
Performance Based Specifications

2011 Alabama Transportation Conference
Montgomery, AL



What is a Specification?

- An explicit set of requirements to be satisfied by a material, product, system, or service
- By Engineer to the contractor
- Basis of legal contract between owner and contractor and establishes joint and separate responsibilities

What is a Prescriptive Specification?

- Specifies material quantities, methods
 - 7 bag minimum cement, combined grading, restrictions on fly ash, slag, maximum w/cm
- Intended performance not clearly indicated
 - Performance may be implied and conflict with prescription

“Experience has shown that prescriptive specifications tend to obligate the agency to accept the completed work regardless of quality”

Glossary of Highway Quality Assurance Terms. Transportation Research Circular Number E-C137

What is a Performance Specification?

- Performance requirements of concrete
 - Plastic state for constructability
 - Hardened state for service
- Measurable and enforceable
- Does not prescribe materials, proportions
- Performance assured with prequalification, job site acceptance testing

What is the P2P Initiative?

- Prescription-to-Performance
 - **Alternative** to prescriptive provisions
- Industry effort spearheaded by the NRMCA from 2002
- Leverage expertise of all parties
 - Roles and responsibilities based on expertise
 - Improve partnering

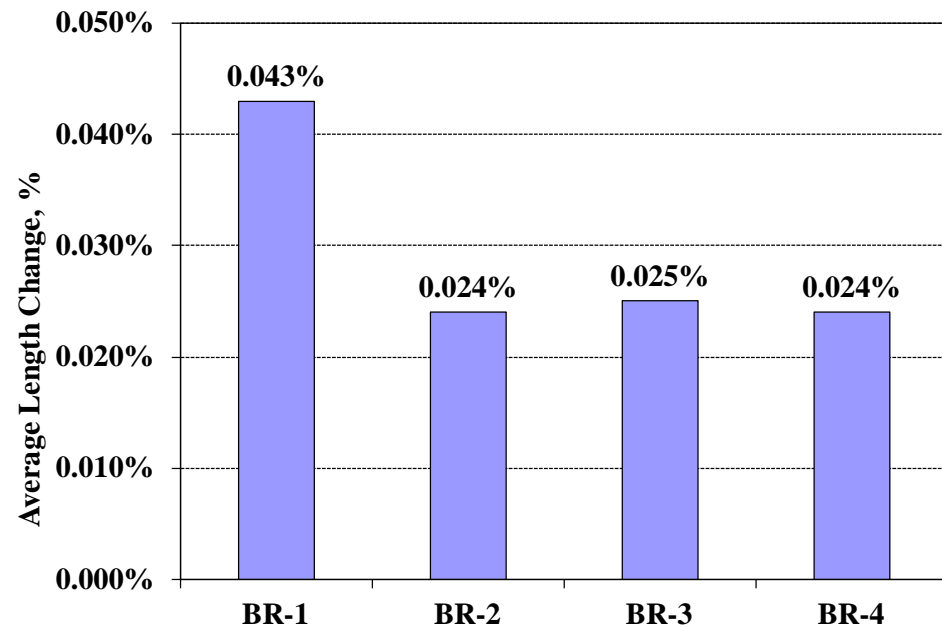
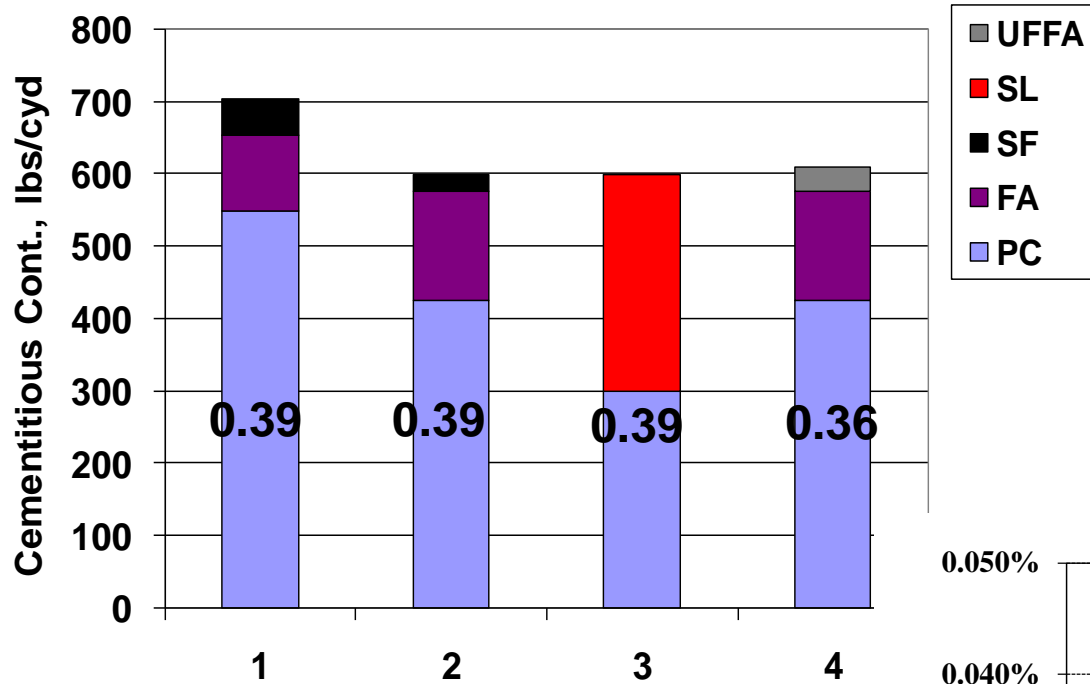


Bridge Deck Application (prescriptive vs performance) – A lab study

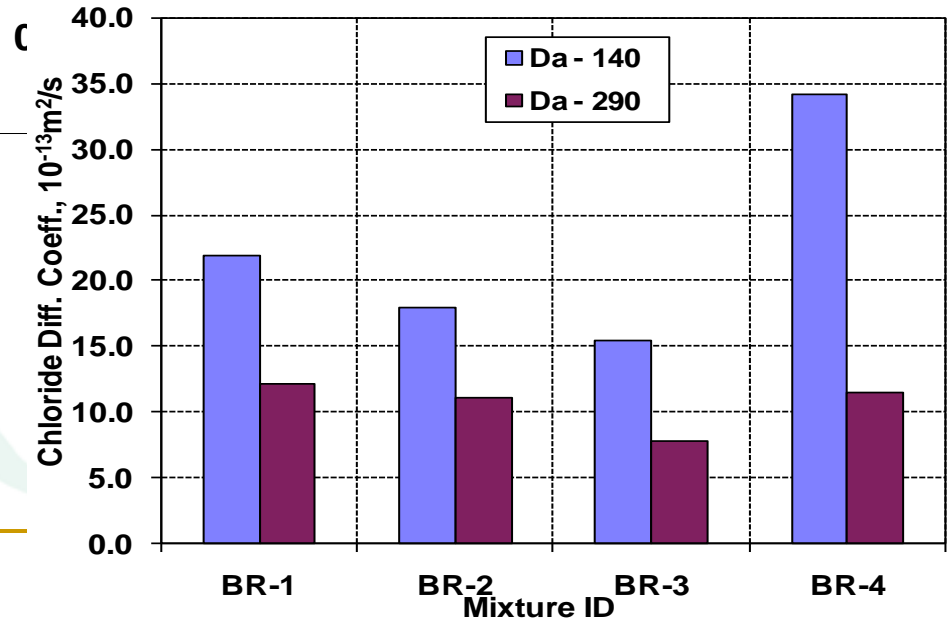
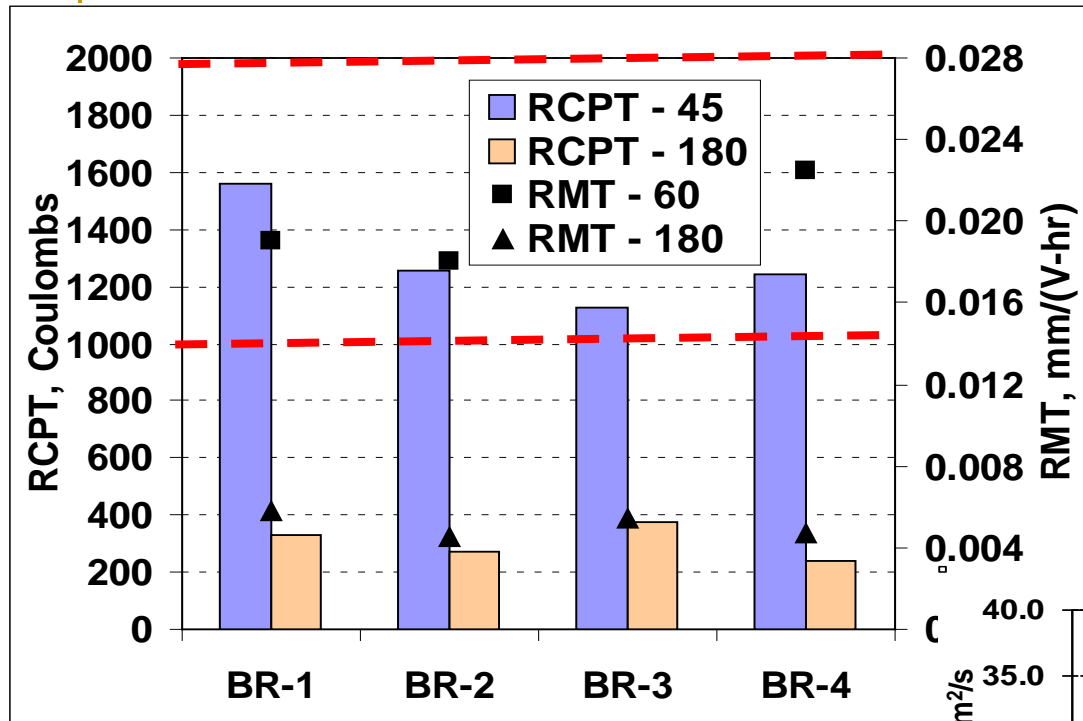
- Specified = 4000 psi
- Slump = 4 to 6 in., Air = 4% to 8%

Prescriptive	Performance Alternative
Max w/cm = 0.39 Total CM = 705 15% FA + 7% to 8% SF	SCM allowed RCPT < 1500 coulomb Shrinkage < 0.04%

Experimental Program



RCPT, RMT



Summary – Bridge Deck Mixtures

- Performance specs ensure performance
 - Strength, Resistance to chloride ingress
- Prescriptive specs may not ensure performance
 - Higher shrinkage, poorer workability
- Performance specs allow mix optimization
 - Encourage cost savings and sustainability

Another Job Specification

- Specification required
 - Min. CM = 650 lb/yd³; 15% fly ash; 4000 psi
- 25% fly ash needed for ASR
 - Spec allowed only 15% cement replacement
- Mixture finally used
 - Total CM = 714 lb/yd³ (552/162)

Optimized Prescriptive Mix?

- Good materials engineer can optimize mix
- But cannot specify it!
- Minimum CM = 600 lb/yd³ can ensure 3000 psi even with poorer materials, production, testing
 - Shortchanges the better performers

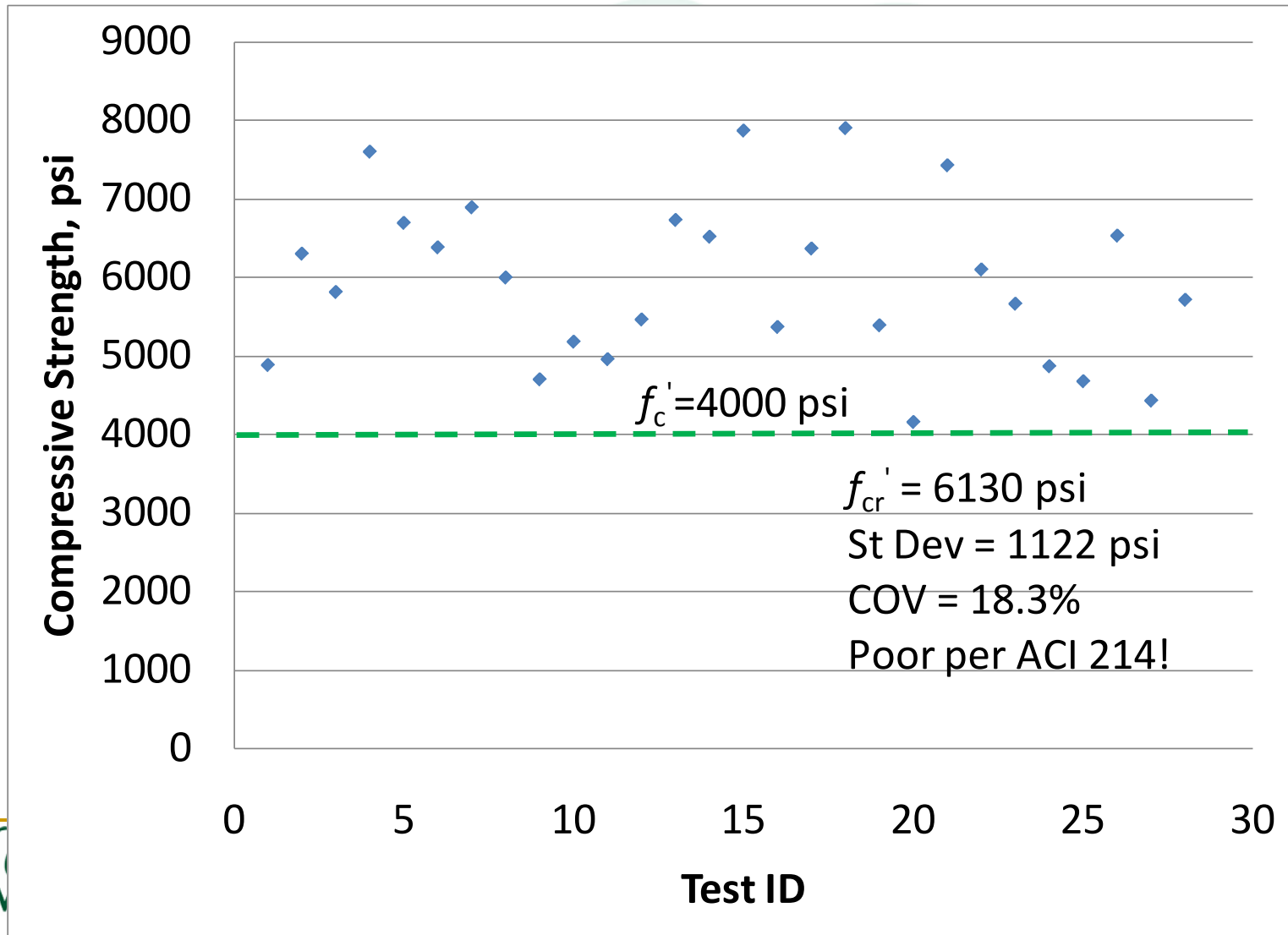
Can this be a Prescriptive Mix?

- New I-35W bridge – CI, February 2009

Component	fc', psi	w/cm	CM, lb/yd ³	PC, %	FA, %	SL, %	SF, %
Super structure	6500	0.35	700	71	25	-	4
Piers	4000	0.45	575	15	18	67	-
Footings	5500	0.45	<600	40	18	42	-
Drilled Shafts	5000	0.38	<600	40	18	42	-

Prescriptive Minimum CM Spec

- No incentive to improve quality



Prescriptive SCM dosage limits

- SCM limits only for very severe FT but often overused

TABLE 4.4.2 — REQUIREMENTS FOR CONCRETE SUBJECT TO EXPOSURE CLASS F3

Cementitious materials	Maximum percent of total cementitious materials by weight*
Fly ash or other pozzolans conforming to ASTM C618	25
Slag conforming to ASTM C989	50
Silica fume conforming to ASTM C1240	10
Total of fly ash or other pozzolans, slag, and silica fume	50 [†]
Total of fly ash or other pozzolans and silica fume	35 [†]

* The total cementitious material also includes ASTM C150, C595, C845, and C1157 cement.

The maximum percentages above shall include:

(a) Fly ash or other pozzolans in Type IP, blended cement, ASTM C595, or ASTM C1157;

(b) Slag used in the manufacture of an IS blended cement, ASTM C595, or ASTM C1157;

(c) Silica fume, ASTM C1240, present in a blended cement.

[†] Fly ash or other pozzolans and silica fume shall constitute no more than 25 and 10 percent, respectively, of the total weight of the cementitious materials.

Overuse of max w/cm spec

- No. 8 aggregate non-air topping mix
 - w/cm = 0.40; 4000 psi, 4 to 6 in.
- Mixture required 290 lb/yd³, Type F = 10 oz/cwt., Type A = 3 oz/cwt.
- Mixture finally used
 - Total CM = 725 lb/yd³ (544/181)
- Exposure did not warrant 0.40
 - With w/cm=0.50, Total CM=580 lb/yd³ (20% lower)

Performance Specifications - Advantages

- Right focus - guarantees performance
- Incentive for producer to be knowledgeable
 - Clearer responsibilities for performance
- Incentive for quality, technology investments
 - Incentive for lower SD
 - Allows mixture optimization, adjustments
- Improved product quality, consistency
 - Reduced construction time, cost

Responsibility and Authority


- Responsibility and authority in concrete construction should be congruent and every entity should be responsible for its own work
 - ***ACI Responsibilities in Concrete Construction***
- Producers and contractors responsible for meeting performance criteria need authority on proportions and construction means and methods

How does Performance Specification work?

- Qualification – plant, practices, personnel
- Performance criteria set by A/E
- Constructability requirements by contractor
- Submittal to demonstrate compliance
 - Pre-qualification, limited jobsite acceptance tests, dealing with non-conformance

Concrete QA

- Installer Qualifications
 - ❑ ACI Flatwork Finisher, or equivalent
- Manufacturer Qualifications
 - ❑ NRMCA plant certification or equivalent
 - ❑ Green Star certification
 - ❑ QC personnel - NRMCA Concrete Technologist Level 2, or equivalent
 - ❑ Quality Plan
 - ❑ Producer quality certification being developed, 2011 (est)






Quality Management System
for Ready Mixed Concrete
Companies

Parts A and B prepared by:
William C. Twitty, Jr., P.E.

Part C Developed by the NRMCA P2P Steering Committee

Reviewed and Approved by the
NRMCA P2P Steering Committee



Concrete QA

- Independent Testing Agency
 - Meets C1077
 - Field tests for acceptance by ACI Concrete Field Testing Technician Grade I, or equivalent
 - Laboratory tests for acceptance by ACI Concrete Strength Testing Technician or Concrete Laboratory Testing Technician (Level I), or equiv.
 - Acceptance test results certified by a registered PE with test lab



Performance Options for Typical Mixture Prescription

Performance Options – Bridge decks, marine structures, parking garages

- Requires low chloride permeability concrete

Prescription	Performance Alternative
Low w/cm, Minimum CM content, and SCM types/dosages	RCPT (ASTM C1202) - 1500 coulombs at 56 days OR 7 d moist, 21 d in 100°F water

Performance Options – Floor Slabs

- Requires concrete with low tendency to crack, curl, good finishability, flatness

Prescription	Performance Alternative
Cement content, aggregate grading, water content, mortar content	Shrinkage (ASTM C157) for mixture qualification - 0.05% after 28 days drying Trial placement for finishability evaluation

Performance Options – Waste water structures

- Requires sulfate resistance, low permeability

Prescription	Performance Alternative
Low w/cm, strength, cement types per ACI 318 Class S exposure	318 allows ASTM C1012 in lieu of cement types Moderate < 0.10% at 6 m Severe < 0.10 at 12 m Very Severe < 0.10% at 18m

Performance Options – ASR

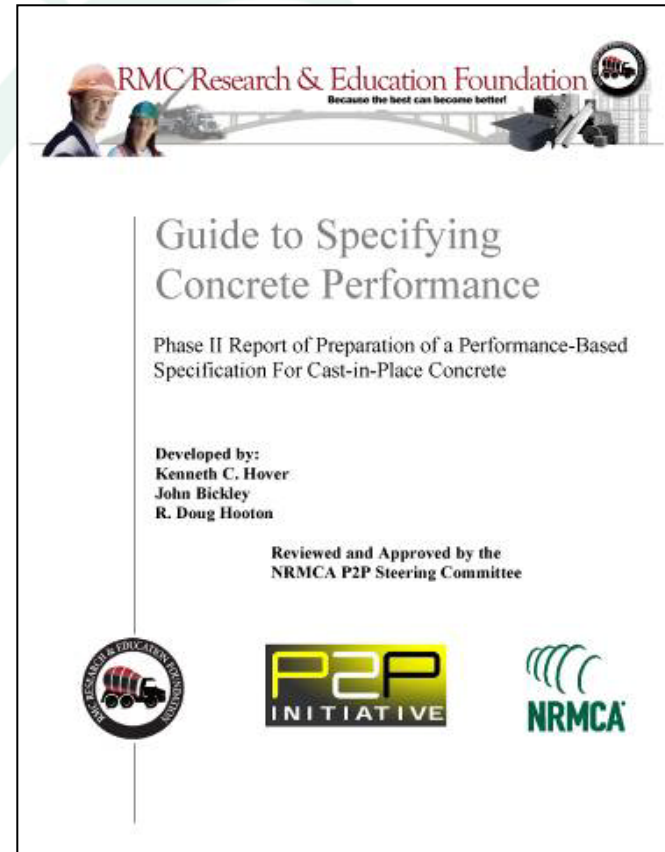
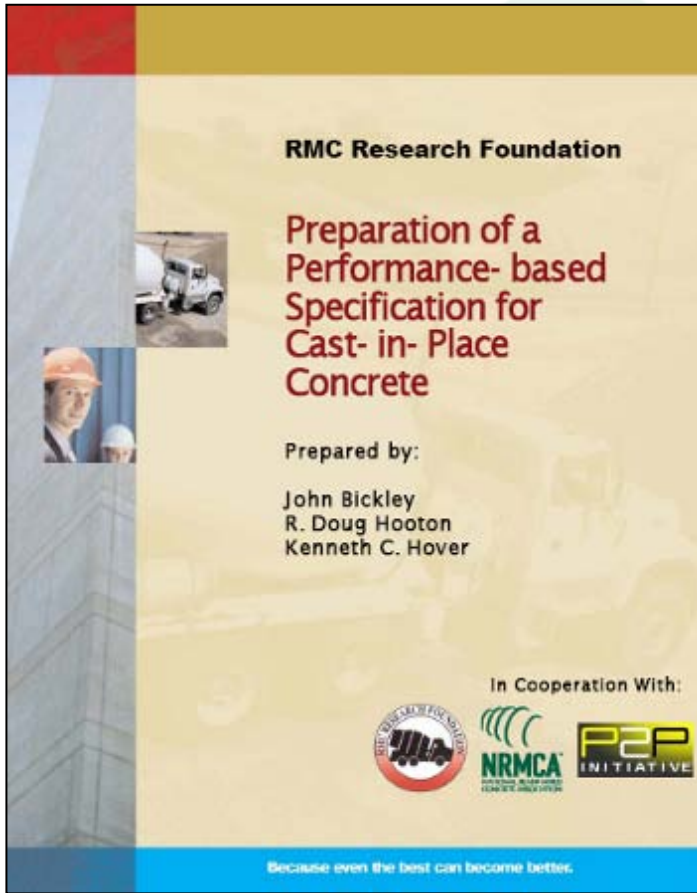
- Requires non reactive aggregates

Prescription	Performance Alternative
SCMs types/dosages, low alkali cement, Lithium	ASTM C1567 for mixture qualification < 0.10% at 16 days

FHWA Report on Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction, FHWA-HIF-09-001,

<http://www.fhwa.dot.gov/pavement/concrete/asr/hif09001/>

Guide to Performance Specification



- ACI 329 - Performance Criteria for Ready Mixed Concrete
- ACI 318-08 has durability exposure class concepts

Report on Performance-Based Requirements for Concrete

Reported by ACI Innovation Task Group 8



American Concrete Institute®

Pooled Fund Research

- Develop performance tests and specification criteria for chloride, sulfate, F-T exposures
- Funded by
 - FHWA
 - 10 state agencies – IN lead state
 - RMC Research and Education Foundation
 - Portland Cement Association (partial)
- PI – Purdue; NRMCA subcontractor

FHWA PRS

- DOT experience with performance specs
 - Virginia
 - Ontario
 - Port Authority of NY/NJ
 - Minnesota
 - Illinois
 - Florida, New Hampshire, California interested

FHWA Performance Related Specs

- Statistically based and has incentive/penalty clauses for strength, permeability, thickness etc
- Sublot – 1/day or 100cyds
- Lot – Class of concrete or 500 cyds

$$LQI = \frac{\bar{X} - LSL}{s}$$

$$UQI = \frac{USL - \bar{X}}{s}$$

X = average; s = standard deviation from the n sub-lots

LSL = specified Strength; USL = specified Permeability

FHWA Performance Related Specs

PWL = % of material within lot above the LQI or below the UQI

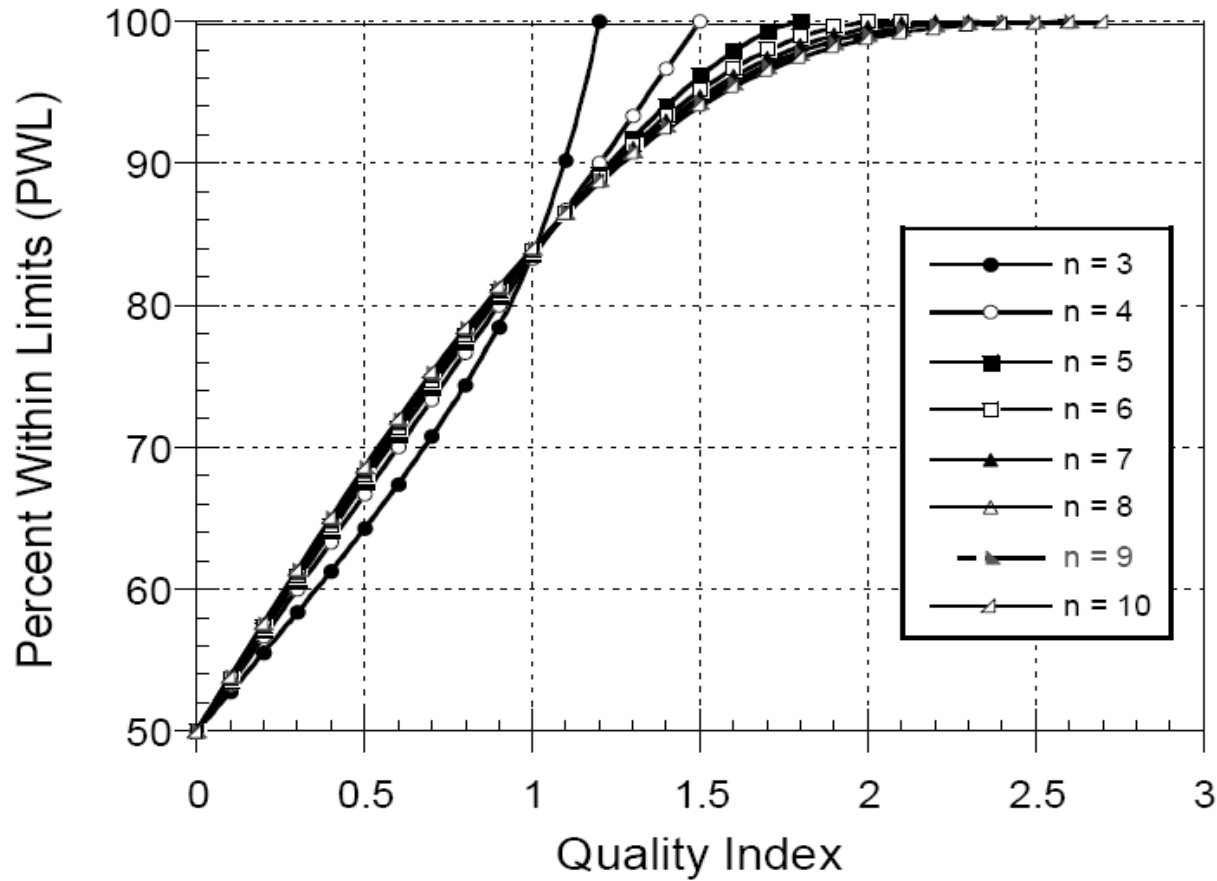


Figure 5.1---Relationship between quality index and percent within limits (values from AASHTO R 9).

FHWA PRS

Table 5.2—Adjustment to Unit Price of Concrete Based on Strength (MTO 2007)

PWL	Action
> 95 %	Bonus payment
90 % to 95 %	Payment at contract price
< 90 % to 50 %	Penalty assessed
< 50%	Rejectable and subject to removal and replacement

$$PF = 82 + 0.2(PWL)$$

If PWL is 100 – 2% incentive

If PWL is 50 – 8% penalty

Summary

- Performance specifications has many advantages
- As a start reduce prescription, incorporate performance

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<http://www.nrmca.org/p2p/>

NRMCA Publication 2PE003

Guide to Improving Specifications for Ready Mixed Concrete

May 2009



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