Improving Accuracy of the AI Model for Concrete Strength and Reducing Strength Variability

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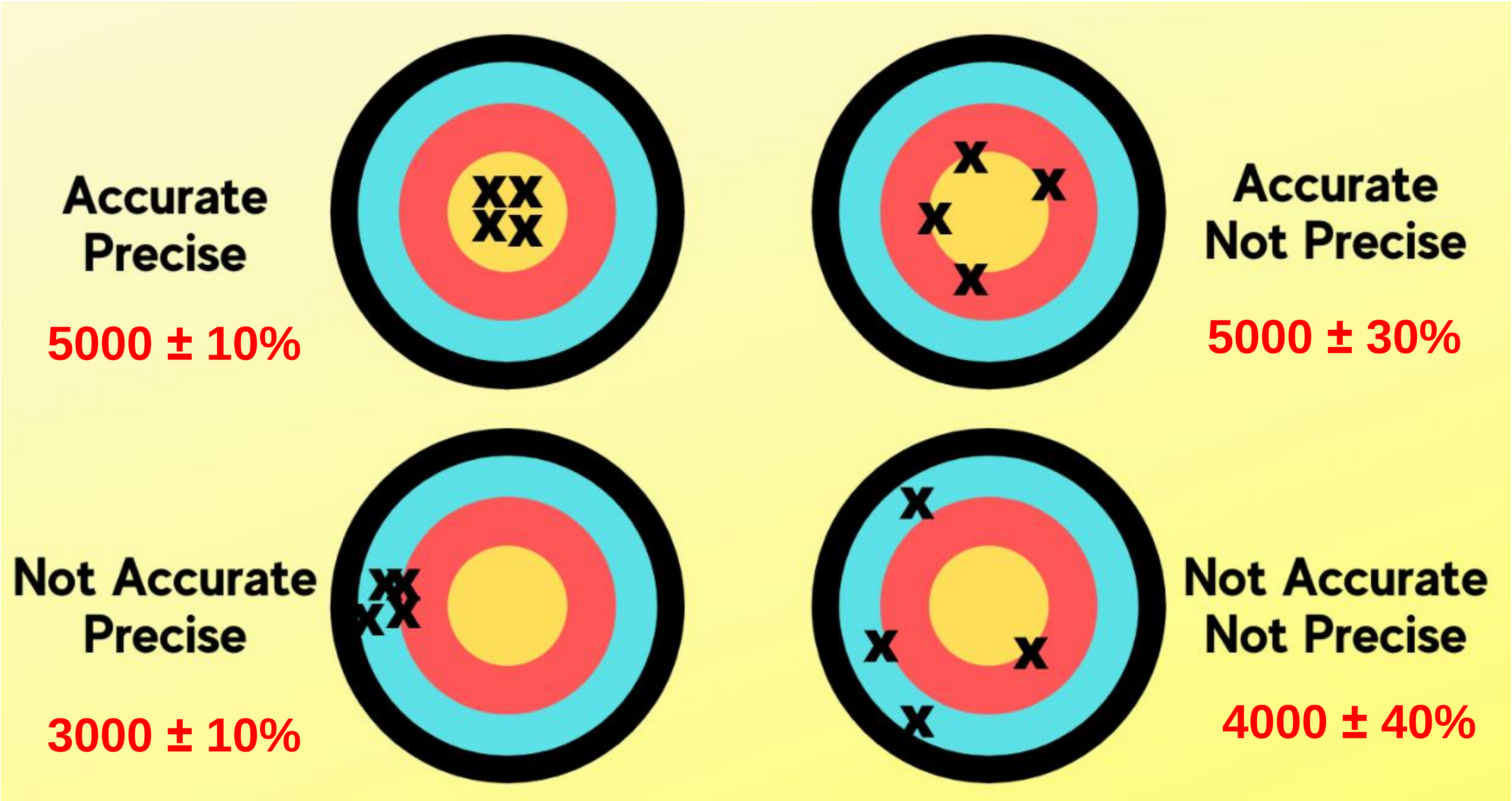
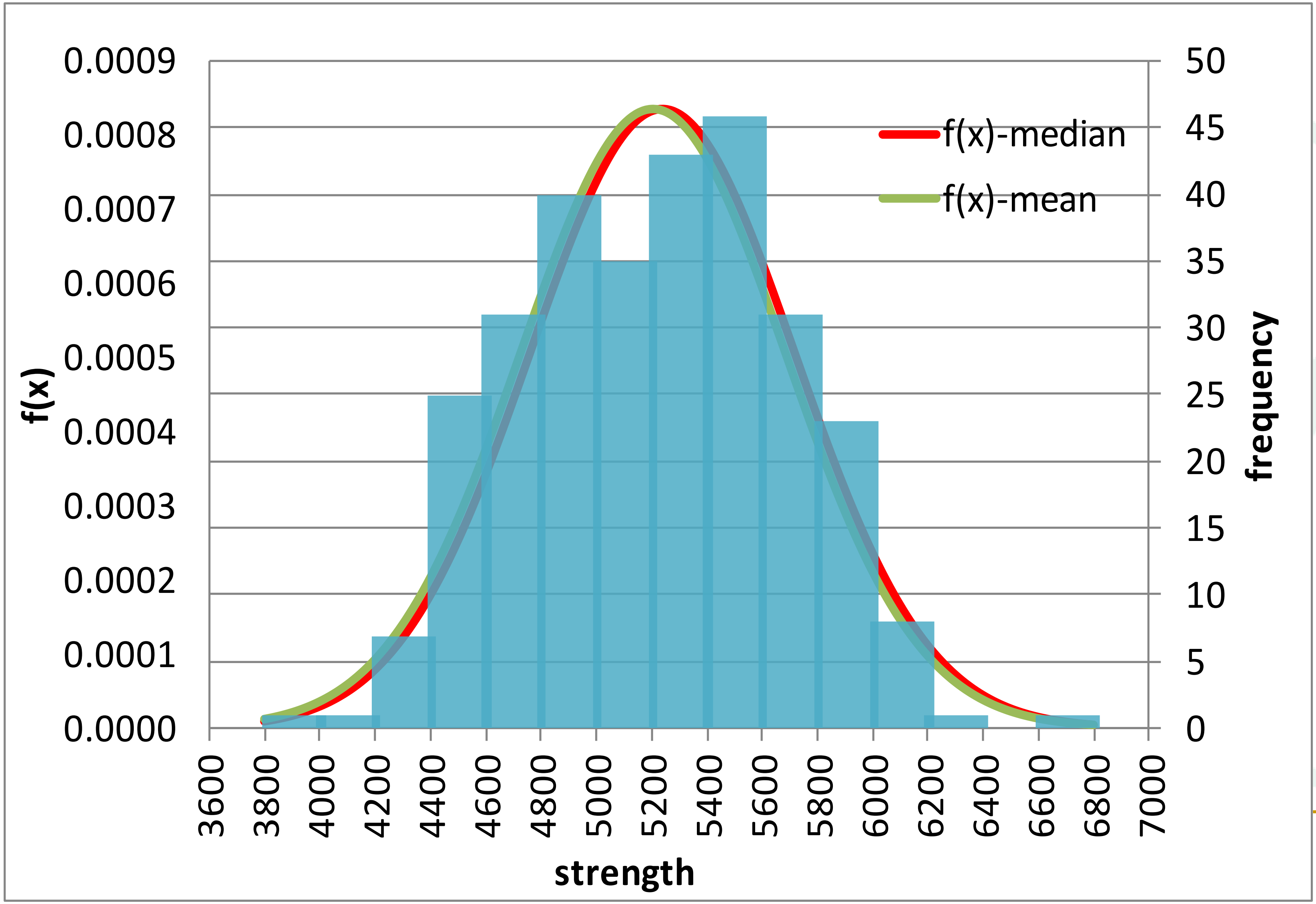
NRMCA

Accuracy and Precision

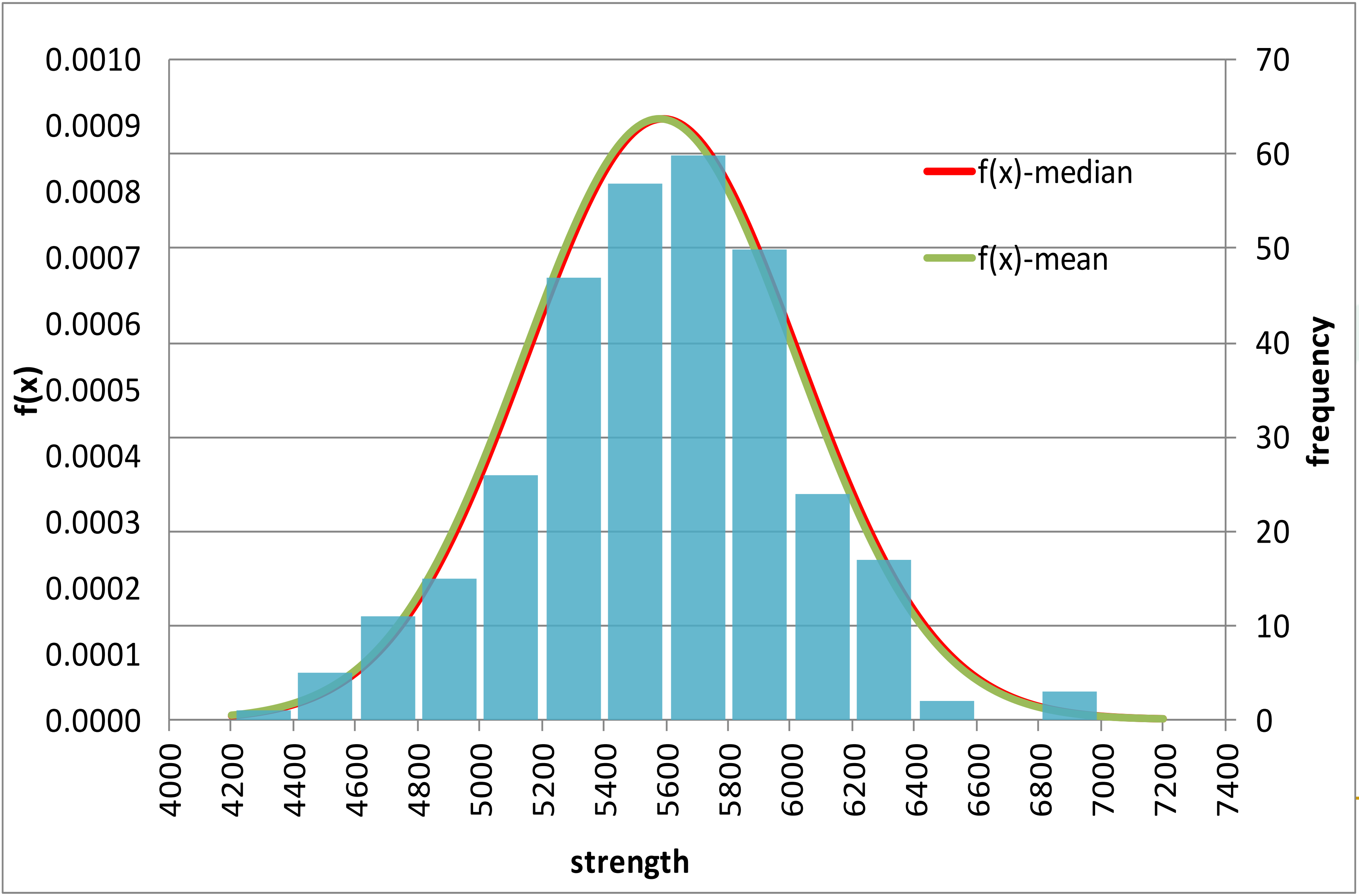


Project data, Florida, Non-air concrete (4 months – 300 tests)



- X = 5210 psi
- S = 478 psi (very good per ACI 214)
- Range = 2770 psi or 5.8xS
- Estimated f'_c (ACI 301) = (5210–1.34x478) = 4570
- Data shows 2 instances where test result is <4070 and 16 instances where Running avg. of 3 <4570
- People design more conservatively than ACI 301's 1-in-100

Project data, Columbus, Air-entrained (7 months – 300 tests)



- X = 5580 psi
- S = 438 psi (very good per ACI 214)
- Range = 2630 psi or 6.0xS
- Estimated f'_c (ACI 301) = 5580–1.34x438 = 4990 psi
- Data shows 2 instances where test result is <4490 and 9 instances where Running avg. of 3 <4990
- People design more conservatively than 1-in-100

Our Problem

Even for very good quality concrete (S = 500 psi)

- Expect actual test data range of 3500 to 6500 psi, i.e. (5000 ± 30%)
  - Variation due to material, manufacturing, and testing changes
- AI model needs to consider the effect of these parameters
- Even then how good can it be?
  - Predict a range of 3000 to 7000 psi (± 40%) - is that enough?
- Can the AI model help reduce the strength variability?

Material Variations

Introduction

- A 1000 yd^3/wk plant uses 12 shipments of cementitious, 40 (coarse), 24 (fine) (@25 tons each)
- Material even from the same source varies between shipments

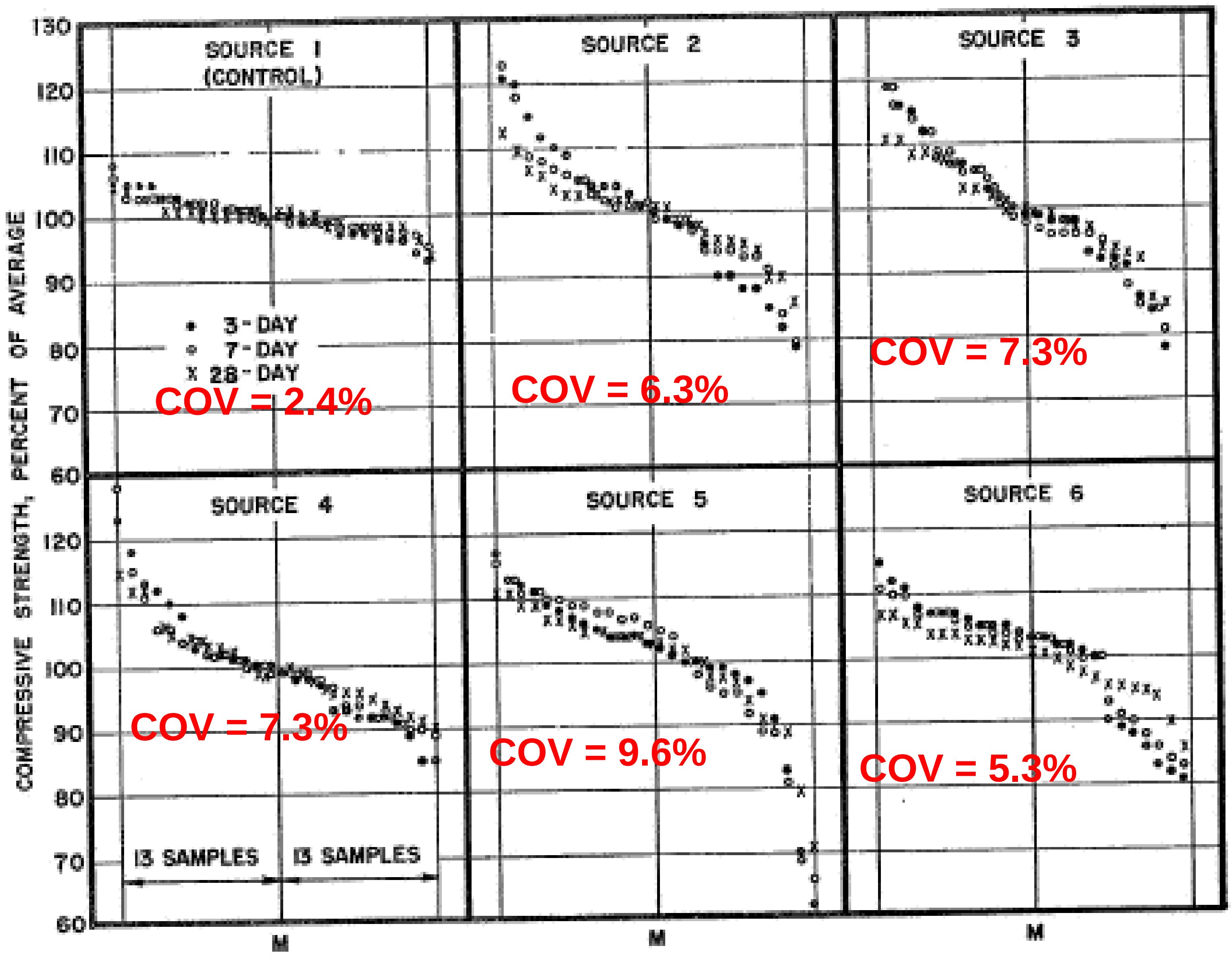
Cement Variations

- ASTM C150 documents specification compliance
  - Tests on composite samples
  - Same C150 mill test report once every few weeks
    - Applicable for hundreds of concrete truck loads!

Past NRMCA Research

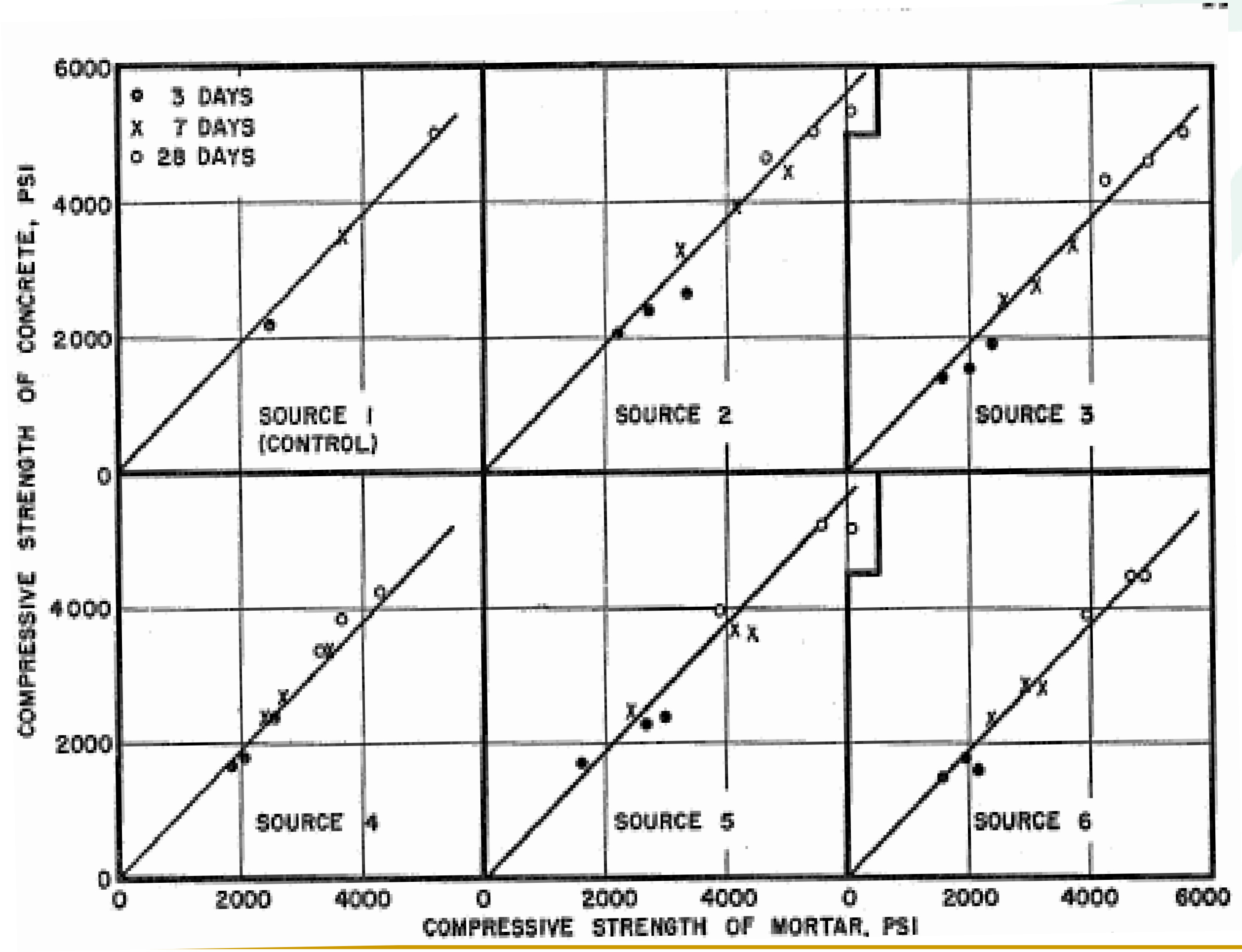
- 1955 study on variation due to cement
  - 5 sources + control (cement blend)
  - Sample / 2 weeks – for 1 year
  - Each sample batched on 5 different days
  - Mortar (7000 cubes) – 1 operator, concrete testing
  - Concrete mixtures on best, average, worst samples for each source
- 1962 study
  - 14 cements

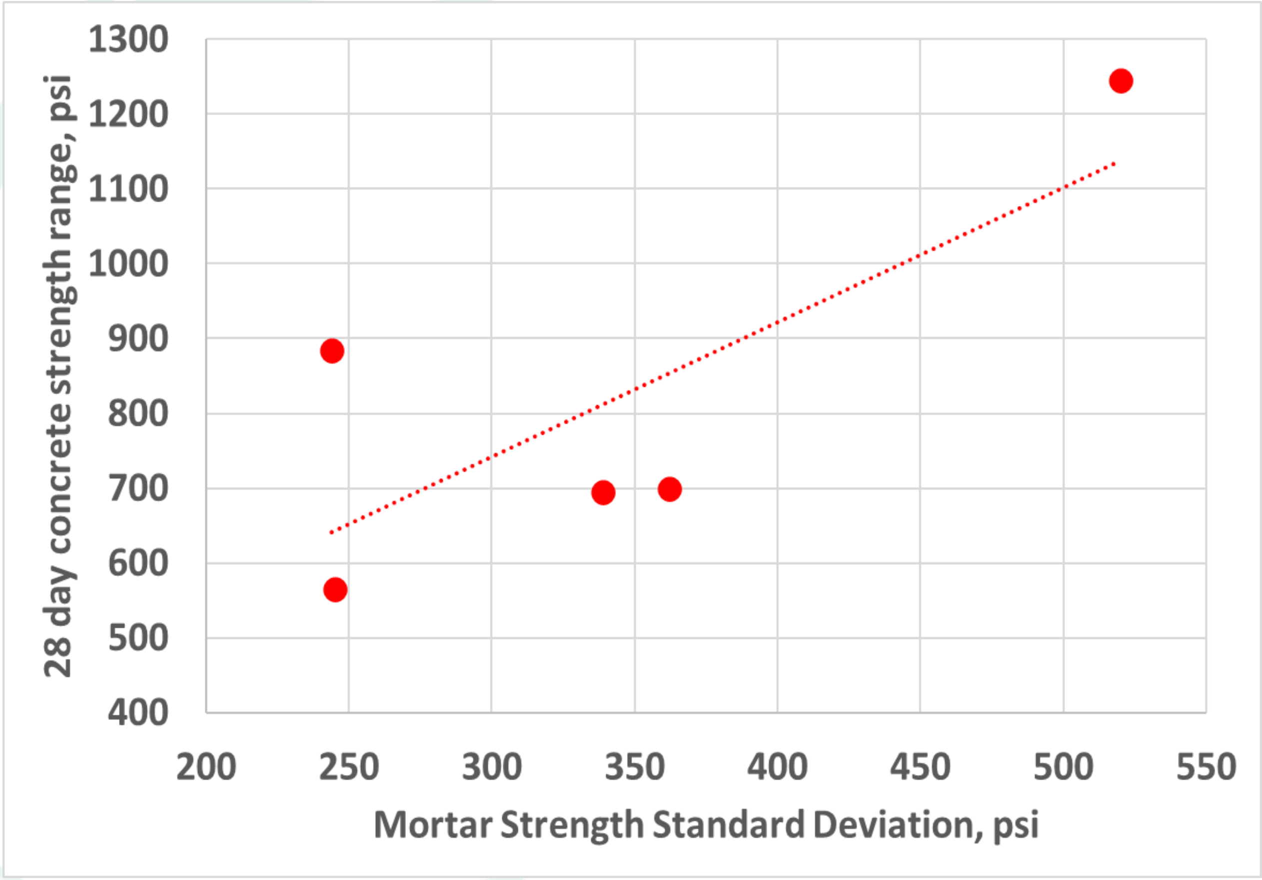
Mortar Test Results



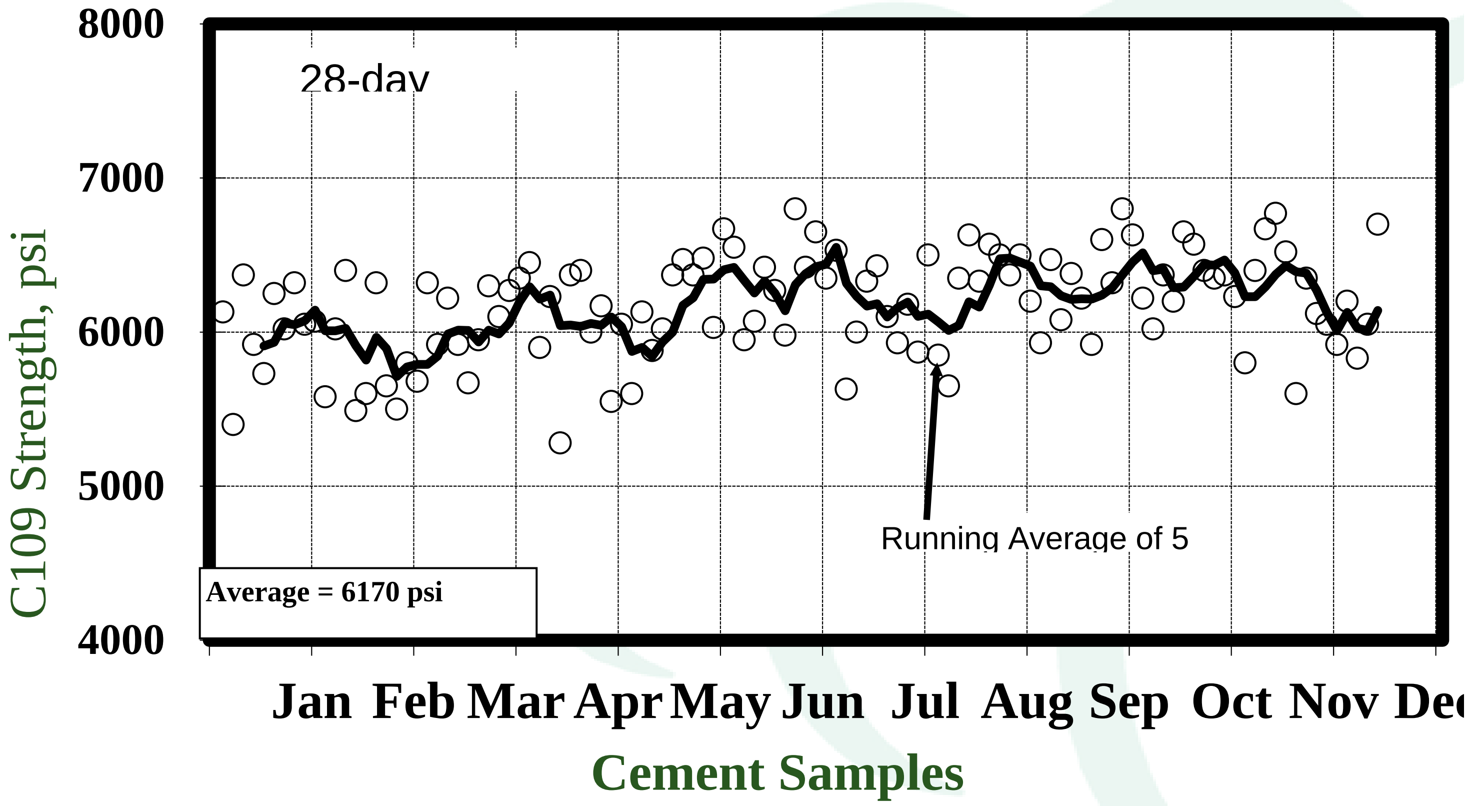
Comparison - Concrete vs Mortar Test Results

- Δ 28d concrete strength of 800 psi





Variability of Cement from single source - ASTM C917



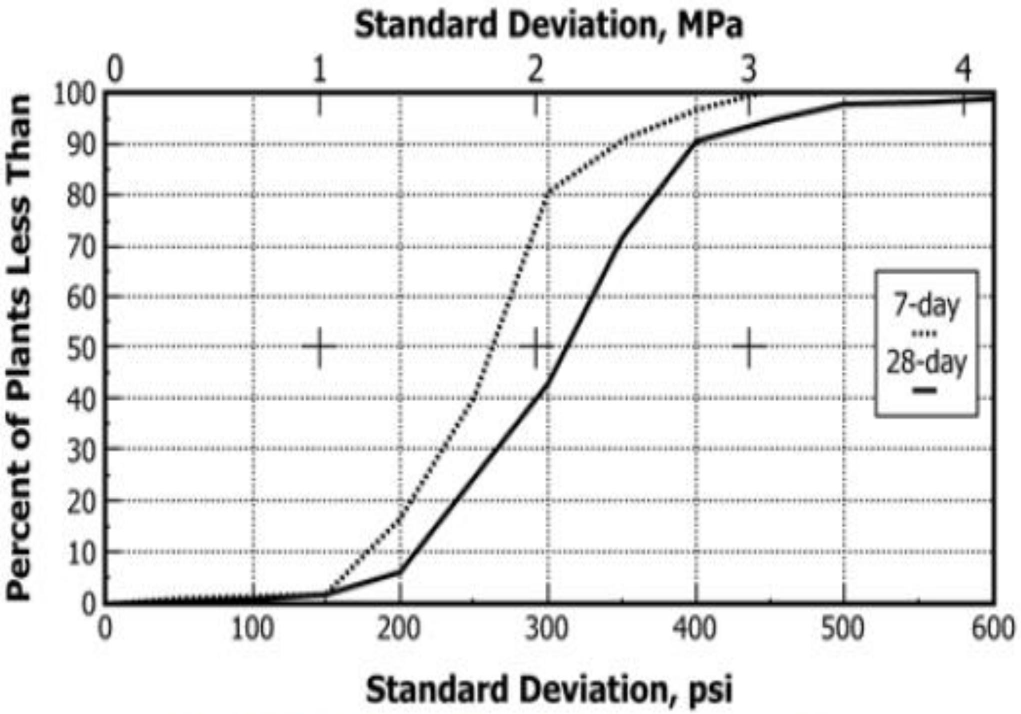
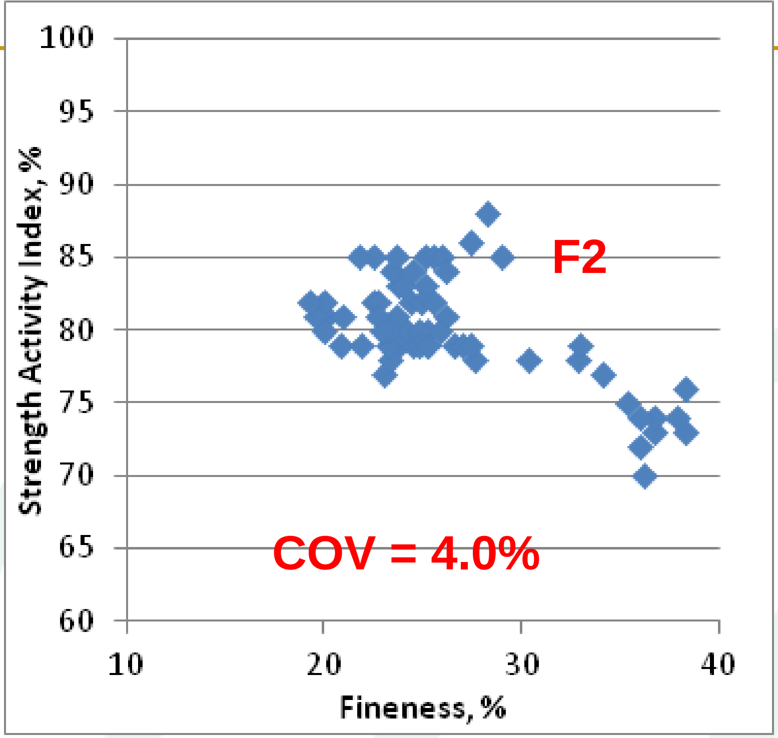
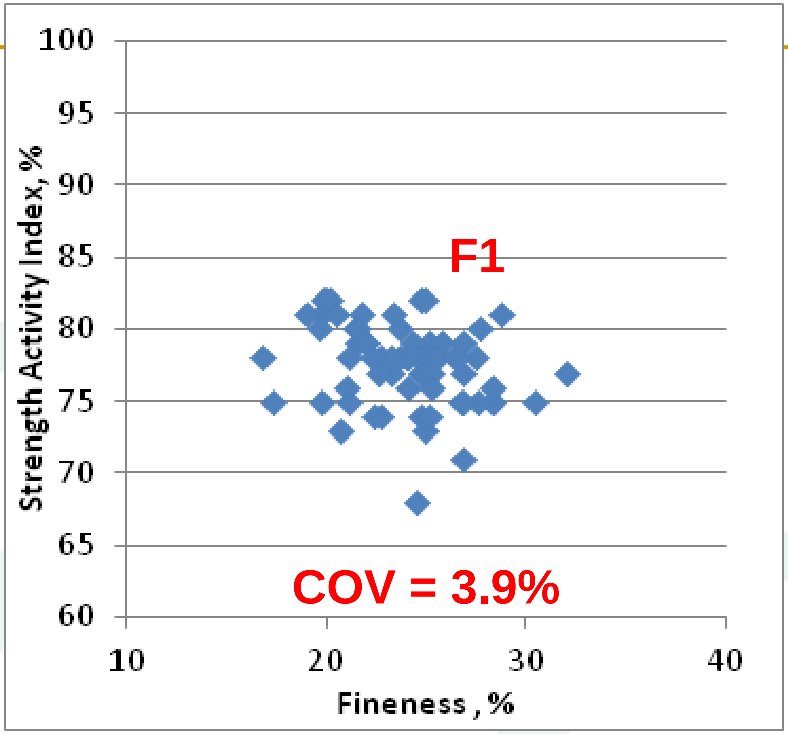
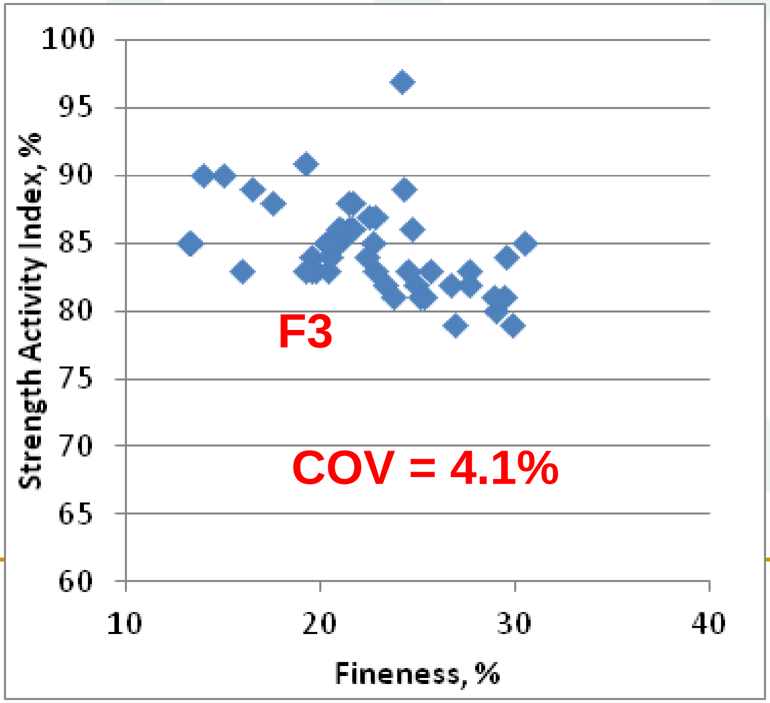
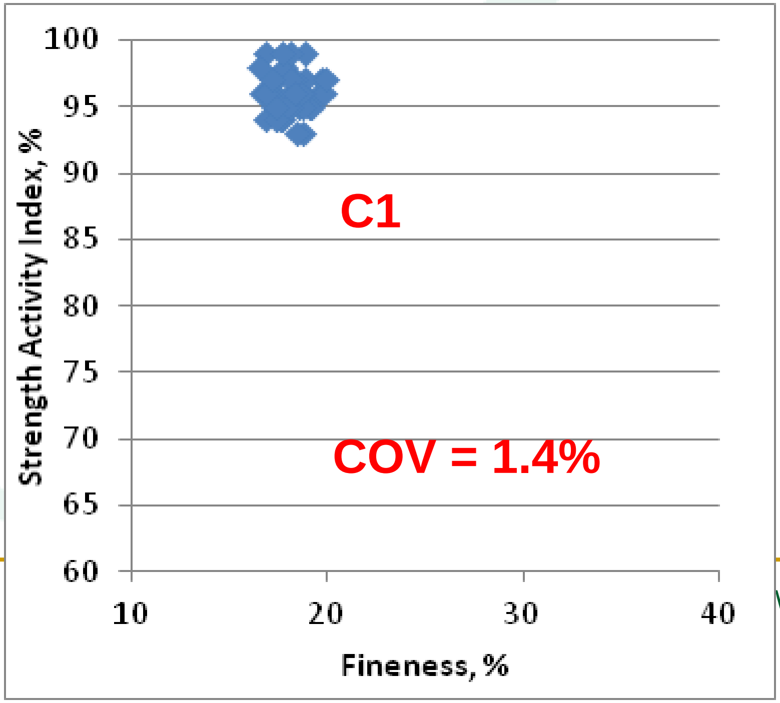


FIG. X2.1 Total Standard Deviation, S_t


F2
COV = 4.0%
Strength Activity Index, %
Fineness, %


F1
COV = 3.9%
Strength Activity Index, %
Fineness , %


F3
COV = 4.1%
Strength Activity Index, %
Fineness, %


C1
COV = 1.4%
Strength Activity Index, %
Fineness, %

Manufacturing Variation

How can AI handle manufacturing Variation?

- Batch weights, mixing speed/time, # of techs/technical managers, % rejected, internal audit, # claims, certified plants/trucks, labs, material tests, calibrations, internal tests, truck time, etc. – measured
- Material handling, mixing sequence, uniformity
  - Not measured, best practices
- Direct / indirect measure of mixing water
  - High slump, concrete / air temperature, delivery time, high air and low density can imply high water content
- Producers have plant operations data – truck age, yd^3/h

Testing Variation

Factors Affecting Strength

NRMCA Publication No. 179

Review of Variables that Influence Measured Concrete Compressive Strength

By David N. Richardson

TABLE 1. Measured Strength Reduction by Nonstandard Conditions

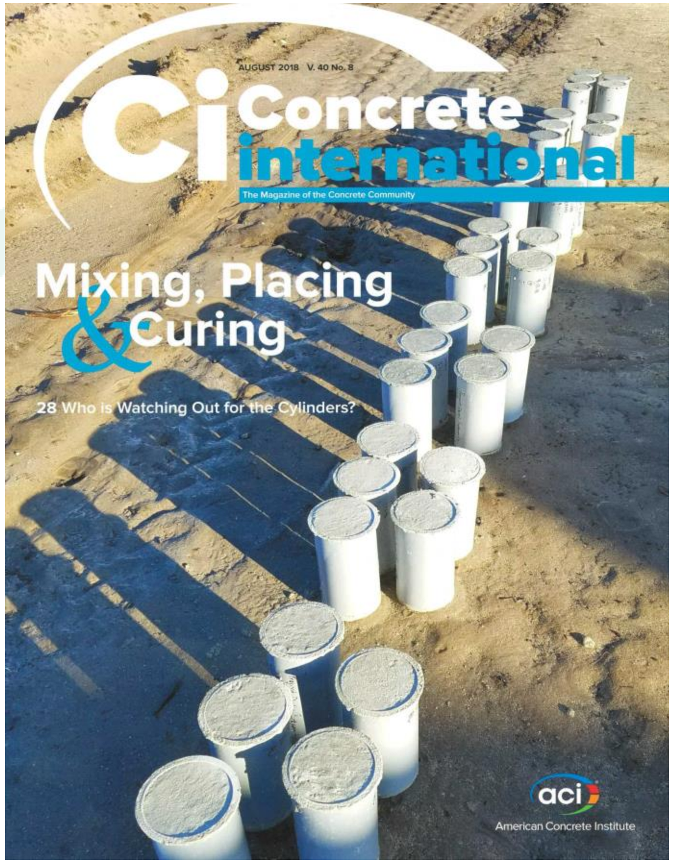
Variable (1)	Strength loss (%) (2)	Lab (L) or field (F) (3)
Convex ends	up to 75	L
Insufficient consolidation	up to 61	F
Immediate freezing for 24 hours	up to 56	F
Rubber cap, no restraint	up to 53	L
Weak, soft capping compound	up to 43	L
Flat particle vertical orientation	up to 40	F
Concave ends	up to 30	L
Rough end before capping	up to 27	F
Seven days in field, warm temperature	up to 26	F
Reuse of plastic molds	up to 22	L
Cardboard mold	up to 21	F
Seven days in field at 73° F, no added moisture	up to 18	F
Plastic mold	up to 14	F
Rough end, air gaps under cap	up to 12	F
Convex end, capped	up to 12	F
Eccentric loading	up to 12	L
Out-of-round diameter	up to 10	F
Ends not perpendicular to axis	up to 8	F
Rough handling	up to 7	F
Three days at 37° F, mixed at 73° F	up to 7	F
One day at 37° F, mixed at 46° F	up to 7	F
Excessive tapping	up to 6	F
Thick cap	up to 6	L
Sloped end, leveled by cap	up to 5	F
Wet mix subjected to vibrations	up to 5	F
Chipped cap	up to 4	L
Rebar rodding	up to 2	F
Insufficient cap cure	up to 2	L
Slick end cap	up to 2	L
Slow loading rate	up to 2	L

Standard Curing (ASTM C31) Strength

- Maintain moisture
- Initial temperature in field
  - 60°F to 80°F
  - *f´c* > 6000 psi - 68°F to 78°F
- Transport to lab within 48 hrs or 8h after final set
- Transportation time 4 hrs or less
  - Proper Cushioning, Protect from Freezing, Moisture Loss
- Lab curing 73.5±3.5°F and moist

Standard Curing unfortunately is uncommon

- 20% strength loss possible



Summary

- Even very good quality concrete has ±30% strength variations due to material, manufacturing, testing
- Input data and AI model needs to capture effect of all these measurements
  - Batch tickets, mill test reports insufficient – Consider C917, SCM fineness, daily physical and chemical properties of CM and SCM; Manufacturing and testing parameters
- Concrete strength AI model can help reduce variability, overdesign, low breaks
  - Predict strength using daily real time material, manufacturing, testing data
  - Quantity impact of sources of variability and lower it by better quality practices / mix adjustments
  - Further refine prediction post measurement/estimation of slump, density, air etc.
- Consider a cement strength AI model that predicts ASTM C917 strength from measured physical and chemical properties of the cement
  - Cement producers can reduce the variation in cement strength and optimize for carbon footprint