What is Concrete?

- One of the planets' largest CO₂ sources
- Immovable blocks
- Gray, cracked and hard
- Makes our trucks dirty
- Money
- The backbone of civilization

What was Good Concrete?

- Easy to work with
- Strong
- Lasts forever
- Cost effective
The Way We Were

- Cements
  - Wet kilns
  - High C₃S / low C₂S
  - Straight OPC

- Proportions
  - Ordinary 1:2:4
  - Fancy 1:1:½
  - Add water to taste

- Chemical Composition

The Way We Were

- Cements
  - Dry kilns
  - Low C₂S / high C₃S

- SCM
  - Slag cement and fly ash

- Admixtures
  - Air entrainers
  - Water reducers

- Proportions
  - Recipes (564/1200/1800/255)
  - ACI 211
    - Guess water
    - Add cement
    - Estimate rock
    - Fill with sand

- Do what you did on the last project
The Way We Were

• Equipment

The Way We Were

• Curing

The Way We Were

• Design Life
  • 20 years
  • ...
  • 40 years

The Way We Were

Quality Assurance

• Slump
• Strength
• Thickness

• Air
### Why Bother with Change?

- Current approaches
  - May not measure critical parameters
  - Are often built around previous failures – thereby introducing unintended consequences
  - Limit innovation
  - Need to reduce risk of premature failure

### The Journey Toward Performance

**Engineered Mixes (PEM)**

- Near the millennium, concerns about concrete durability and poor pavement performance became a common topic of discussion in many concrete intensive states.

### 1967 vs. 2017

<table>
<thead>
<tr>
<th></th>
<th>1967</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of ingredients</td>
<td>Cement, water, rock, sand, AEA</td>
<td>Add SCMs, Non-Portland cements, admixtures, intermediate aggregates, limestone…</td>
</tr>
<tr>
<td>Opening</td>
<td>Weeks</td>
<td>Days (or hours)</td>
</tr>
<tr>
<td>Curing</td>
<td>Weeks</td>
<td>Days</td>
</tr>
<tr>
<td>De-icing</td>
<td>Sand, NaCl</td>
<td>Other chlorides, formates, acetates</td>
</tr>
<tr>
<td>Design life</td>
<td>20 years</td>
<td>50 years</td>
</tr>
<tr>
<td>Knowledge base</td>
<td>In house</td>
<td>Contracted out</td>
</tr>
</tbody>
</table>
What is Good Concrete?

- Constructible (Workable)
- Dimensionally stable
  - Aggregates
  - Shrinkage
- Impermeable (Transport properties)
- Cold weather resistant
  - Freeze thaw
  - Salt attack
- Strong (enough)

A Better Specification

- Require the things that matter
- Measure them at the right time
  - Prequalification
  - Process control
  - Acceptance

The Goal…

Long-lasting pavement

Construction Activities

Acceptance

QC

QC data should be invisible to the Acceptance process

MCTC

Quality Control and Agency Acceptance

Quality Assurance

Quality Control

Agency Acceptance

Independent Assurance

Qualified Labs

Dispute Resolution

Qualified Personnel
Learning Outcomes

- Understand the purpose of producer/contractor QC
- Recognize that QC includes both inspection and testing
- Describe the relationship between QC and acceptance

Quality Control

- A good Producer/Contractor QC system:
  - Doesn’t try to accommodate Agency requirements
  - Implements QC procedures as a standard practice
  - Isn’t just paperwork...it’s a mindset

  Uses real time feedback

QC Tests are the Building Blocks for Acceptance

- Acceptance tests
- QC tests
- Process control

QC is NOT doing more of what the Agency does for acceptance!

Producer/Contractor Responsibility for QC

- Agencies assumed the QC Responsibility under Method Specifications
- QA Specifications transferred the QC Responsibility to the Producer/Contractor

- Party producing/placing the product controls quality
- Agencies communicate what they are willing to accept
- Agency ensures QC takes place
Scope of Quality Control Activities

Producer/Contractor’s QC system should address:

- Materials production processes
- Materials transportation and handling
- Field placement procedures
- Calibration and maintenance of equipment
- Activities (sampling, testing and inspection) to maintain each process in control
- Means to make timely adjustments and corrections

Variability in Quality Control

Material | Process | Sampling | Testing

Composite Variability

Quality Control Function

- Should be integrated throughout the organization
- QC not just the responsibility of QC personnel
- Quality can only be achieved by skilled and properly trained workers

QC Personnel Requirements

- QC Laboratory Personnel
- Field QC Technicians/Inspectors
- Production Personnel
**Quality Control Plan**

- Project specific document
- Prepared by the Producer & Contractor
- Identifies QC personnel and procedures
- Used to maintain control of production and placement processes

**QC for Concrete Pavement Construction**

- Implementation of a QC Process
  - Mixture design (prequalification)
  - Mixture verification (field setup)
  - Mixture production and construction QC
  - Mixture and construction acceptance

See Section 5 in *Quality Control for Concrete Pavements* (Cavaline, Fick, Innis. 2021) heavily based on materials presented in:


**QC Plan Review Objectives**

- QC plan may serve as an extension of the project specifications
- Agency should review the QC plan to ensure:
  - Includes all required items
  - Contains sufficient detailed content addressing project specifics
- When the QC plan is deficient, agency should require revision

**Inspection by Production Personnel**

- Adopt Safety Culture Philosophy for Quality
- Contractors should strive to create a “Quality Culture” throughout the company
- Personnel are aware of how their actions can affect the quality of the product
- Contractors must invest in the continual education and training of their work force in order to maximize their involvement in Quality Control
Inspection by Production Personnel

- Should take initial responsibility for accepting or rejecting it
- Should always communicate their findings and proposed actions with their QC staff

Visual Inspection for Quality Control

- Visual inspection is also essential to achieving quality
- Observations and measurement of
  - Equipment
  - Materials
  - Environmental conditions
  - Workmanship
- Prevention based
  - See something, say something

QC Testing

- Testing is not done just for the sake of testing
- Test results are used to assess production consistency
- Use control charts to monitor trends in production
- Control charts are tools to identify when a production adjustment is necessary

Control Charts

- Used to plot and monitor consecutive test results
- Results can be tracked against a process target/limits
- Can help identify whether the process is in control
- May indicate that adjustments process is necessary
**Concrete Pavement Resources for Industry/Agency/Academia**

**Safe & Long Lasting Concrete Pavements**

**Improved Working Atmosphere**

**Fewer Quality Disputes**

**Improved Public Image**

**Quality Control for Concrete Paving: A Tool for Agency and Industry**

**Improved Quality**

**Reduced Costs for Agency & Competitive Advantage for Contractor**

**Quality Control Fundamentals**

- **Introduction to QC**
  - 1. PLAN
    - identify problems
    - define desired outcomes
    - identify potential solutions
    - develop policies and procedures
  - 2. DO
    - test potential solutions
    - create process structure
    - establish systems
    - conduct training
    - measure quality characteristics
    - collect data
  - 3. CHECK
    - monitor and analyze data
    - study the results
    - draw conclusions
  - 4. ACT
    - identify lessons learned
    - implement the most promising corrective and preventative actions

“Any product, process, or service can be improved, and a successful organization is one that consciously seeks and exploits opportunities for improvements at all levels.” (Swift et al. 1998)

**Introduction**

In this age of high demands on quality and dependability of engineering materials and systems, and the manufacturer’s potential involvement in product liability, well-developed quality control systems have become an indispensable part of doing business in many industries. Ready-mixed concrete involves several unique factors which require attention.
• Part A: Preparation Guidelines for Quality Manual for Ready Mixed Concrete Companies
• Part B: Sample Quality Manual: Global Ready Mixed Company
• Part C: Ready Mixed Concrete Company External Quality Audit Checklist for Compliance with Quality Plan

Closing

• Contractor QC is an integral part of QA
• Agencies have various requirements for QC, but those requirements are only minimum provisions
• A successful QC program/plan
  • engages the appropriate personnel
  • manages the necessary processes
  • measures what matters, and
  • uses the appropriate test methods.
• QC required for each project will differ, and approaches will be unique to the contractor
• QC programs achieve success over time, and provide benefits to both agency and contractors

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