Prescription to Performance
--The Search for the Holy Grail--

Michael F. Praul, P.E.
Construction & Materials Engineer
FHWA--Maine
Topics

• Variability

• Discuss different types of specifications

• Discuss Maine’s move away from prescriptive specifications for concrete
There are four (4) primary components or sources of *Inherent Variability* in individual test results for material samples:

- Sampling Variability
- Testing Variability
- Material Variability
- Construction (Production and Placement) Variability
1958 AASHO Road Test: Normal Distribution

Property
Per Cent Within Limits (PWL)
Specifications--Some Definitions

- Method specifications
- End result specifications
- Quality assurance specifications
- Performance-related specifications
- Performance-based specifications
Method Specification
(aka Recipe specs, Prescriptive specs)

• Specifications that require the Contractor to produce and place a product using specified materials in definite proportions and specific types of equipment and methods under the direction of the Agency.

• Contractor = Hired labor
Method Specifications

--Features--

• Provide “cookbook” directions for the contractor to follow
• Utilize agency inspection, sampling, and testing to control the work
• Acceptance based on “reasonable conformance” or “substantial compliance”
• 100% pay across a range of quality
Method Specifications
--Drawbacks--

- Does not allow for contractor innovation
- Acceptance decision is arbitrary, no defined quality levels
- Acceptance is statistically invalid
- Questionable legality of “reasonable conformance” or “substantial compliance”
- No financial reward for contractor providing superior quality
End Result Specifications

• Specifications that require the contractor to take the entire responsibility for producing and placing a product. The Agency’s responsibility is to either accept or reject the final product or to apply a pay adjustment commensurate with the degree of compliance with the specifications.
End Result Specifications

--Features--

• Allow for maximum innovation; no controls on contractor methods or equipment
• Quality Control at the discretion of the contractor
• Acceptance of the final product
• Pay adjustment based on specification compliance
End Result Specifications
--Drawbacks--

• Minimizes engineering knowledge of the Agency
  – Process controls
  – Inspection
• Little opportunity to correct deficiencies
• Acceptance target values based on “experience” rather than data
• Lawyer fodder
Quality Assurance Specifications

• Specifications that require Contractor Quality Control and Agency Acceptance activities throughout production and placement of a final product. Final acceptance is usually based on a statistical sampling of the measured quality level for key quality characteristics.
Quality Assurance Specifications
--Features--

- Clear delineation of QC and acceptance roles and responsibilities
- Recognizes inherent material and process variability (PWL)
- Agency identifies key quality measures and levels
- Rational pay according to quality
Quality Assurance Specifications

--Advantages--

• Statistically valid acceptance
  – Random sampling
  – Lot basis vs. single test

• Quality characteristics may be independently evaluated

• Full use of QC and agency inspection

• Real time feedback to production

• Rational basis for modifications to pay
Performance-related Specifications

• Specs that use quality characteristics and life cycle cost relationships that are correlated to product performance.

• Improved QA specs
Performance-related Specifications

--Features--

• Acceptance based on key quality characteristics that correlate fundamental engineering properties to performance
  – HMA: asphalt content or smoothness
  – Concrete: air content

• Mathematical models for LCC
Performance-based Specifications

• QA specifications that describe the desired levels of fundamental engineering properties that are predictors of performance. Those properties predict performance and pay is adjusted accordingly.
Performance-based Specifications

--Features--

• Similar to performance-based but *engineering properties* are measured, not key quality characteristics
  – e.g. Fatigue resistance, creep properties, modulus

• LCC models that relate properties to performance

➢ Not developed yet
Maine

In 7th year of implementing “HPC” through the use of Quality Assurance specs
Maine’s Modified QA Concrete Specification

- QA principles
- Some PWL pay factor (all in Fall ’04)
- Retain some method spec principles
- Aggressive QC requirements
Common Measurables

- Strength
- Air
  - Cover
- Chloride Permeability
  - Link to cover in spec
- w/c ratio
Some Non-measurables

• Curing
• Cold weather practices
• Hot weather practices
• Consolidation
• Stockpile management
• Workmanship
Quality Assurance for Concrete
--Issues--

• Non-measurables; impact on quality

• Industry issues

• Statistical strength and permeability issues
Pay Factors

- Permeability
- Air
- Strength

Fall 2004: Composite pay factor
  - 40% permeability, 40% air content, 20% strength
Current Strength Spec

- Statistical strength analysis per ACI
  - Avg. of 3 tests within 150 psi of $f'_c$ or 1 test 200 psi below $f'_c$ = remedial action
  - Pay factor is not PWL, linear based on avg. $f'_c$
  - No positive pay adjustment
Current Permeability Spec
--AASHTO T-277--

• 7.5% or 5% max. bonus for permeability
  – HPC criteria
• Test @ 56 days unless >10% fly ash, then up to 120 days
• Average of two tests per sublot
Permeability Pay Factor

Max

PAY FACTOR

PAY FACTOR

1.0

800  Coulombs  2000/3000
Air Content

- 2.5% max. bonus for air
- PWL calculation
Mix Design Approval

- Permeability trial batches
- Gradation limits
- ASR remediation
- Deleterious aggregate test
- Coarse aggregate absorption
- Limit pozzolan content
  - 30% fly ash; 50% slag
- Limit total cementitious content (660#/yd^3)
Typical Mixes

• Class A (structural)
  330# Type II cement
  330# GGBFS
  1200# Fine agg.
  1800# Coarse agg.

• Class LP (overlays, sidewalks, etc.)
  318# Type II cement
  318# GGBFS
  10 to 25# silica fume
  1200# Fine agg.
  1800# Coarse agg.
MDOT Specification

• Attempts to address workmanship
  – Surface tolerance
  – Finish

• Evaporation rate for flatwork
  – 0.1 #/sf/hr to start
  – 0.15#/sf/hr = remediation per QC Plan
MDOT’s QC Plan

• Submitted prior to any construction of QA items
• Includes all the items in the traditional plan

PLUS

• Contractor’s method of complying with specs for non-measurables that significantly affect quality
• Significant financial penalties for violating QC Plan
What Has Maine Done and Learned?

• If QA specs are used, appropriate attention must be paid to the non-measurables
• Detailed QC Plans with monitoring are a must
• Statistical analysis can be a hard sell with industry
The End