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Batching, Placing, and Curing Concrete

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References

- ASTM C94 / C94M-17a, Standard Specification for Ready-Mixed Concrete, ASTM International, West Conshohocken, PA, 2017, www.astm.org
- ASTM C138 / C138M-17a, Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete, ASTM International, West Conshohocken, PA, 2017, www.astm.org
- ASTM C143 / C143M-15a, Standard Test Method for Slump of Hydraulic-Cement Concrete, ASTM International, West Conshohocken, PA, 2015, www.astm.org
- ASTM C156-17, Standard Test Method for Water Loss [from a Mortar Specimen] Through Liquid Membrane-Forming Curing Compounds for Concrete, ASTM International, West Conshohocken, PA, 2017, www.astm.org
- ASTM C172 / C172M-17, Standard Practice for Sampling Freshly Mixed Concrete, ASTM International, West Conshohocken, PA, 2017, www.astm.org
- ASTM C231 / C231M-17a, Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method, ASTM International, West Conshohocken, PA, 2017, www.astm.org
- ASTM C1064 / C1064M-17, Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete, ASTM International, West Conshohocken, PA, 2017, www.astm.org
- Portland Cement Association – 16th Edition, Design and Control of Concrete Mixtures
- Silica Fume Association – Presentation, "Silica Fume in Concrete"

Agenda

Batching, Placing, and Curing Concrete

- **Mixing, Transport and Consolidation of Concrete**
- Sampling and Concrete Fresh Property Testing
- Curing
- Hot Weather Concreting
- Mass Concrete

Ordering Ready Mixed Concrete

ASTM C94 – Standard Specification for Ready-mixed Concrete

- Requirements for Materials (Cement, SCMs, Aggregate, Water, Admixtures, etc.)
- Requirements for Batching Tolerances
- Mixer Requirements
- Inspection Requirements

Batching

Stationary Mixers

Stationary Mixer

Stationary Mixers

- Onsite or Central Mix R/M plant
- Used for complete or shrink mixing

Mixer Types — up to 9m3

- Tilting or non-tilting drum
- Open top revolving blade or paddle

Typical complete mixing times

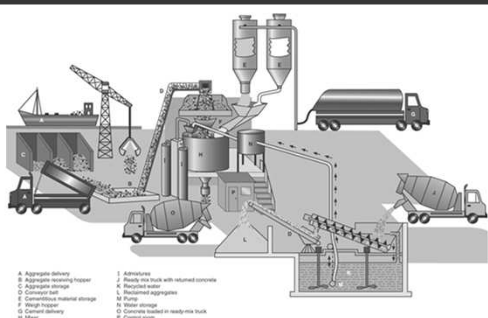
- Minimum of 1 min. for up to 1 yd3 or less mixer capacity plus 15 sec. for each additional yd3 or fraction thereof

Ready Mixed Concrete

Central-mixed concrete

- Mixed completely in a stationary mixer
- Delivered in:
  - A truck agitator,
  - A truck mixer operating at agitating speed, or
  - A nonagitating truck.

Ready Mix Plant



Transporting and Handling

Transporting and Handling

Cranes and Buckets

- **Used for:** Work above ground level.
- **Advantages:** Can handle concrete, reinforcing steel, formwork, and sundry items.
- **Watch for:** Has only one hook. Careful scheduling between trades and operations is needed to keep crane busy

Transporting and Handling

Pumps

- **Used for:** Conveying concrete from central discharge point to formwork.
- **Advantages:** Pipelines take up little space and can be readily extended. Delivers concrete in continuous stream. Pump can move.
- **Watch for:** Constant supply of freshly-mixed concrete is needed without any tendency to segregate.

Placing Concrete

Basic Requirements for Placing Concrete (1)

Preserve concrete quality

- Water-cement ratio
- Slump
- Air-content
- Homogeneity

Avoid separation of aggregate and mortar

Basic Requirements for Placing Concrete (2)

Avoid excessive horizontal movement

Consolidate adequately

Maintain sufficient placement capacity

Choose the right equipment for the concrete

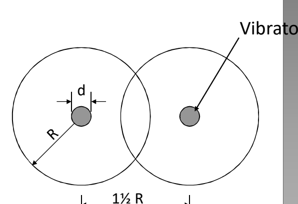
Consolidating Concrete

Internal Vibration

External Vibration

Consolidating Concrete

Internal Vibration

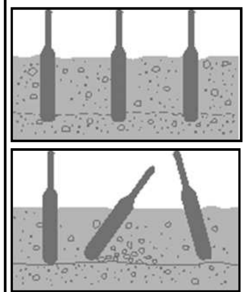


Radius of Action
(~3-5 X d)

Internal Vibrators

Diameter of head, mm (in.)	Recommended frequency, vibrations per minute	Approximate radius of action, mm (in.)	Rate of placement ,m³/h (yd³/h)	Application
20-40 (3/4-1½)	9000-15,000	80-150 (3-6)	0.8-4 (1-5)	Plastic and flowing concrete in thin members. Also used for lab test specimens.
30-60 (1¼-2½)	8500-12,500	130-250 (5-10)	2.3-8 (3-10)	Plastic concrete in thin walls, columns, beams, precast piles, thin slabs, and along construction joints.
50-90 (2-3½)	8000-12,000	180-360 (7-14)	4.6-15 (6-20)	Stiff plastic concrete (less than 80-mm [3-in.] slump) in general construction .

Systematic Vibration of Each New Lift



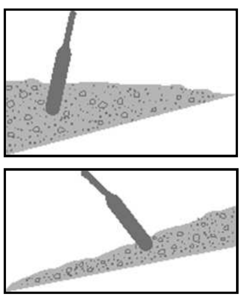
CORRECT

Vertical penetration a few inches into previous lift (which should not yet be rigid) of systematic regular intervals will give adequate consolidation

INCORRECT

Haphazard random penetration of the vibrator at all angles and spacings without sufficient depth will not assure intimate combination of the two layers

Placing Concrete in a Sloping Lift



CORRECT

Start placing at bottom of slope so that compaction is increased by weight of newly added concrete. Vibration consolidates the concrete.

INCORRECT

When placing is begun at top of slope the upper concrete tends to pull apart especially when vibrated below as this starts flow and removes from concrete above.

External Vibration

Form vibrators

Vibrating tables

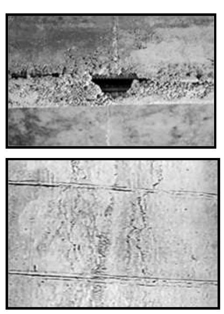
Surface vibrators

- Vibratory screeds
- Plate vibrators
- Vibratory roller screeds
- Vibratory hand floats or trowels

Consolidating Concrete

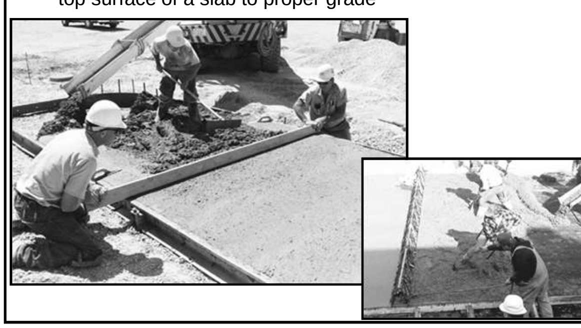
Inadequate consolidation can result in:

- Honeycomb
- Excessive amount of entrapped air voids (bugholes)
- Sand streaks
- Cold joints
- Placement lines
- Subsidence cracking



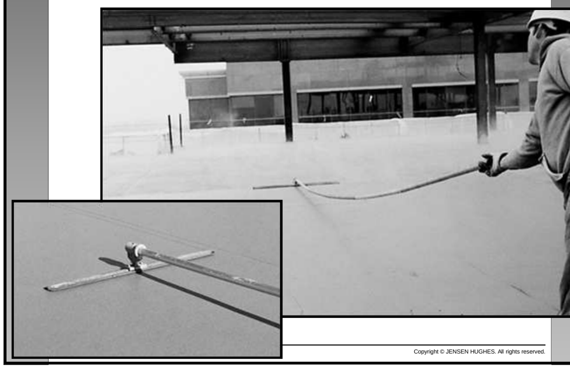
Screeding (Strikeoff)

The process of cutting off excess concrete to bring the top surface of a slab to proper grade



Vibratory Screeds

Bullfloating



Floating (Power or Hand)

To embed aggregate particles just beneath the surface

To remove slight imperfections, humps, and voids

To compact the mortar at the surface in preparation for additional finishing operations.

Troweling

Creates smooth, hard, dense surface

Exterior concrete should not be troweled because:

- it can lead to a loss of entrained air caused by overworking the surface
- troweled surfaces can be slippery when wet.

Brooming

Proper Finishing and Jointing

Curing and Protection

Cure for 7 days

Agenda

Batching, Placing, and Curing Concrete

- Mixing, Transport and Consolidation of Concrete
- **Sampling and Concrete Fresh Property Testing**
- Curing
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- Mass Concrete

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Overview

Fresh Concrete Sampling and Testing

ASTM C172 – Sampling Freshly Mixed Concrete

ASTM C1064 – Temperature

ASTM C143 – Slump of Concrete

ASTM C138 – Density (Unit Weight), Yield, and Air Content

ASTM C231 – Air Content (Pressure Method)

Scope

This practice addresses procedures for obtaining a representative sample of fresh concrete in the field.

~~This practice also addresses procedures for removing aggregate, larger than a designated size, from the sampled concrete.~~

- ~~this procedure is known as wet sieving~~

General Requirements: Sampling

The time between obtaining the first and final portions of the composite sample shall not exceed 15 min.

After obtaining the necessary portions, transport the material to the location where tests are to be conducted or specimens are to be molded.

If wet sieving is necessary, it is performed at this point in the sampling process.

General Requirements: Sampling

Combine and mix the portions,

- use a shovel
- mix the minimum amount necessary to achieve uniformity
- do not exceed any time limitations

After the portions of the sample are combined, the concrete is then referred to as a composite sample.

General Requirements: Sampling

Be expeditious (quick) in obtaining and using the sampled concrete.

Protect the sample from,

- sun
- wind
- rapid evaporation
- contamination

General Requirements: Sampling

Start tests for slump, temperature, and air content (pressure or volumetric) within 5 min. after obtaining the final portion of the composite sample.

Start molding strength specimens (cylinders or beams) within 15 min. after fabricating the composite sample.

General Requirements: Sample Size

A minimum of 28 L of material is needed when strength specimens are to be molded.

- smaller sized samples are permitted for routine temperature, slump and air content tests

Sample sizes shall be based on the maximum aggregate size.

Sampling procedures shall be such that a representative sample is obtained.

Procedure: Stationary Mixer

Sampling from stationary mixers, except paving mixers.

These sampling requirements apply to tilting and non-tilting mixers.

Obtain 2 or more portions at regular intervals from the middle portion of the batch.

Note 3 - Do not obtain material before 10% or after 90% of the batch has been discharged.

Procedure: Stationary Mixer

Sample either by,

- passing a receptacle completely through the discharge stream
- completely diverting the discharge into a container

If necessary, discharge the entire batch of concrete into a receptacle before obtaining a sample as described above.

- the receptacle must accommodate the entire batch

Procedure: Stationary Mixer

Do not restrict the flow of the concrete, or otherwise cause segregation.

Combine all portions into a single sample for testing.

Procedure: Paving Mixer

Sampling from paving mixers.

Sample the concrete after the contents of the mixer have been discharged.

Obtain material from at least 5 different portions of the pile of discharged concrete.

Avoid contamination, or prolonged contact, of the concrete with the subgrade.

Procedure: Paving Mixer

As an alternative to taking samples from the discharge pile,

- place three shallow containers on the subgrade
- discharge the concrete into the containers

Combine all portions into a single sample for testing.

Procedure: Paving Mixer

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Procedure: Revolving Drum Mixer

Sampling from revolving drum mixers or agitators.

Obtain 2 or more portions at regular intervals from the middle portion of the batch.

Do not obtain any material until all water and any admixtures have been added to the mixer.

Note 3 - Do not obtain material before 10% or after 90% of the batch has been discharged.

Procedure: Revolving Drum Mixer

Sample either by,

- repeatedly pass a receptacle through the entire discharge stream
- completely diverting the discharge into a container

Control the rate of discharge by controlling the rate of revolution of the drum.

Combine all portions into a single sample for testing.

Procedure: Revolving Drum Mixer

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Procedure: Other Units

Sampling from open-top truck mixers, agitators, non-agitating equipment, or other types of open-top containers.

Take samples by the most applicable procedure from those previously described.

Sampling Time Line

The following slides present a summary time line with respect to sampling and testing concrete in the field.

- This time line is based on concrete being delivered to a project site by means of a revolving drum truck mixer

Sampling Time Line

Concrete arrives → Obtain the first portion of a sample → Obtain the final portion of a sample → Move the material to the testing location → If necessary, wet sieve the concrete → Mix all portions into a composite sample → Begin tests for temperature, slump and air content → Begin molding strength specimens

Sampling Time Line

Concrete arrives → Obtain the first portion of a sample → Obtain the final portion of a sample

Time shall not exceed 15 min.

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Time shall not exceed 5 min.

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Time shall not exceed 15 min.

Begin tests for temperature, slump and air content → Begin molding strength specimens

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ASTM C1064 – Temperature

ASTM C143 – Slump of Concrete

ASTM C138 – Density (Unit Weight), Yield, and Air Content

ASTM C231 – Air Content (Pressure Method)

ASTM C1064 – Temperature

Scope: This test method covers the determination of **temperature** of **freshly mixed** hydraulic-cement **concrete**.

Apparatus: Temperature Measuring Device

Accuracy ± 0.5°C (± 1°F)

Range 0 to 50°C (32 to 120°F)

Length greater than 75 mm (3 in.)

Procedure: Sampling Concrete

It is **acceptable** to measure the temperature of freshly mixed concrete in either the **transporting equipment** or the **forms** after discharge provided the sensor of the temperature measuring device has at least 75 mm (3 in.) of concrete cover.

Procedure: Sampling Concrete

A sample of concrete shall be obtained by:

- Prior to sampling, the **container** shall be **dampened** with **water**.
- **Sample** the concrete in accordance to **ASTM C172**, except that composite samples are not required for the purpose of temperature.
- Place the freshly mixed concrete into the container.

Procedure: Temperature Measuring

Position the **temperature measuring device** so that the end of the temperature measuring device is submerged a minimum of **75 mm (3 in.)**

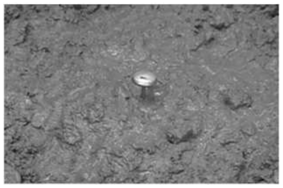
Close the void around the temperature measuring device at the surface of concrete to prevent ambient air temperature from affecting the reading.



Procedure: Temperature Measuring

Leave the temperature measuring device in the freshly mixed concrete for **at least 2 min. but not more than 5 min.**

Read and record the temperature to the nearest 0.5˚C (1˚F).



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Summary of Test Method:

- A sample of concrete is placed in a mold and consolidated.
- The mold is then raised vertically and the concrete is allowed to settle.
- Slump is the vertical distance between the original and displaced center of the concrete surface.

Historical Purpose

The slump test was originally devised to provide a method to monitor the consistency of unhardened concrete.

Under field conditions a relationship between slump and strength cannot be clearly and consistently shown.

Apparatus: Mold

May be metal or an alternate material.

Shall be in the shape of the frustum of a cone.

- 100 mm wide top, 200 mm wide base, 300 mm height

Dimensions shall be checked and recorded,

- when purchased or first used
- at least annually

Shall have foot fins and handles.

Procedure: Sample

Obtain a representative sample of concrete according to ASTM Practice C 172.

Procedure: Dampen Mold

Dampen the mold and place on a rigid, flat, level, moist, and non-absorbent surface that is free of vibration.

Procedure: Secure Base

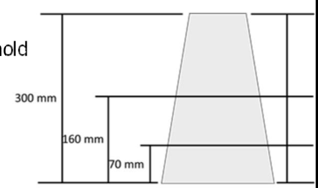
Stand on the two foot fins while filling the mold and cleaning the perimeter.

- clamping the mold to a base is also permitted

Procedure: Filling Mold

Use a scoop to place concrete in the mold.

Move the scoop around the mold opening so material is evenly distributed and segregation is minimized.



Fill the mold in three layers of approximately equal volume.

- fill the mold to 70 mm, 160 mm, and then 300 mm from the base

Procedure: Rodding Concrete

Rod each layer 25 times.

- uniformly distribute the rodding strokes over the cross section of a layer
- rod the bottom layer through its depth
- rod each upper layer through its depth and into the layer below approximately 25 mm

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- rod the bottom layer through its depth
- rod each upper layer through its depth and into the layer below approximately 25 mm

While rodding the bottom layer,

- slightly incline the rod
- rod around the mold perimeter using about half of the 25 strokes
- conclude with vertical strokes near the center of the mold

For the top layer,

- heap concrete above the mold prior to rodding
- add concrete as necessary to keep an excess above the top of the mold at all times

Procedure: Strike-off Concrete

Strike-off the mold with the tamping rod in a screeding and rolling motion.

Procedure: Raising the Mold

Holding the mold down firmly, clear away any concrete from the area surrounding the base.

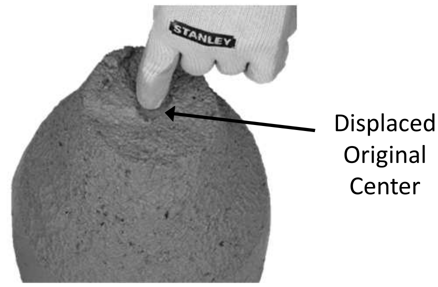
- prevent interference with the slumping concrete

Remove the mold immediately after clearing the base of concrete.

Raise the mold vertically in 5 ± 2 seconds.

- there should be no lateral or torsional (twisting) motion

Procedure: Measurement Location



Procedure: Measurement Procedure

Procedure: Measurement Procedure

Limitations and Errors

- Slump test is suitable for slumps of medium workability, slump in the range of 15 – 230 mm.
- Test fails to determine the difference in workability in stiff mixes which have zero slump, or for wet mixes that give a collapse slump.
- Limited to concrete formed of aggregates of less than 37.5 mm
- Lacks to tell you anything about water content, w/c, w/cm, strength, air, shrinkage, pump-ability, response to the vibrator and slip forms, and finishability.
- User dependent.
- Very sensitive to time from mixing and time in cone.

Factors Affecting Slump

1. Content, proportions, chemistry, fineness, particle size distribution, moisture content and temperature of cementitious;
2. Content, proportions, size, texture, combined grading, cleanliness and moisture content of the aggregates;
3. Dosage, type, combination, interaction, sequence of addition, effectiveness of chemical admixtures;
4. Air content;
5. Batching, mixing and delivery methods and equipment;
6. Temperature of the concrete;
7. Sampling, slump-testing technique and the condition of test equipment;
8. The amount of free water in the concrete; and
9. Time since batching at the time of testing.

Slump is Influenced by Everything!

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ASTM C231 – Air Content (Pressure Method)

ASTM C138 – Density (Unit Weight), Yield, and Air Content

This test method addresses the procedures for determining the density and calculating the yield, cement content, and air content of fresh concrete.

Density: mass per unit volume of concrete, kg/m^3

Yield: volume of concrete produced for a batch, m^3

Gravimetric Air Content: air content computed as a percentage of the volume of concrete and determined on the basis of a theoretical and measured density, %

Terminology

Theoretical Density: density of the concrete computed on an air free basis, kg/m^3.

- density computed based on the mass and volume of the liquids and solids only
- volume occupied by air (both entrapped and entrained) is taken as zero
- T = M / V
- M = Σ M = Σ [all masses]
- V = Σ V = Σ [Mass / (1000*Specific Gravity)]

Procedure: Sample

Obtain a representative sample of concrete according to ASTM Practice C172.

Procedure: Rodding

Fill the measure in three layers of approximately equal volume.

Consolidate the concrete using the rounded end of the tamping rod.

- uniformly distribute the rodding strokes over the cross section of the measure
- rod the bottom layer through its depth
- rod each upper layer through its depth and into the layer below approximately 25 mm.

Procedure: Rodding

After rodding a layer, tap the outside of the measure 10 to 15 times with a mallet.

- This closes voids left by the rod and releases large air bubbles

Avoid overfilling the measure when adding the final layer of concrete.

Procedure: Strike off

Strike off the top surface using a flat strike-off plate.

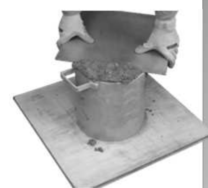
- produce a smooth finish to the top surface

Strike off should result in a measure that is just level full.

Procedure: Strike off

While pressing down,

- cover 2/3 of the concrete surface
- push down and pull back with a sawing motion
- keep plate level and in contact with the measure at all times



Procedure: Strike off

While pressing down,

- cover the same 2/3 of the concrete surface
- push down and advance the plate forward with a sawing motion
- move the plate across the entire surface until its back edge slides completely off the measure
- keep the plate level and in contact with the measure at all times

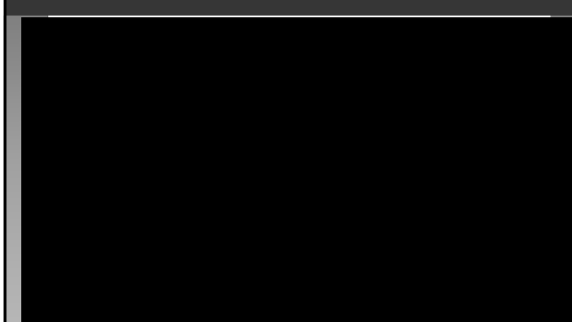
Procedure: Strike off

Incline the plate and use an edge to produce a smooth finished surface.

Procedure: Clean and Weigh

Clean the exterior of the measure and determine its mass (weight) when full.

Procedure



Calculation

Density (unit weight), kg/m^3

$$= \frac{\text{Mass of measure full - Mass of measure empty}}{\text{Volume of measure}}$$

Yield, m^3

$$= \frac{\text{Total mass of all batched material}}{(\text{Density})}$$

Calculation

Relative Yield

$$= \frac{\text{Actual Yield}}{\text{Design (Intended) Yield}}$$

Ratio of Actual Concrete Obtained to Volume as Designed

- Value greater than 1.00 indicates excessive concrete being produced.
- Value less than 1.00 indicates short designed volume

Calculation

Air Content, %

$$= \left(\frac{\text{Theoretical Density - Measured Density}}{\text{Theoretical Density}}\right) \text{x100 } \%$$

Terminology

Theoretical Density: density of the concrete computed on an air free basis, kg/m^3.

- density computed based on the mass and volume of the liquids and solids only
- volume occupied by air (both entrapped and entrained) is taken as zero
- T = M / V
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<u>ASTM C231 – Air Content (Pressure Method)</u>

ASTM C231 – Air Content (Pressure Method)

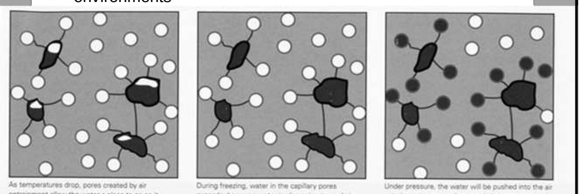
Measuring Air Content (Pressure Method)

- This test method covers determination of the ***<u>air content</u>*** of ***<u>freshly mixed concrete</u>*** from observation of the ***<u>change in volume</u>*** of concrete with a ***<u>change in pressure</u>***.
- Measures air content ***<u>exclusive</u>*** of any air that may exist inside ***<u>voids within aggregate</u>*** particles. For this reason, it is not applicable to light weight concrete.

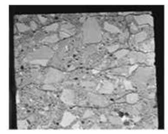
Why Do We Measure Air Content?

Specifications limit:

- **Maximum** air content to **minimize entrapped air** (in warm environments)
- To provide **freeze-thaw resistance** to concrete in **cold weather** climates (entrained air)
- Quality control – to prevent **unwanted** air in warm weather environments



Freeze-thaw Damage



Determining Air Content (Fresh Concrete)

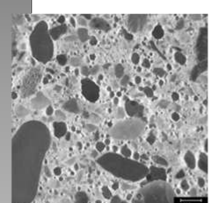
ASTM C138 - Gravimetric Air Content

ASTM C173 – Air Content (Volumetric Procedure)

Super Air Meter (Still Undergoing Research)

Determining Air Content (Hardened Concrete)

ASTM C457 – Hardened Air Void Analysis



Operation Equipment and Overview

Consist Of:

- Measure bowl:
  - Cylindrical in shape and
- Cover assembly
- Pressure gauge

Operation Overview:

- Equalize known volume of air at known pressure in a sealed air chamber with unknown volume of air in concrete sample.
- Pressure gauge should be calibrated in terms % air for observed pressure when equilzation takes place.
- Pressures range from 50-205 kPa (7.5-30 psi)

Procedure

1. Dampen the measuring bowl.

2. Fill the container 1/3 of its volume.

3. Rod the layer 25 times.

Procedure

4. Tap 10-15 times with a rubber mallet.

5. Fill the container to 2/3 of its volume.

6. Rod the layer 25 times penetrating 25 mm (1 inch) into the layer below.

Procedure

7. Tap 10-15 times with a rubber mallet.

8. Fill the remaining volume of the container.

9. Rod the layer 25 times penetrating 25 mm (1 inch) into the layer below.

Procedure

10. Tap 10-15 times with a rubber mallet.

11. Strike off the surface by using a strike off plate or bar.

Procedure

12. Thoroughly clean the top flange of the measuring bowl.

13. Clamp the cover assembly to the measuring bowl. 14. Open both petcocks on the cover.

14. Use a bottle or syringe inject water through one of the petcocks until water comes out of the opposite petcock.

Procedure

15. Close the air bleeder valve and pump air into the chamber until the dial gauge reaches the initial pressure line.

16. Open the main air valve and tap the sides of the measuring bowl with a mallet.

17. While continuing to hold the valve open lightly tap the gauge and take a reading.

Reporting

Report the air content to the nearest 0.1% up to 8%, to the nearest 0.5% if it exceeds 8%.

Air Content of Sample Tested:

$$A_s = A_1 - G$$

A_s = air content of the sample tested, %

A_1 = apparent air content of the sample tested, %

G = aggregate Correction factor, %

Agenda

Batching, Placing, and Curing Concrete

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- **Curing**
- Hot Weather Concreting
- Mass Concrete

Curing

Curing requires adequate:

- Moisture
- Temperature
- Time

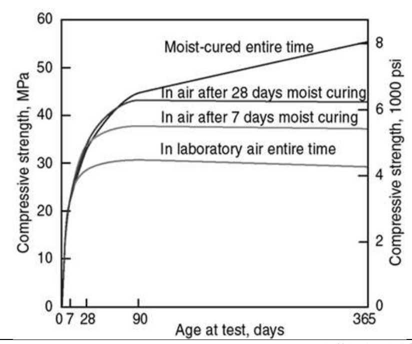
If any of these factors are neglected, the desired properties will not develop

Effect of Adequate Curing on Hardened Concrete

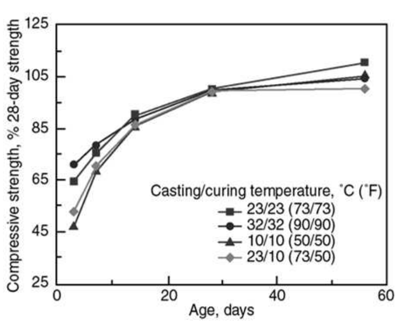
Increased:

- Strength
- Watertightness (decrease permeability)
- Abrasion resistance
- Freeze-thaw resistance
- Volume stability (decrease shrinkage)

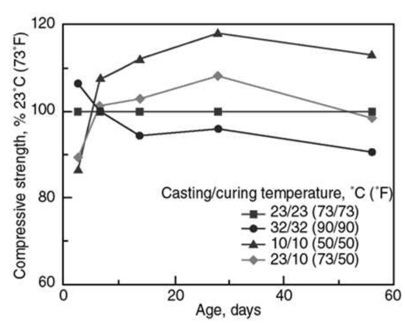
Effect of Moist Curing



Effect of Curing Temperature on Strength



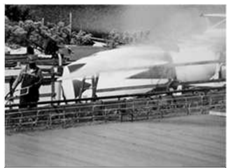
Effect of Curing Temperature on Strength



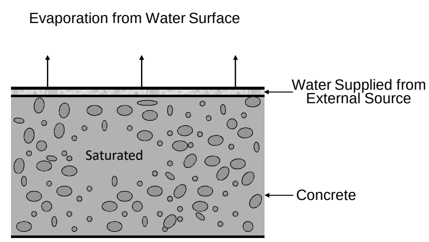
Curing Methods

1. Supply additional water:

- Spraying or fogging
- Saturated wet coverings



Curing of Concrete by Supplying Water

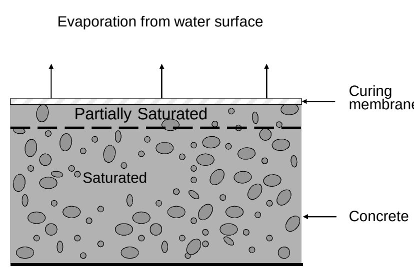


Curing Methods

1. Seal in mixing water:

- Plastic sheets
- Membrane-forming curing compounds

Membrane Curing of Concrete



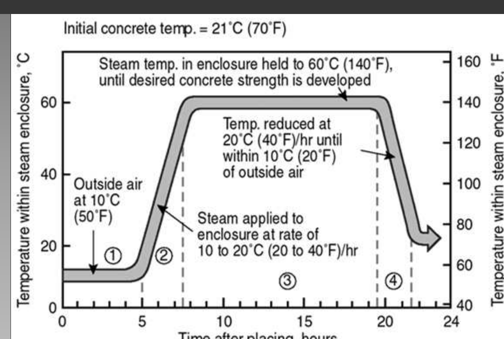
Curing Methods

3. Strength gain is accelerated with:

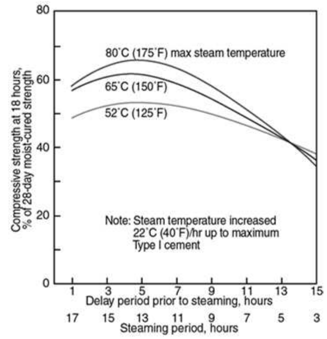
- Live steam
- Heating coils
- Electrically heated forms or pads

Source: http://civilengineersforum.com

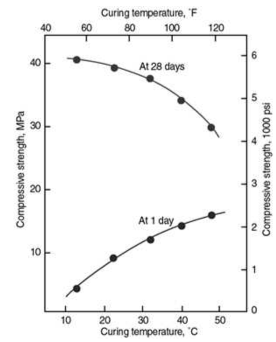
Steam Curing



Strength vs. Steam Curing



Strength vs. Curing Temperature



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What is Hot Weather?

One or a combination of the following **conditions** that tends to **impair** the quality of **freshly mixed** or **hardened concrete** by accelerating the rate of moisture loss and rate of cement hydration or otherwise causing detrimental results:

- High ambient temperature
- High concrete temperature
- Low relative humidity
- High wind speed, and
- Solar radiation

ACI 305R-10: Guide to Hot Weather Concreting

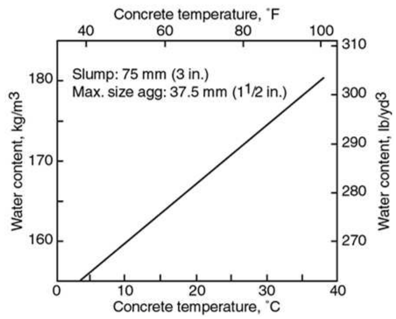
Hot Weather Effects on Concrete

- Increased water demand
- Accelerated slump loss
- Faster set
- Increased tendency for plastic cracking
- Difficulties controlling entrained air
- Increased potential for thermal cracking

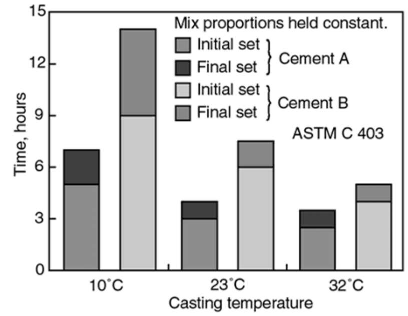
Precautions

- Preconstruction conference
- Utilize proven mixtures
- Schedule at favorable times (Night)
- Cool concrete
- Cool concrete ingredients
- Reduce the time of transport, placing and finishing
- Use sunshades, windscreens, fogging, or spraying to limit moisture loss during placing and finishing (Reduce Evaporations)

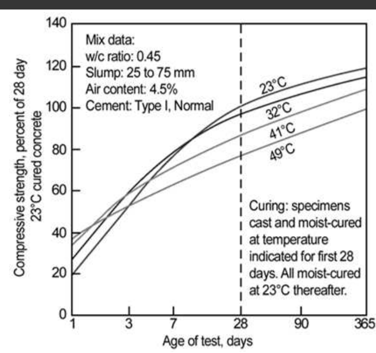
Effect of Concrete Temperature on Water Demand



Effect of Concrete Temperature on Setting Time



Effect of Concrete Temperatures on Strength

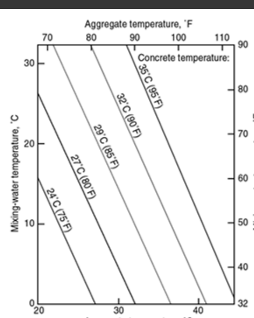


Effect of Materials Temperature on Concrete Temp.

$$T = \frac{0.22(T_a M_a + T_c M_c) + T_w M_w + T_{wa} M_{wa}}{0.22(M_a + M_c) + M_w + M_{wa}}$$

- T = temperature of the freshly mixed concrete, °C (°F)
- T_a, T_c, T_w, and T_{wa} = temperature in °C (°F) of aggregates, cement, added mixing water, and free water on aggregates, respectively
- M_a, M_c, M_w, and M_{wa} = mass, kg (lb), of aggregates, cementing materials, added mixing water, and free water on aggregates, respectively

Temperature of Freshly Mixed Concrete

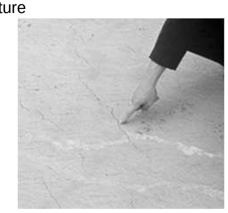


Plastic Shrinkage Cracking

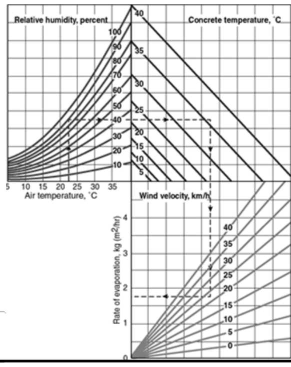
Cracks occur when water evaporates from the surface faster than it can be replaced by the bleeding process.

Occurrences increased by:

- High air and concrete temperature
- Low humidity
- High wind speed



Evaporation of Surface Moisture from Concrete



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Precautions to Minimize Plastic Shrinkage Cracking

- Moisten aggregates
- Cool aggregates and mixing water
- Dampen subgrade
- Erect temporary windbreaks and sunshades
- Cover concrete
- Fog slab immediately after placing
- Add plastic fibres

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Fogging

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Curing and Protection

Hot Weather

- **Air Temperature 27°C or above** Basic curing by water or saturated fabric
- **Mass Conc. air 20°C or above** Basic curing by water
- **White pigmented curing compound** Where water is not practical or available

Curing water should not be more than about 11°C cooler than the concrete

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QUESTIONS?

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