Advanced Concrete Inspection

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Achieving the Goal

Design:
• Control the constituents (cement, aggregate, water, admixtures) to achieve a specific performance.

Inspection:
• Verify the design.
• Ensure the conditions for the best chance of desired performance.
Concrete History

Named after quarry stone from the Isle of Portland in Britain.

First used by Joseph Aspdin from Leeds, England in 1824.

Other forms used throughout antiquity.
Pantheon, Rome
built by Emperor Hadrian ~126 AD
Colosseum, Rome
built by Emperor Titus ~80 AD
Stabiae Baths, Pompeii
built 1st Century
Temple of Mercury, Baiae
built ~19 BC
Glossary of Terms

Batch Ticket
Mix Design
Cement Certificate
Compressive Strength
Slump
W/C Ratio
Air Entrainment

Porosity
Permeability
Durability
Hydration
Drying
Curing
Unit Weight
Yield
Cross Section of Hardened Concrete

Concrete made with siliceous rounded gravel

Concrete made with crushed limestone
Concrete Components

- Cement
- Water
- Fine Aggregate
- Coarse Aggregate
Range in Proportions

Mix 1
- Cement: 15%
- Water: 18%
- Air: 8%
- Fine agg.: 28%
- Coarse agg.: 31%

Air-entrained concrete

Mix 2
- 7% 14% 4% 24% 51%

Mix 3
- 15% 21% 3% 30% 31%

Non-air-entrained concrete

Mix 4
- 7% 16% 1% 25% 51%
Properties

• The only construction material that when delivered has none of its intended properties.
Properties

- Hard
- Solid
- Dry
- Without cracks
- Flat/Level
- Impermeable
- Permanent
- Durable
Properties

The final result depends on:

• Workmanship
• Constituents
• Environment
Cement Types

• Type I: general purpose portland cement suitable for most uses.
• Type II: moderate sulfate resistant for use in sulfate-rich conditions.
• Type III: high early strength.
• Type IV: hydration retarding.
• Type V: high sulfate resistant.
• Type _A: air entrained variants.
Cement Types

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- **Type IV**: hydration retarding.
- **Type V**: high sulfate resistant.
- **Type _A**: air entrained variants.
Concrete Inspection

Concrete Inspection Consists of:

- Documentation review
- Field inspection
- Field testing
- Laboratory testing
Documentation Review

Batch Ticket:

• Confirm mix design
• Batch time
• Water added
• Admixtures
• W/C Ratio
• Drum revolutions
Field Inspection

Reinforcement:
- ICC, ACI, design criteria
- Rebar diameter
- Lap splicing
- Location and spacing
- Cover dimension
- Special bends and connections
Field Testing

Slump:
• Measures consistency
• ASTM C 143

Air Entrainment:
• Measures total air content
• ASTM C 173 or 231
• Must be corrected for aggregate
Laboratory Testing

Cylinder Castings (ASTM C 31):

- Four specimens of 6X12-inch
- Laboratory cured
- Compressive strength (ASTM C 39)
  - Design strength is the uniaxial load capacity of at least two, 28-day specimens.
  - 7 and 14-day specimens can also be tested.
Laboratory Testing

Additional Test Parameters:

- ASTM C 138
  - Unit weight (density) of concrete
  - Yield (volume) of concrete
  - Total air content
Who Owns the Concrete?

• The ready mix provider owns the concrete until it leaves the chute.

• During placement, the contractor has an obligation to place, finish, and cure the concrete to meet specified performance criteria.

• When to reject a load?
Who Owns the Concrete?

- They own it
- Inspection
- You own it
Why Inspection?

• Verify the concrete delivered is the proper mix design.
• Ensure the proper workmanship.
• To achieve **durability**.
Durability

Ability of the Concrete to Resist its Environment:

• Weathering/erosion
  ⇒ Moisture
  ⇒ Freezing and thawing
  ⇒ Temperature changes
• Physical impact
• Chemical attack
Durability

• The ability of a concrete to achieve the designed service life without excess deterioration.

• Is not only dependent upon concrete strength.

• A typical minimum service life for normal concrete is 50 years. 75 years is proposed by ACI and PCA. Nuclear reactors are designed for 120 years.
Durability

Three Keys to Durability:

• Low w/cm
• Air entrainment
• Curing
Hydration

- Is the chemical reaction between the cement and water in which new compounds with strength producing properties are formed.

Heat of Hydration

- Is the heat given off during the chemical reaction as the cement hydrates.
Curing

• Maintenance of moisture and temperature in concrete for a suitable period immediately following placement & finishing to develop desired physical properties:
  ✓ Time
  ✓ Temperature
  ✓ Moisture
Drying

• Independent of curing. Drying is the process of free-water (water not consumed in hydration) volatilizing from the concrete.

• Concrete will cure even when placed under water.

• Water that dries out leaves void space in the cement.
W/CM Ratio

• Ratio of mass of water to mass of cementing materials in a concrete mix expressed as a decimal.

• Theoretical minimum w/cm ratio of typical concrete ranges from 0.24 to 0.35, but difficult to hydrate fully.

• Common practice w/cm ratio ranges from 0.40 to 0.55.
W/CM Ratio
W/CM Ratio

To Calculate (by weight):

- \( \frac{w}{cm} = \frac{\text{water wgt}}{\text{cement wgt}} \)

- \( = 300 \text{ lbs} / 450 \text{ lbs} + 150 \text{ lbs} \)

- \( = 300 / 600 \)

- \( = .50 \)
W/CM Ratio

- Reducing w/cm ratio is the most effective way to increase the durability of concrete.
- Maintain workability using admixtures while achieving high-strength and low permeability.
Permeability

• Is a function of porosity and is controlled by w/cm.

• Improves durability by making the concrete more dense.

• Opportunity to control permeability occurs during placement.
Permeability

How to Control:

• Verify mix design, especially w/cm.
• Do not add water on-site.
• Use admixtures to achieve desired workability.
  ➞ Fly ash
  ➞ WRA
  ➞ Plasticizer
Air Entrainment
Air Entrainment

The only effective protection against freeze/thaw damage.

Consists of:

- Microscopic bubbles (1µm to 1 mm)
- Evenly dispersed (.008 in. spacing)
- At 4% by volume (±1%)
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Field Measurement (fresh):

• Volumetric method by ASTM C 173
• Pressure method by ASTM C 231
  - Is most commonly used
  - Must be corrected for aggregate porosity
  - Measures total air (entrained + entrapped air)
Air Entrainment

Laboratory Measurement (hardened):

• Unit Weight by ASTM C 138
  ➞ Quick and inexpensive
  ➞ Measures total air only

• Air Void System by ASTM C 457
  ➞ Measures entrained air separately
  ➞ Provides spacing factor, specific surface, and fineness (size)
Air Entrainment

All concrete contains air bubbles:

- Large, entrapped, *accidental* air
- Small, entrained, *intentional* air
  - Made small by the type of agent
  - Stabilized by static charge
  - Kept spherical by surface tension
Air Entrainment

Large bubbles: low shell to air ratio.

Small bubbles: high shell to air ratio.
Air Entrainment

Microscopic Air Void System Analysis:

- Requires a polished, rectangular, 3” X 5” sample.
- Performed using stereomicroscope at 400X; counting 1350 points.
- Reports only the entrained air fraction; entrapped air is ignored. Results are always less than field measured air.
Curing

Maintaining satisfactory moisture content and temperature in concrete for a suitable period of time immediately following placing and finishing so that the specified properties may develop:

• Time
• Temperature
• Moisture
Curing

Time:
• At least 3 days
• Ideally until 75% strength is achieved

Temperature:
• 60 to 90°F

Moisture:
• Keep the surface damp
• Protect with wet burlap or plastic
Cold-Weather Concrete Practice

General weather conditions that may trigger cold-weather practices:

• <40°F for 3 successive days
• Wind-chill factor
• Bleed water will freeze below about 25°F
Cold-Weather Concrete Practice

Recommended mitigation for freezing temperatures:

- Warm mix water
- Accelerant admixture (non Cl-)
- Cover with insulating blankets
- Provide heat
- Until 500 psi (at least 2 days)
Hot-Weather Concrete Practice

Potential problems:

- Early setting
  - 10 hours @ 60°F
  - 4 hours @ 100°F
- Slump loss (workability)
- Loss of air entrainment
- Rapid drying shrinkage
- Thermal cracking (large mass)
Hot-Weather Concrete Practice

General weather conditions that may trigger hot-weather practices:

- Temperatures >90°F
- Relative humidity <25%
- Winds in excess of 20 mph
Hot-Weather Concrete Practice

Recommended mitigation for high temperatures:

• Reduce cement content
• Add retarding admixture
• Chill mix water
• Cool rebar
• Deliver during cool periods of day
• Use water fog
Recommended mitigation for windy conditions:

• Use water fog
• Use wet burlap
• Apply pigmented curing agents
• Cover with plastic sheeting
QUESTIONS?