected to **1-Day Dry** conditioning:



Cores (regardless of mix type) subjected to **1-Day Wet** conditioning required **"larger and less consistent correction factors,"** and the average **errors would be "significantly higher"** than if subjected to 1-Day Dry conditioning:



Summary of Correction Factors for All Slabs

		Min	Best	Max	For Pair
R1	Dry, Reg Str.	1.00	1.05	1.11	1.05
R2		1.02	1.06	1.11	
R3	Wet, Reg Str.	1.12	1.16	1.22	n/a
R4		1.02	1.06	1.10	
R5	Dry, Rebar-Inner	1.08	1.11	1.15	1.08
R6		1.01	1.04	1.09	
R8	Dry, Rebar-Outer	1.05	1.10	1.17	1.10
R9	Dry, Hi Str.	0.97	1.00	1.04	1.03
R10		0.98	1.09	1.22	
R11	Wet, Hi Str.	1.19	1.22	1.27	1.21
R12		1.12	1.19	1.27	
R13	Dry, Low Str.	1.00	1.04	1.10	1.05
R14		1.03	1.06	1.11	
R15	Wet, Low Str.	1.18	1.23	1.30	1.24
R16		1.21	1.26	1.34	

Conclusions

For this study, the correction factors providing the **most confident strength estimations** were determined to be when the cores were subjected to the **1-Day Dry conditioning** as follows:

1.05 for ≥2 pavement cores not containing rebar

1.08 for ≥3 pavement cores containing rebar

1.05 for ≥3 pavement cores in which some have, and the others do not have, rebar

1.03 for ≥3 high-strength concrete cores without rebar

Please note that in addition to what is presented herein, the final report also details efforts made to evaluate the accuracy of various non-destructive test methods (e.g., rebound hammer) often suggested to estimate in situ strength.