Section 7

Admixtures, Hot & Cold Weather Concreting

WMTC Concrete Training & Certification Seminar

Types of Admixtures

Air-entraining Agents

(ASTM C260, AASHTO M154)

Chemical Admixtures

(ASTM C494, AASHTO M194)

Type A	Water-reducing
Type B	Retarding
Type C	Accelerating
Type D	Water-reducing & Retarding
Type E	Water-reducing & Accelerating
Type F	Water-reducing, High Range
Type G	Water-reducing, High Range & Retarding

Supplementary Cementitous Materials

Pozzolans - Fly Ashes (Types F & C)
Natural Pozzolans
Silica Fume
Ground, Granulated Blast-furnace Slag (GGBFS)

Requirements for Admixtures

- No chemical composition requirements
- Must meet specified physical requirements as set by ASTM or AASHTO
- Must be approved by WYDOT

TABLE 1 Physical Requirements[A]

	Type A, Water Reducing	Type B, Retarding	Type C, Accelerating	Type D, Water Reducing and Retarding	Type E, Water Reducing and Accelerating	Type F, Water Reducing, High Range	Type G, Water Reducing, High Range and Retarding
Water content, max, % of control	95	...	...	95	95	88	88
Time of setting, allowable deviation from control, h:min:							
Initial: at least	...	1:00 later	1:00 earlier	1:00 later	1:00 earlier	...	1:00 later
not more than	1:00 earlier nor 1:30 later	3:30 later	3:30 earlier	3:30 later	3:30 earlier	1:00 earlier nor 1:30 later	3:30 later
Final: at least	...	...	1:00 earlier	...	1:00 earlier	...	...
not more than	1:00 earlier nor 1:30 later	3:30 later	...	3:30 later	...	1:00 earlier nor 1:30 later	3:30 later
Compressive strength, min, % of control:[B]							
1 day	...	...	...	...	...	140	125
3 days	110	90	125	110	125	125	125
7 days	110	90	100	110	110	115	115
28 days	110	90	100	110	110	110	110
6 months	100	90	90	100	100	100	100
1 year	100	90	90	100	100	100	100
Flexural strength, min, % control:[B]							
3 days	100	90	110	100	110	110	110
7 days	100	90	100	100	100	100	100
28 days	100	90	90	100	100	100	100
Length change, max shrinkage (alternative requirements):[C]							
Percent of control	135	135	135	135	135	135	135
Increase over control	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Relative durability factor, min[D]	80	80	80	80	80	80	80

[A] The values in the table include allowance for normal variation in test results. The object of the 90 % compressive strength requirement for a Type-B admixture is to require a level of performance comparable to that of the reference concrete.

[B] The compressive and flexural strength of the concrete containing the admixture under test at any test age shall be not less than 90 % of that attained at any previous test age. The objective of this limit is to require that the compressive or flexural strength of the concrete containing the admixture under test shall not decrease with age.

[C] Alternative requirements, see 17.1.4, % of control limit applies when length change of control is 0.030 % or greater; increase over control limit applies when length change of control is less than 0.030 %.

[D] This requirement is applicable only when the admixture is to be used in air-entrained concrete which may be exposed to freezing and thawing while wet.

Handling & Storage

- Come in solids, flakes or liquid
- Come in different concentrations
- Available in 5, 55 or 5,000 gallon supplies
- Some admixtures need to be protected from freezing

Adding Admixtures to Fresh Concrete

Must keep the following consistent

- Dosage amount
  - Based on cementitious material content

    (*x ounces per 100 lbs of cement*)
- Rate of discharge
- Timing in batching sequence

Otherwise, expect different admixture performance

Ways to Measure Admixtures

- Use Calibrated Dispenser
  - Positive volumetric displacement
  - Visual volumetric containers
  - Timer controlled
  - Weight
- Batching Accuracy: ±3%

Things that Affect Air Content in Concrete …

Everything!

	Characteristic/Material	Effects	Guidance
Portland cement	Alkali content	Air content increases with increase in cement alkali level. Less air-entraining agent dosage needed for high-alkali cements. Air-void system may be more unstable with some combinations of alkali level and air-entraining agent used.	Changes in alkali content or cement source require that air-entraining agent dosage be adjusted. Decrease dosage as much as 40% for high-alkali cements.
	Fineness	Decrease in air content with increased fineness of cement.	Use up to 100% more air-entraining admixture for very fine (Type III) cements. Adjust admixture if cement source or fineness changes.
	Cement content in mixture	Decrease in air content with increase in cement content. Smaller and greater number of voids with increased cement content.	Increase air-entraining admixture dosage rate as cement content increases.
	Contaminants	Air content may be altered by contamination of cement with finish mill oil.	Verify that cement meets ASTM C 150 (AASHTO M 85) requirements on air content of test mortar.
Supplementary cementitious materials	Fly ash	Air content decreases with increase in loss on ignition (carbon content). Air-void system may be more unstable with some combinations of fly ash/cement/air-entraining agents.	Changes in LOI or fly ash source require that air-entraining admixture dosage be adjusted. Perform "foam index" test to estimate increase in dosage. Prepare trial mixes and evaluate air-void systems.
	Ground granulated blast-furnace slag	Decrease in air content with increased fineness of GGBFS.	Use up to 100% more air-entraining admixture for finely ground slags.
	Silica fume	Decrease in air content with increase in silica fume content.	Increase air-entraining admixture dosage up to 100% for fume contents up to 10%.
	Metakaolin	No apparent effect.	Adjust air-entraining admixture dosage if needed.
Chemical admixtures	Water reducers	Air content increases with increases in dosage of lignin-based materials. Spacing factors may increase when water-reducers used.	Reduce dosage of air-entraining admixture. Select formulations containing air-detraining agents. Prepare trial mixes and evaluate air-void systems.
	Retarders	Effects similar to water-reducers.	Adjust air-entraining admixture dosage.
	Accelerators	Minor effects on air content.	No adjustments normally needed.
	High-range water reducers (Plasticizers)	Moderate increase in air content when formulated with lignosulfonate. Spacing factors increase.	Only slight adjustments needed. No significant effect on durability.
Aggregate	Maximum size	Air content requirement decreases with increase in maximum size. Little increase over 37.5 mm (1½ in.) maximum size aggregate.	Decrease air content.
	Sand-to-total aggregate ratio	Air content increases with increased sand content.	Decrease air-entraining admixture dosage for mixtures having higher sand contents.
	Sand grading	Middle fractions of sand promote air-entrainment.	Monitor gradation and adjust air-entraining admixture dosage accordingly.

Mix water and slump	Characteristic/Material	Effects	Guidance
	Water chemistry	Very hard water reduces air content. Batching of admixture into concrete wash water decreases air. Algae growth may increase air.	Increase air entrainer dosage. Avoid batching into wash water.
	Water-to-cement ratio	Air content increases with increased water to cement ratio.	Decrease air-entraining admixture dosage as water to cement ratio increases.
	Slump	Air increases with slumps up to about 150 mm (6 in.). Air decreases with very high slumps. Difficult to entrain air in low-slump concretes.	Adjust air-entraining admixture dosages for slump. Avoid addition of water to achieve high-slump concrete. Use additional air-entraining admixture; up to ten times normal dosage.

	Procedure/Variable	Effects	Guidance
Production procedures	Batching sequence	Simultaneous batching lowers air content. Cement-first raises air content.	Add air-entraining admixture with initial water or on sand.
	Mixer capacity	Air increases as capacity is approached.	Run mixer close to full capacity. Avoid overloading.
	Mixing time	Central mixers: air content increases up to 90 sec. of mixing. Truck mixers: air content increases with mixing. Short mixing periods (30 seconds) reduce air content and adversely affect air-void system.	Establish optimum mixing time for particular mixer. Avoid overmixing. Establish optimum mixing time (about 60 seconds).
	Mixing speed	Air content gradually increases up to approx. 20 rpm. Air may decrease at higher mixing speeds.	Follow truck mixer manufacturer recommendations. Maintain blades and clean truck mixer.
	Admixture metering	Accuracy and reliability of metering system will affect uniformity of air content.	Avoid manual-dispensing or gravity-feed systems and timers. Positive-displacement pumps interlocked with batching system are preferred.
Transport and delivery	Transport and delivery	Some air (1% to 2%) normally lost during transport. Loss of air in nonagitating equipment is slightly higher.	Normal retempering with water to restore slump will restore air. If necessary, retemper with air-entraining admixture to restore air. Dramatic loss in air may be due to factors other than transport.
	Haul time and agitation	Long hauls, even without agitation, reduce air, especially in hot weather.	Optimize delivery schedules. Maintain concrete temperature in recommended range.
	Retempering	Regains some of the lost air. Does not usually affect the air-void system. Retempering with air-entraining admixtures restores the air-void system.	Retemper only enough to restore workability. Avoid addition of excess water. Higher admixture dosage is needed for jobsite admixture additions.

Chemical Admixture Summary

All admixtures are somewhat sensitive to concrete temperature

***As the temperature of the mix increases, the effectiveness of the admixture decreases*, so ...**

- As temperature increases, may need to increase dosage rate for same effects
- As temperature decreases, may need to reduce dosage rate for same effects

All admixtures are somewhat sensitive to brands, types, mix design, cement composition and batching sequence

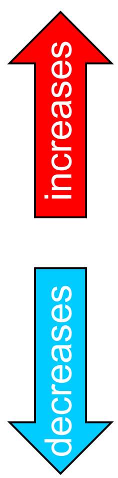
If anything changes, then expect different performance from admixtures

Hot & Cold Weather Concreting

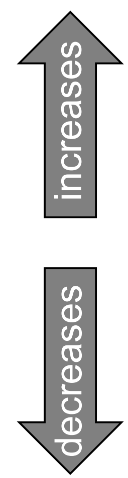
Rate of hydration is sensitive
to temperature of the fresh concrete

Hydration – chemical reaction between portland cement & water

Temperature



Rate of Hydration



How Do We Define Hot Weather?

Any combination of the following that impair quality of freshly mixed or hardened concrete

- **High air temperatures**
- **High concrete temperatures**
- **Low relative humidity**
- **Wind velocity**
- **Solar radiation**

These conditions will accelerate …

Rate of Cement Hydration
and
Rate of Moisture Loss

Knowing this is the *key* to understanding how to handle hot weather concreting

Hot Weather Increases Water Demand

Amount of water to produce a given slump increases with increasing concrete temperature

If fresh concrete temperature increases 10°F, then

- **About 1 gal/cuyd is needed to maintain slump**
- **Air content decreases about 1%**
- **Decreases strength from 150 psi to 200 psi**

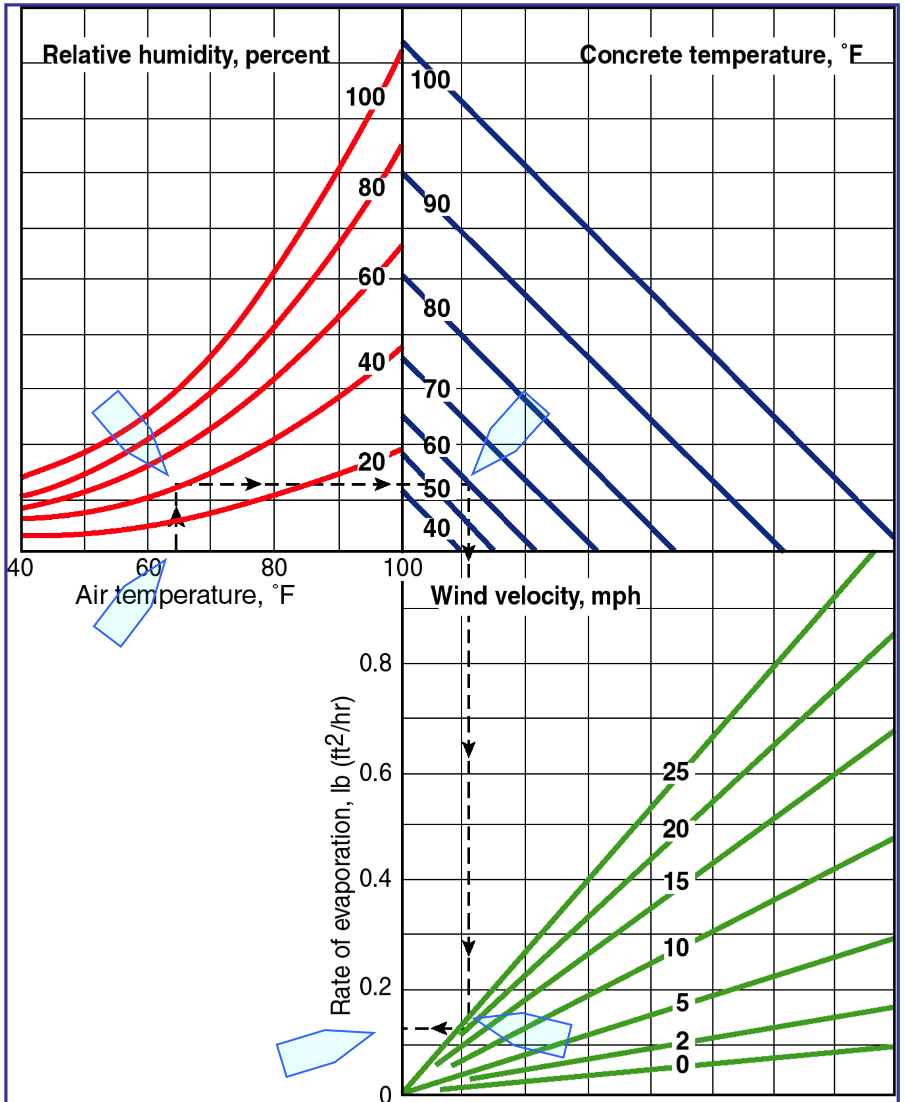
Air Content & Fresh Concrete Temperature

Less air is entrained as the concrete temperature increases.

- Monitor fresh concrete air test & concrete temperature
- Offset loss of air by increasing dosage of air-entraining admixtures

Plastic Shrinkage Cracks

Evaporation Chart (SSRBC Figure 513.4.2-2)



Instructions

1. Air temperature (65F)
2. Relative humidity (40%)
3. Concrete temperature (60F)
4. Wind velocity (20 mph)
5. Read evaporation rate

0.13 lb sqft per hr

When evaporation exceeds 0.2 lbs(sqft per hr), take precautions.
(SSRBC 513.4.2.5)

Foggers

Water Reducing & Retarding Admixtures

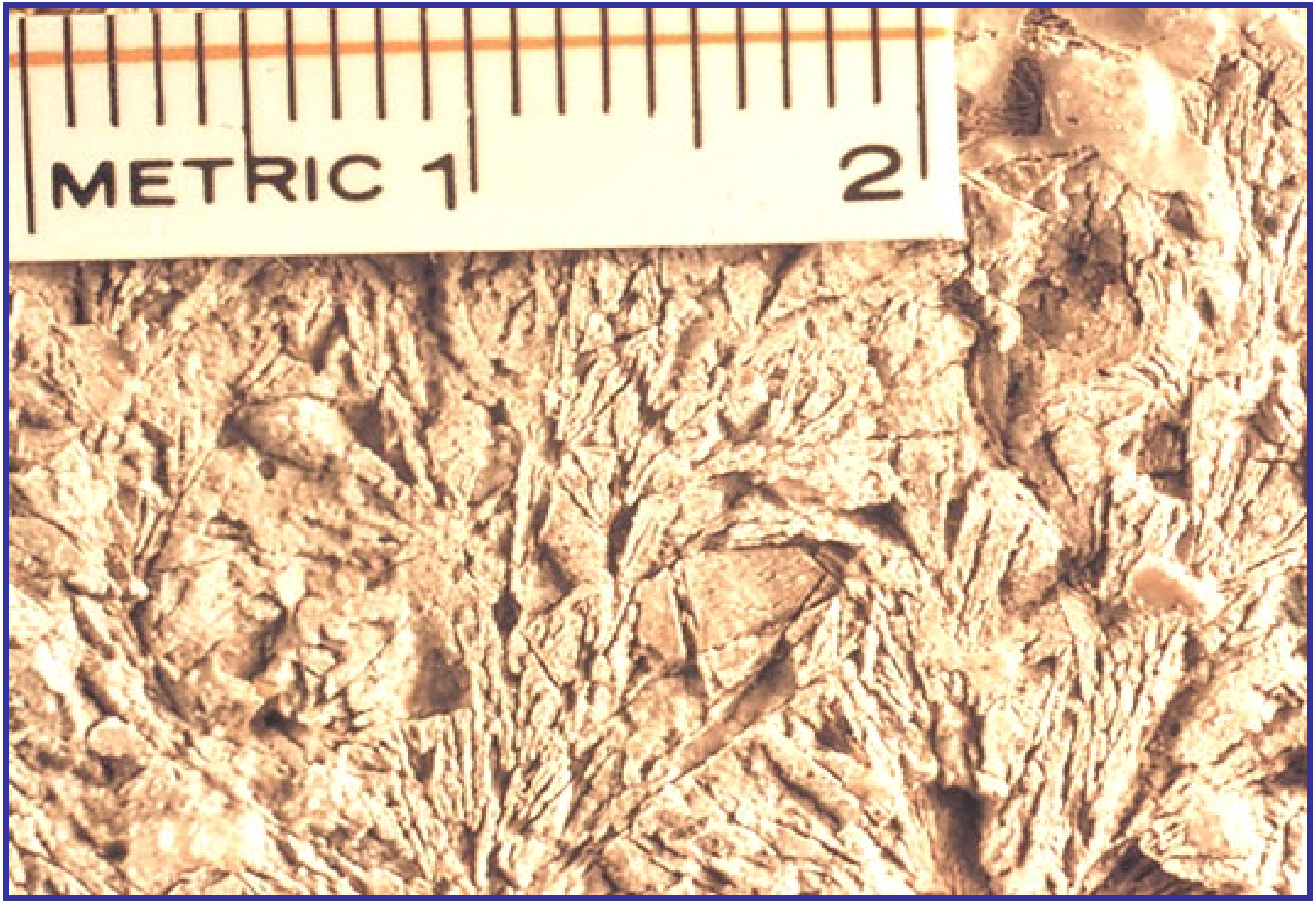
- **Type B – Water Reducing**
  - Delays setting & hardening from 1 to 3½ hrs

- **Type D - Water Reducing & Retarding**
  - Reduces water content 5% min.
  - Retards set from 1 to 3½ hrs

- **Type G – Water Reducing & Retarding**
  - Reduces water 12% to 30%
  - Retards set from 1 to 3½ hrs

Cold Weather Objectives …

1. Protect from Early Age Freezing
2. Strength Development
3. Prevent Thermal Shock & Cracking



If batch water freezes,up to 50% strength reduction can occur.

Mix Design Options

- Type III portland cement
- Additional portland cement

  (100 to 200 lbs cuyd) can increase shrinkage & curling, especially if cement content exceeds 600 to 625 lbs/cy
- Hot water & heated aggregates
- Chemical admixtures (non-chloride)

Chemical Accelerators

- **Type C - Accelerator (non-chloride)**
- **Type E – Water-Reducer & Accelerator**
  - Offsets slow set times
  - Aids finishing process
  - Reduces bleed water
  - May contain some chlorides (check project limits)

Maintaining Curing Temperatures

Insulate & Capture Heat of Hydration

- Internal heat generate for first 3 days
- Want to capture as much as possible

Supply Heat ($$$)

- Hydronic Systems
- Electric (Heat) Blankets
- Heated Enclosures

Cover fresh concrete ASAP but don't damage finish

Want to capture heat of hydration to maintain cure temperature.


Wind?
Plan ahead on how you will hold blankets in place.
Insulation value of blue tarp?