

# Control Tests for Concrete

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# Objectives

- Purpose
- Frequency
- Planning
- Testing fresh concrete



# Purpose of Control Testing

- Provides assurance that specified properties are achieved
- Provides feedback for mixture adjustments



# Frequency of Control Testing

- Random tests occur to accept a material or component
- Process control tests are nonrandom and occur often to allow process adjustments
- Frequency depends on uniformity of materials





# Frequency of Control Testing

- Process control tests occur twice per day at a batch plant
- Frequency reduces as material uniformity is established for a project
- ASTM C1451, *Standard Practice for Determining Uniformity of Ingredients of Concrete From a Single Source*



# Avoiding Problems

## QA/QC Plan

- Communication & Planning
- Pre-Construction Meeting
  - ◆ Owner
  - ◆ Architect/Engineer
  - ◆ General Contractor
  - ◆ Sub-Contractors
    - Ready-Mix Supplier
    - Concrete Contractor
  - ◆ QA/QC Inspector

# Qualification of Personnel



- Knowledge and Skills
- Certification Required
  - ◆ ASTM C94
  - ◆ ACI 318
- ACI Concrete Field Testing Technician
- ACI Concrete Strength Testing Technician
- ACI Concrete Laboratory Testing Technician



# Testing Fresh Concrete

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- Sampling
- Temperature
- Consistency
- Density and yield
- Air content
- Strength



# Reference Documents

## ASTM

- C31, *Standard Practice for Making and Curing Concrete Test Specimens in the Field*
- C39, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*
- C138, *Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete*
- C143, *Standard Test Method for Slump of Hydraulic Cement Concrete*
- C172, *Standard Practice for Sampling Freshly Mixed Concrete*
- C173, *Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method*
- C231, *Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method*
- C1064, *Standard Test Method for Temperature of Freshly Mixed Portland Cement Concrete*

# Sampling and Testing Fresh Concrete



- Purpose: to obtain a truly representative sample of the freshly mixed concrete
- ASTM C172
- Required for all tests except temperature

# ASTM C172 Procedure

- 1 ft<sup>3</sup> minimum
- All water added
- Middle portion of batch
- Composite samples
- Re-mixed
- Time limits



# Frequency of Sampling



- Once per day, per class, but not less than:
- Once for each  $115 \text{ m}^3$  ( $150 \text{ yd}^3$ ) of each class placed each day, but not less than:
- Once for each  $500 \text{ m}^2$  ( $5000 \text{ ft}^2$ ) of slab or wall surface area placed each day



# Temperature

## ASTM C1064



- Purpose of Test: To determine if fresh concrete temperature falls within allowable specification limits.



# ASTM C1064 Procedure

- Place device in concrete with at least 75 mm (3 in) clear cover in all directions
- Allow temperature to stabilize over at least 2 minutes
- Complete test within 5 minutes of sampling



# Typical Specification Limits

## ASTM C94

- ACI 306-For Cold Weather Concreting:

### Section Size Min. Temperature

< 12 in.    55° F (13° C)

12-36 in.    50° F (10° C)

36-72 in.    45° F ( 7° C)

> 72 in.    40° F ( 5° C)

Do Not Exceed 90°F (32°C)

- ACI 305-For Hot Weather Concreting:

Try Not to Exceed 90°F (32°C)

# Controlling Temperature

## ACI 305- Hot Weather Concreting



## ACI 306- Cold Weather Concreting





# Slump

## ASTM C143



- Purpose of Test: To determine consistency of fresh concrete and to check uniformity from batch to batch.

# Importance of Slump

- Slump is NOT a measure of Workability!!
- Do NOT compare slumps from different concrete mix designs.



Should Design Mixtures for Placement Conditions not Slump.

# ASTM C143 Procedure

- Place concrete in 3 equal layers within cone
- Vertically raise cone steadily
- Measure height distance of original center





# Typical Specification Limits

- ASTM C94:

<u>Specified Slump</u>	<u>Tolerance</u>
$\leq 2$ in.	$\pm \frac{1}{2}$ in.
2-4 in.	$\pm 1$ in.
$> 4$ in.	$\pm 1\frac{1}{2}$ in.

If Specified “Not to Exceed”

<u>Max.Slump</u>	<u>Tolerance</u>
$\leq 3$ in.	- $1\frac{1}{2}$ in.
$> 3$ in.	- $2\frac{1}{2}$ in.



# Controlling Slump

## (Control Consistency)



- w/cm
- Wash Water
- Agg. Moisture
- Temperature
- Haul Time
- Mixing Time
- Admixture Dosage
  - ◆ Water Reducers
  - ◆ Air-Entrainers



# How about water added on site?

- ACI 301, ACI 302, ASTM C94 **all allow limited addition of water...**
- If water addition is allowed, the w/c ratio and the maximum water content may not be exceeded

# Density and Yield

## ASTM C138



- Purpose of Test: To find the weight per cubic foot of fresh concrete, which is used for determining yield and cement factor.

# Importance of Yield



- Ready Mixed Concrete is sold on the basis of the volume of fresh, unhardened concrete ( $\text{m}^3$  or  $\text{yd}^3$ ).
- Should receive amount ordered and billed



# ASTM C138 Procedure

- Place concrete into container of known mass and volume
- Measure mass of concrete and calculate density
- Calculate yield using batch weights
- Calculate air content using theoretical density



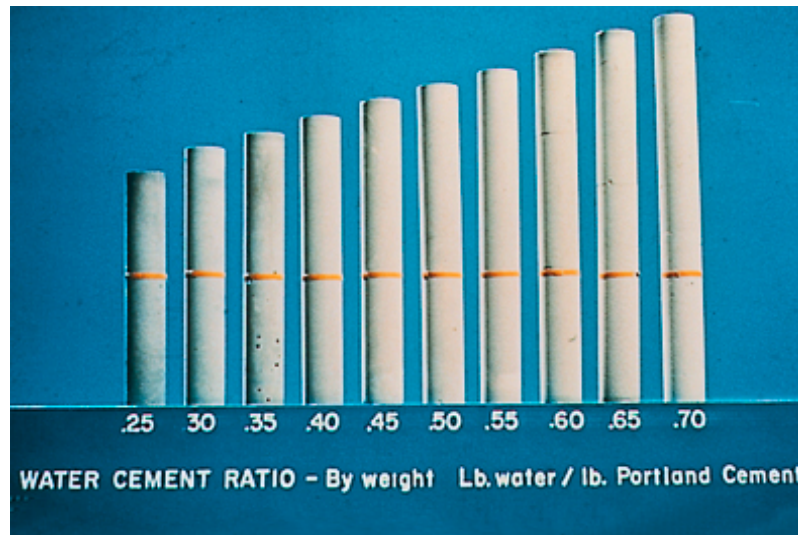
# Typical Specification Limits

## ASTM C94

### Material Tolerance

- Cement:  $\pm 1\%$
- SCM's:  $\pm 1\%$
- Aggregate:  $\pm 2\%$
- Water:  $\pm 1\%$
- Admixtures:  $\pm 3\%$

# Controlling Yield and Under Ordering



- Water content
- Air Content
- Subgrade-
  - ◆ moisture content
  - ◆ levelness  
(highs & lows)
  - ◆ overexcavation
- Distortion of Forms
- Waste (4-10%)



# Air Content

## ASTM C231, ASTM C173



- Purpose of Test: To determine the air content of fresh concrete.



# Importance of Air

- Durability
  - ◆ Freeze-Thaw
  - ◆ Scaling



Photos courtesy  
of M. Thomas

# ASTM C231 Procedure

- Place concrete
- Apply pressure
- Release and read gauge
- Make corrections for aggregates



# ASTM C173 Procedure

- Place concrete
- Add alcohol and water
- Seal container, shake and roll
- Release and read





# Air Content Acceptance

- $\pm 1.5$  of the Specified Percentage
- Low – Additional Dosage of Admixture
- High
  - ◆ Additional Revolutions in Mixer/Agitator
  - ◆ Air Detraining Admixtures
  - ◆ Vibrator in Mixer/Agitator
- Not To Exceed total Mixing or Agitating Time



# Controlling Air Content

- Cement content;
    - ◆ **fineness, alkali**
  - Aggregates;
    - ◆ **fineness, shape**
  - Admixtures
  - w/c
  - Slump;
    - ◆ **<3-in., >6-in.**
  - Temperature
  - Altitude
  - Mixing speed, time, capacity
- Transportation
  - Placement; pumping
  - Consolidation
  - Finishing



# Compressive Strength

## ASTM C31



- Purpose of Test: To check for adequacy of mix proportions for strength.

# Importance of Strength



- To determine acceptance of strength for form removal, and service of structure.

ASTM C39



# ASTM C31 Procedure

- Place concrete into molds on level ground
- Move as little as possible, leaving the specimens near the placement site
- Shelter the specimens from hot or cold weather



# Strength Tests

- Test Methods
  - ◆ ASTM C39 – Cylinders
  - ◆ ASTM C78 – Simple Beam
  - ◆ ASTM C496 – Tensile Splitting
- Cores and In-Situ Tests





# Transporting Test Specimens



- At least 8 hours after final set
- Packed in a sturdy box
- Surrounded with wet sand or wet saw dust
- Protected against freezing
- Transport time less than 4 hours



# Test Cylinders at the Lab



- ASTM C39 – Testing Cylinders
- Capping
  - ◆ ASTM C617 – Capping
  - ◆ ASTM C1231 – Unbonded Caps
- Measurements
- Testing
  - ◆ Maximum Load
  - ◆ Strength, within 10 psi
- Conical Failure



# Controlling Cylinder Strength



- w/cm
- Water Added
- Air Content
- Aggregate Bond
- Handling
- Curing Temperature
- Testing Errors



# Typical Specification Limits

## ASTM C94 (ACI 318)

- The average of any three consecutive strength tests shall be equal to, or greater than, the specified strength,  $f'_c$ .
- No individual strength test shall be more than 500 psi [3.5 MPa] below the specified strength,  $f'_c$ .





# Low Strengths

Test	Individual Strengths $f'_c = 3000$	Average of 2 Strengths	Average of 3 Tests	Evaluation
1	$3110 + 3080 = 6190$	3095	-	OK
2	$3060 + 3020 = 6080$	3040	-	OK
3	$3120 + 3160 = 6280$	3140	3092	OK
4	$2980 + 3010 = 5990$	2995	3058	OK
5	$2800 + 2860 = 5660$	2830	2988	Avg of 3
6	$3040 + 3100 = 6140$	3070	2965	Avg of 3
7	$2510 + 2460 = 4970$	2485	2795	< 500 psi Avg of 3



# What to Do?

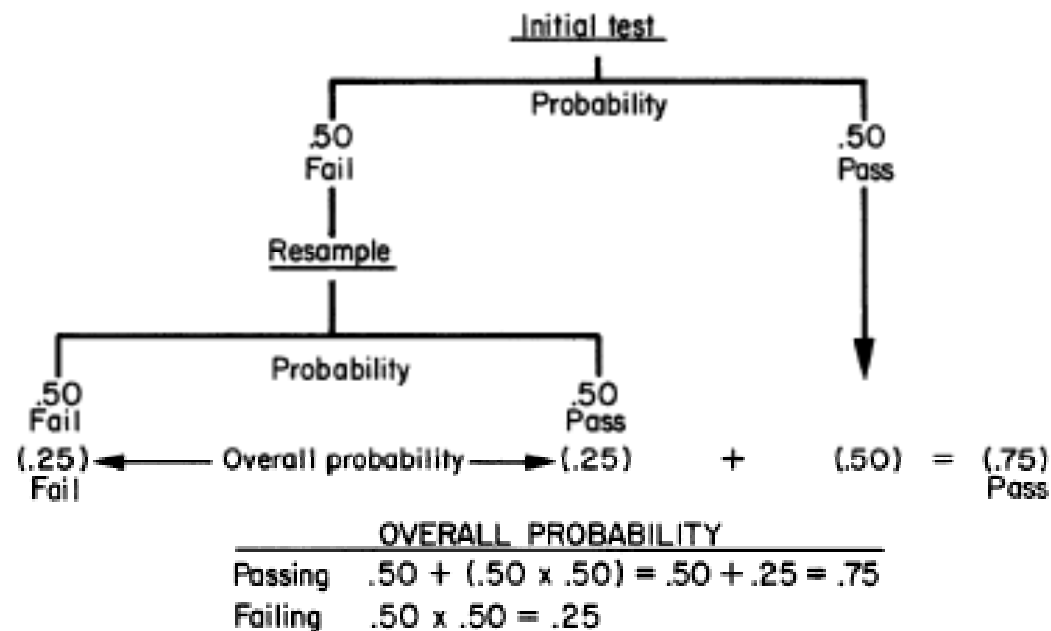
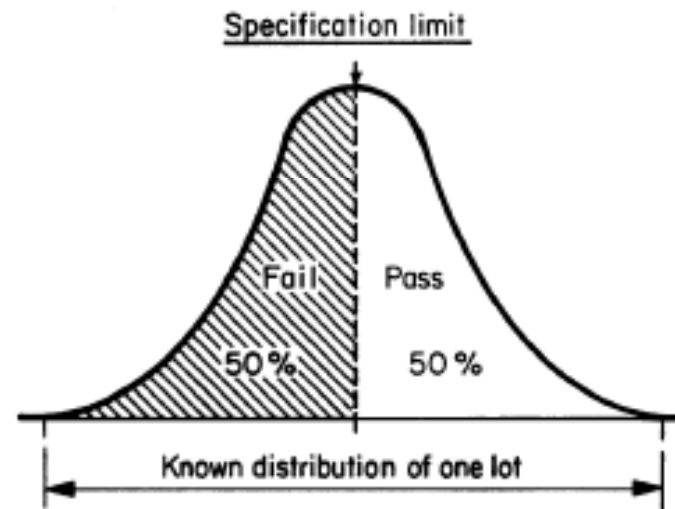
- Increase Cementitious Materials
- Reduce W/CM
- Closer Control of Air Content
- Change Mixture Proportions
- Reduce Delivery Time
- Improve Quality of Testing



# Apply Judgment

- 1 in 100 Tests Fail Even Though Concrete Strength and Uniformity May Be Satisfactory
- Allowance for Statistically Expected Variations
- Investigation of Low Strengths
  - ◆ Nondestructive Testing
  - ◆ Compressive Strengths of Cores

# Apply Judgment





# Summary

- Control testing provides assurance and feedback
- ASTM standards for test methods
- Apply judgment

