

How to Prevent Scaling in Exterior Flatwork

Transportation Association of Canada
Maintenance and Construction Standing Committee
Spring 2006 Technical Meetings
Ottawa April 20-24, 2006



Materials for
building our world

What is Scaling?

“A surface defect, characterized by flaking, peeling or pitting of the concrete surface.”

General Conclusion

Properly ordered, placed, finished and cured concrete will not scale.

Other Problems that can Look Like Scaling

- ▶ Surface peeling
- ▶ Mortar Flaking
- ▶ Pop-outs
- ▶ Spalling
- ▶ Blistering



Surface Peeling

- ▶ Normally related to early finishing
- ▶ A very thin layer peels off with normal traffic, does not require freezing and thawing to cause delamination.



Mortar Flaking

- ▶ Mortar flakes off down to the coarse aggregate. This is more common with smooth, flat aggregate.
- ▶ Often results when concrete is placed on hot, windy days.
- ▶ The area over the aggregate dries out, the aggregate blocks bleed water and the mortar does not gain sufficient strength to bond to the aggregate.
- ▶ Upon freezing in a saturated condition, this thin mortar layer flakes off.
- ▶ Poor finishing practices can also aggravate mortar flaking.
- ▶ Curing and initial protection play a big role in determining if the mortar will flake off or not.



Pop-Outs

- ▶ A pop-out is a small fragment of concrete broken away due to internal freezing and thawing pressure.
- ▶ This pressure is caused by aggregate expansion.
- ▶ The expansion can be caused by freezing of moisture absorbed by the aggregate.



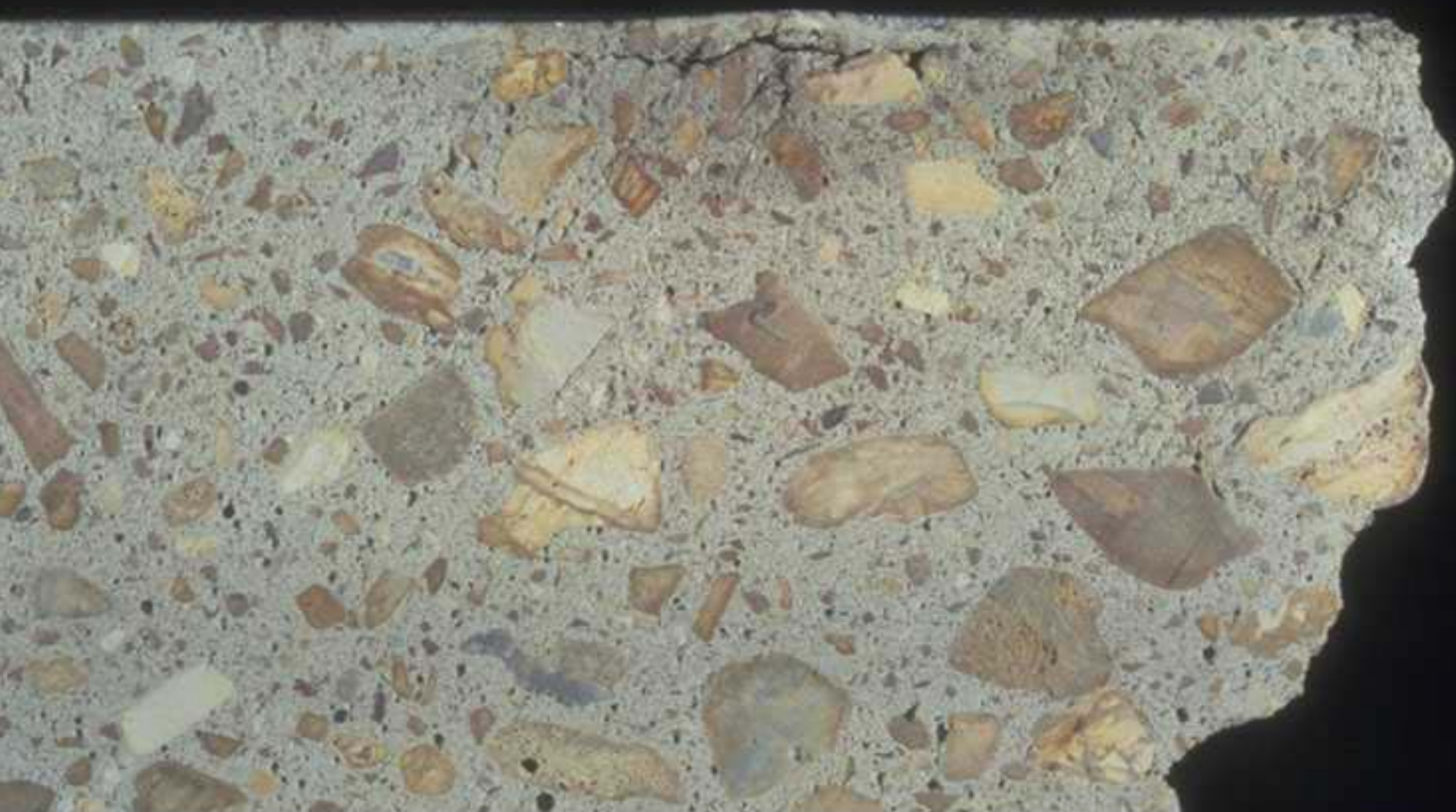
Spalling

- ▶ Spalling is a deeper surface imperfection than scaling and blistering.
- ▶ Corroded reinforcing steel is a common cause of spalling.
- ▶ Improperly constructed joints can cause pressure spalls of concrete.



Blisters

- ▶ Blisters are caused by premature finishing.
- ▶ Skilled finishers should recognize blisters as early finishing and wait longer before final finishing.



The Main Causes of Scaling

- 1. **Sealing the Surface**, trapping bleed water below the surface and creating a poor bond between the densified surface layer and the concrete below.*
- 2. **Not protecting** from dehydration prior to final finishing. Surface drying is probably the main cause of misjudged finishing times*
- 3. **Not curing.***

Changes to Deicer Chemical Application Procedures

- ▶ In order to reduce the amount of Rock Salt (Halite, Sodium Chloride, NaCl_2) that bounces off the road during application, the rock salt is now being "Pre-wetted".
- ▶ Plain Water can be used to pre-wet, but
- ▶ Magnesium Chloride (MgCl_2) and Calcium Chloride (CaCl_2) are more effective.
- ▶ Inhibitors are also being added
- ▶ These changes result in more chloride remaining on the road surface at higher moisture conditions

Hygroscopic

- ▶ Calcium and Magnesium Chloride are Hygroscopic
- ▶ Hygroscopic means a material that readily takes up and retains moisture
 - Calcium Chloride is often applied to dirt roads to keep the dust down because it keeps the road wet.

Magnesium Chloride

- ▶ Magnesium Chloride (MgCl_2) and Calcium Chloride (CaCl_2) are also being used instead of Rock Salt for deicing for severe applications
- ▶ Compared to NaCl , CaCl_2 and MgCl_2
 - Are more effective deicing chemicals
 - Work at lower temperatures
 - May corrodes cars faster
 - Attacks concrete faster
 - CaCl_2 and MgCl_2 stick to surfaces much longer (Hygroscopic)

Types of Freeze Thaw Scaling

1. Very shallow Surface Scaling
2. Shallow Scaling that does not progress deeper
3. Progressive Scaling

1. Very shallow Surface Scaling

- ▶ Generally finishing related
 - Premature finishing – surface peeling
 - Over finishing
 - Hard Trowelling



2. Shallow Scaling that does not Progress Deeper

- ▶ Premature finishing
 - ▶ Lack of protection before setting
 - ▶ Lack of curing
 - ▶ Premature exposure
-
- ▶ This type represents the vast majority of scaling problems

2. Shallow Scaling that does not Progress Deeper

- ▶ Premature finishing
 - ▶ Lack of protection before setting
 - ▶ Lack of curing
 - ▶ Premature exposure
-
- ▶ This type represents the vast majority of scaling problems























3. Progressive Scaling

- ▶ Non durable mix provided
 - Low air entrainment - spacing factor
 - Low strength
 - Extreme exposure

Four Main Factors Affect Salt Scaling Resistance

- | | | |
|--|---|--------------------|
| 1. Strength (CSA A23.1 Class C-2) | } | Ready Mix Supplier |
| • 32 MPa | | |
| • Properly Air Entrained <ul style="list-style-type: none">▪ Category 1
(5 – 8 % for 20 mm agg.) | | |
| 2. Finishing | } | Contractor |
| • Avoid sealing the surface | | |
| 3. Curing | } | Contractor |
| • 7 days with no water loss and 10C minimum | | |
| 4. One Month Air Dry Period | } | Owner |

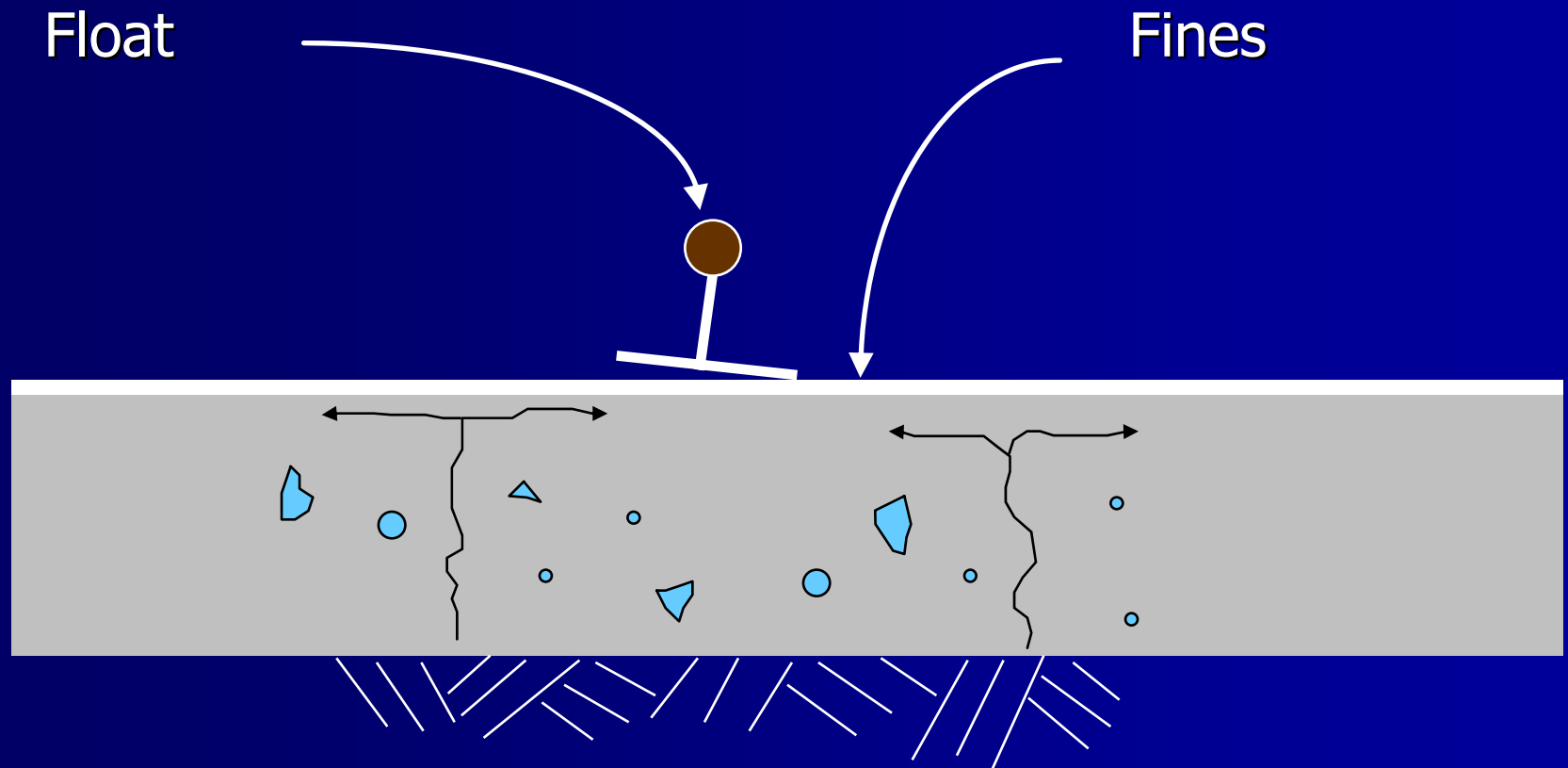
Order the Right Concrete

- ▶ For exterior concrete flatwork exposed to freezing and thawing and deicing salts
 - ***CSA A23.1 Class C-2 requires***
 - 32 MPa
 - Category 1 air entrainment
 - ♦ 5 – 8 % for 20 mm agg.

Effect of Adding More Water (Higher Slump) than the Mix was Designed for

- ▶ Increases shrinkage and cracking
- ▶ Much more challenging to finish properly
 - Increases chance of excessive bleed water
 - Extends finishing times
- ▶ Increases the chance of scaling
- ▶ Reduces strength
- ▶ Can reduce the amount of effective air entrainment

Avoid Sealing the Surface





Two Major Types of Finishing

1. Slip Form

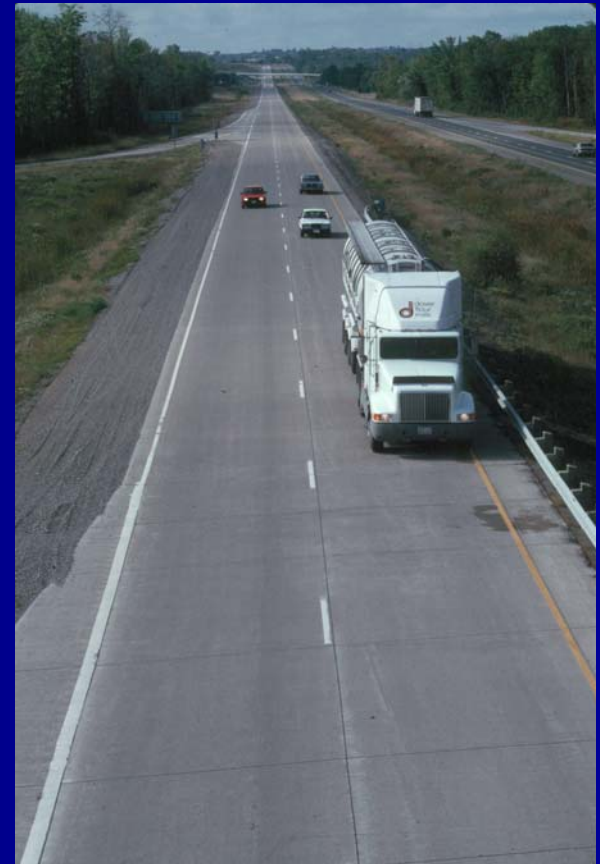
2. Hand Placed

Slip Form

- ▶ Slumps under 70 mm
 - ▶ Very few scaling problems
 - ▶ Almost no bleed water
 - ▶ Usually finished by machine immediately
 - ▶ Never finished during the bleed period
 - ▶ Usually cured properly
-
- ▶ Protection and curing critical because of the lack of bleed water

Finishing - Slip Formed Concrete

- ▶ Slumps under 75 mm (3 inches)
- ▶ Mechanical Placing and Consolidation
- ▶ Limited manual finishing
- ▶ Very few scaling problems
- ▶ Almost no bleed water
- ▶ Usually finished by machine immediately
- ▶ Usually cured properly











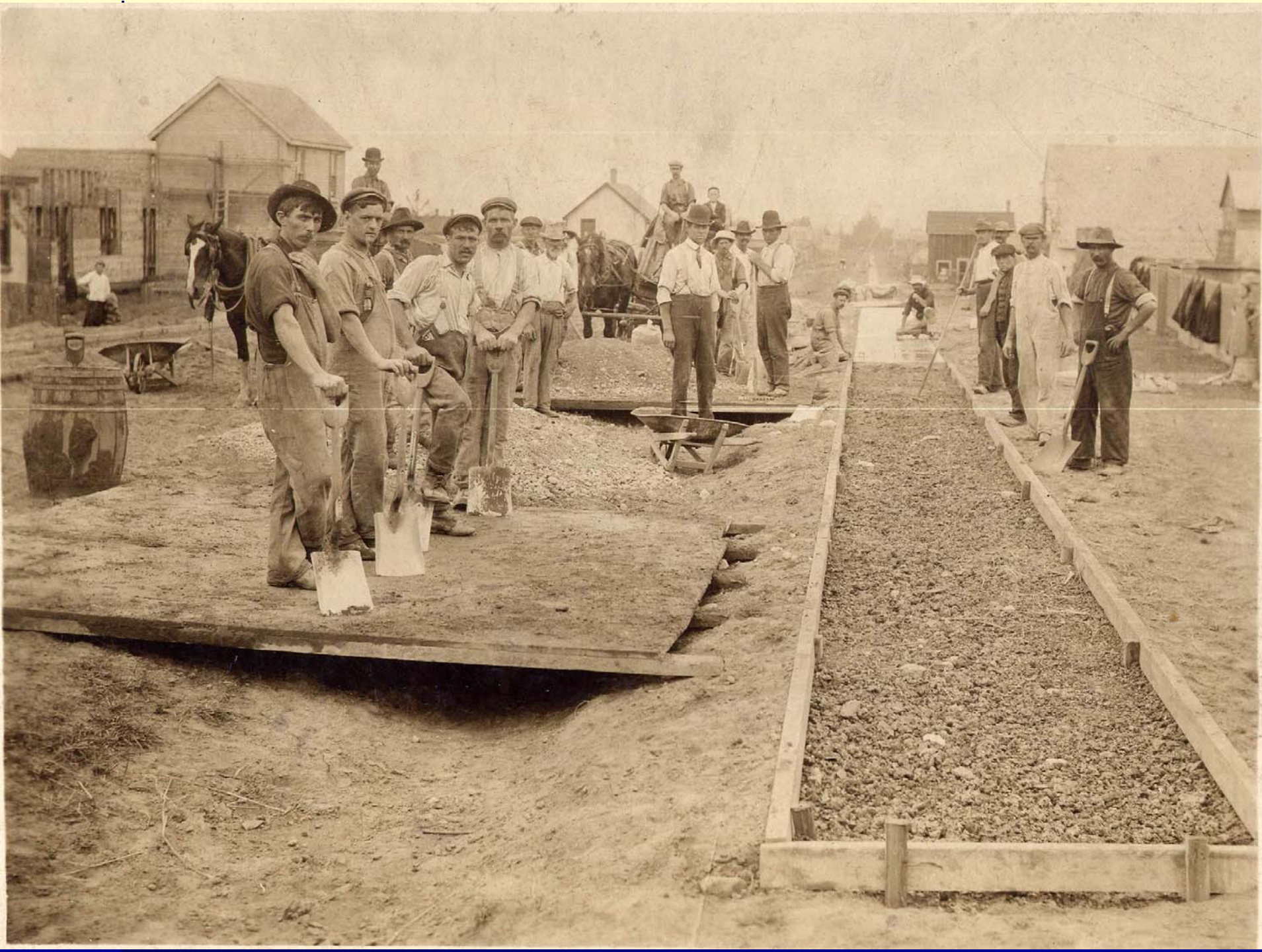






Two Techniques for Hand Placing

1. Final texture applied immediately.
2. Final texturing is delayed until after the bleed period is over (once the concrete begins to set).





Final Texture Applied Immediately

- ▶ Even though finishing is done immediately it is still possible to seal the surface and create a weak layer below the surface.
- ▶ Slumps up to 150 mm are commonly used
- ▶ To avoid sealing the surface
 - Slump should be kept low (100 mm max) to avoid excess bleeding after finishing
 - Do not add excess water to the surface prior to finishing
 - Do not overwork the surface – just what is required to achieve a non-slip surface

Final Texture Applied Later

- ▶ This is the technique recommended in most of the existing literature
- ▶ Typically Slumps up to 150 mm
- ▶ To avoid sealing the surface
 - Final finishing must not begin until after the bleed period is over (once the concrete begins to set “foot print hard”)
 - Do not add excess water to the surface prior to finishing
 - Do not overwork the surface – just what is required to achieve a non-slip surface

**If Final Finishing is delayed,
when do start finishing?**

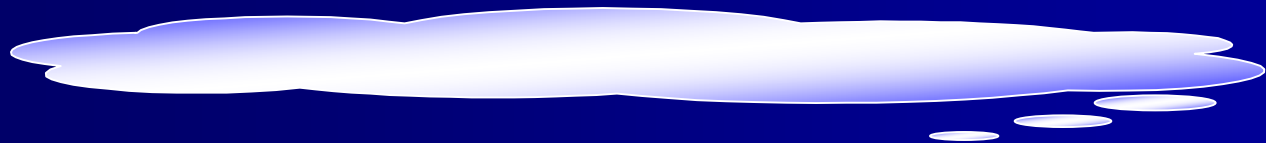


Timing of Final Finishing

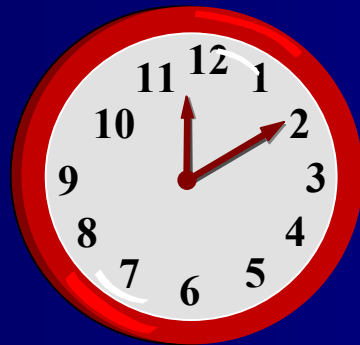
- ▶ Final Finishing should begin...
 - When the concrete has stiffened enough to prevent working of excess mortar to the surface
 - When the concrete is beginning to set
 - When the bleed period is finished
 - When the bleed water has disappeared

Never finish Surface Water into the Concrete

Any finishing operation performed while there is excess moisture or bleed water on the surface, will cause dusting or scaling.



How do you know when it is time to begin Final Finishing Operations?





Final Finishing Operations

Rule of Thumb

Final finishing should begin when the concrete is

Thumb Print Hard,

(after the bleed period is over)



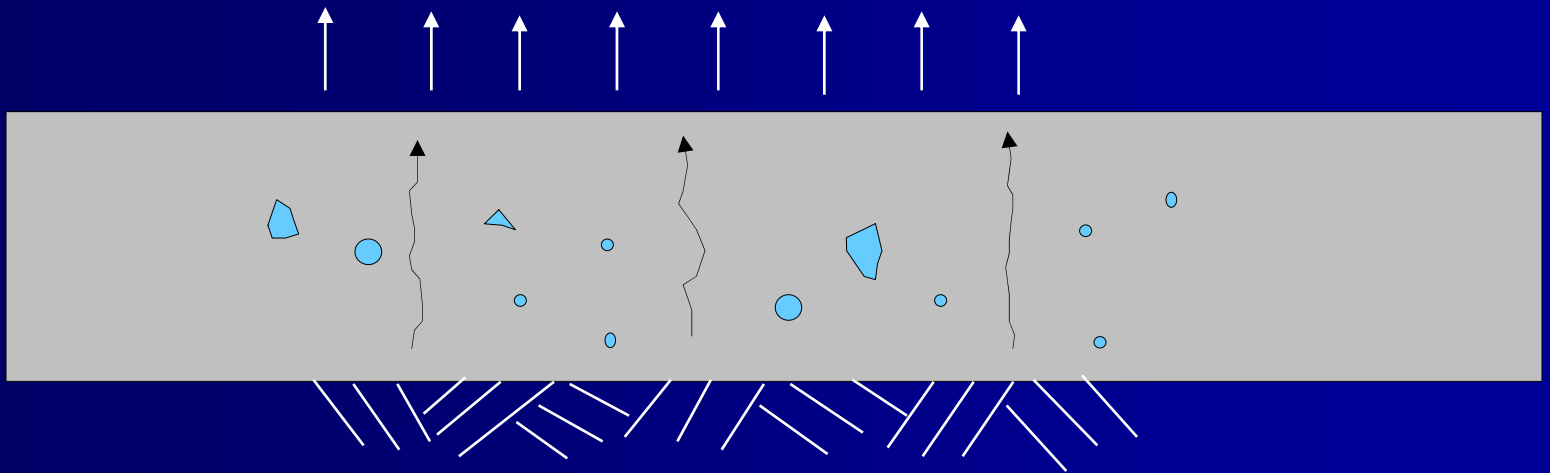


It is ***Impossible*** to judge the correct
time to begin Final Finishing,
if the concrete surface is allowed to
dry !

Factors that Effect Apparent Finishing Time

Evaporation

(Relative Humidity, Temperature, Wind speed)



Bleed water

(Subgrade Temperature, Moisture Content)

CSA A23.1 Protection from Drying

- ▶ Severe Drying Conditions are when evaporation exceeds $1.0 \text{ kg/m}^2\cdot\text{h}$
- ▶ Measures must be taken to prevent rapid loss of moisture

EVAPORATION OF SURFACE MOISTURE FROM CONCRETE

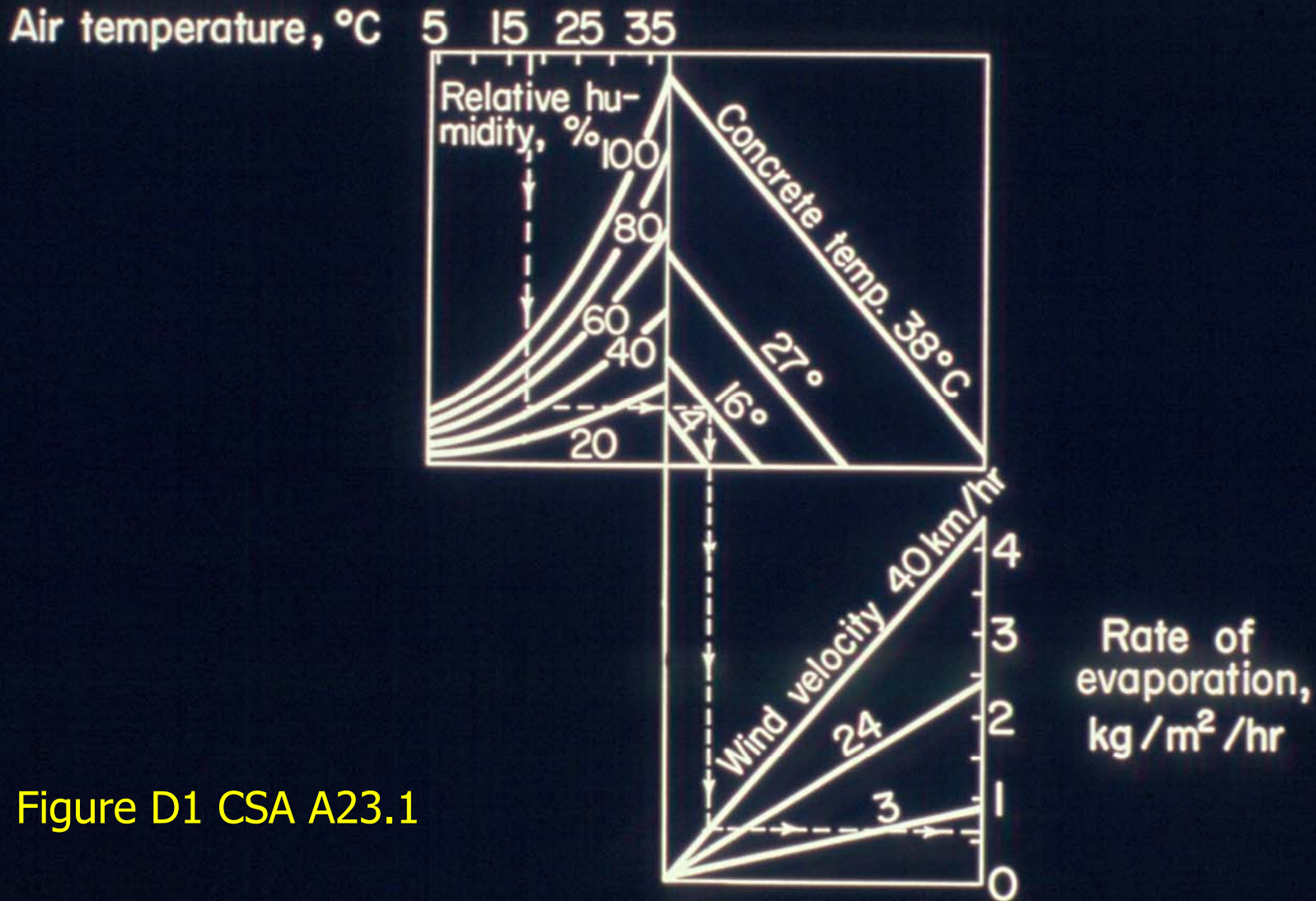


Figure D1 CSA A23.1

Watch out for Wind

- ▶ Even a gentle, low humidity breeze over a warm concrete surface can dry the surface rapidly!





Keep the Concrete Surface Moist

When the concrete surface is allowed to dry, it will begin to stiffen due to dehydration (evaporation) and appear to be ready to finish, even though it has not yet begun to gain strength.

Concrete finished before it sets, will be susceptible to scaling, blistering and other surface defects.

Things can get complicated

- ▶ Surface drying can be faster or slower than the bleed water is accumulating
- ▶ Subgrade can be warmer or cooler than air and concrete temperature, causing the base concrete to set faster or slower than the surface
- ▶ Air entraining reduced bleed water
- ▶ Polypropylene fibres reduce bleeding
- ▶ Some admixtures can lengthen setting (finishing) times
- ▶ Other admixtures can change the finishing characteristics

IMPORTANT TEMPERATURES

AIR

Rapid surface evaporation
produces crazing or cracking

Ideal placement

Critical range
Produces cycles of freezing
and thawing

DANGER!

CONCRETE

Rapid finishing - early curing
required -- reduce temperature

Normal placement temperature

◀ Optimum temp. for max. strength

◀ See CSA A23.1 for protection

◀ Minimum curing temperature

◀ Freezing point of water - water
expands causing damage

DANGER!



**How do you Keep a Concrete
Surface from Drying?**

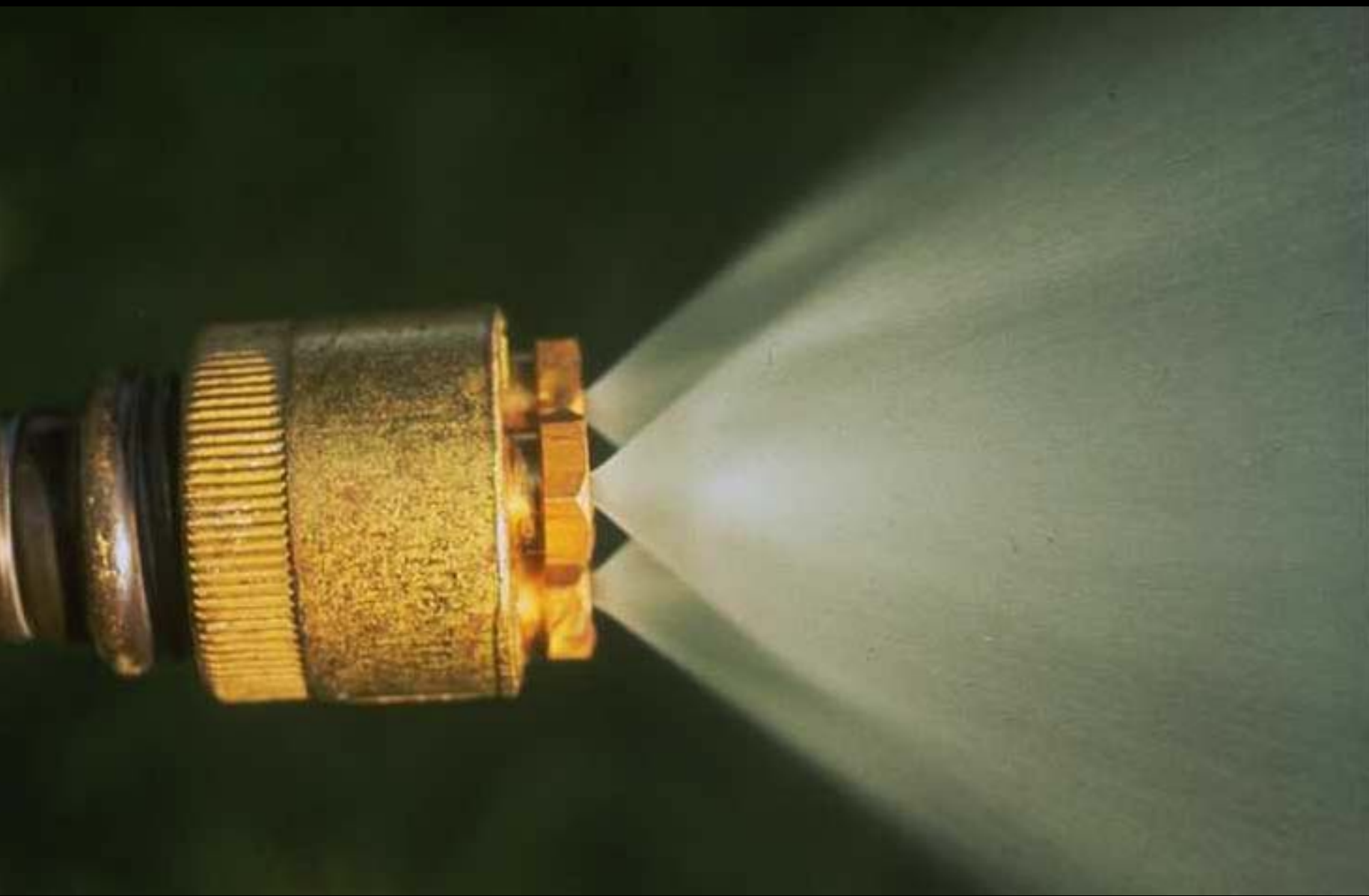
Initial Protection Period

- ▶ Other initial protection period methods can work if weather is cooperative
 - ***Covering with plastic***
 - This is famous for being difficult in high winds
 - ***Scheduling concrete placement after the sun has set***
 - This is standard procedure for some DOTs
 - Uncooperative weather can still lead to problems, but night conditions are typically far better for concrete placement

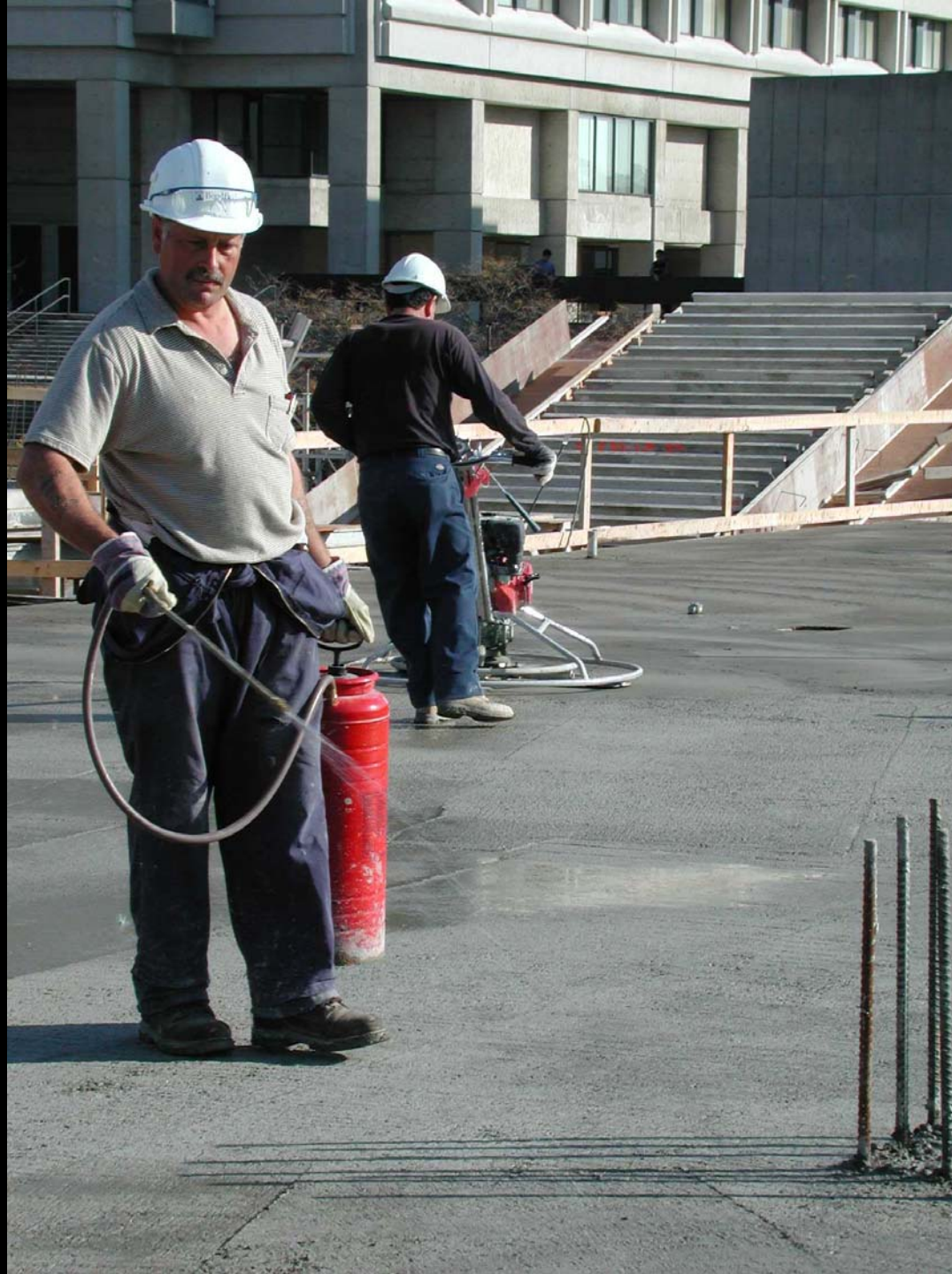
Initial Protection Period

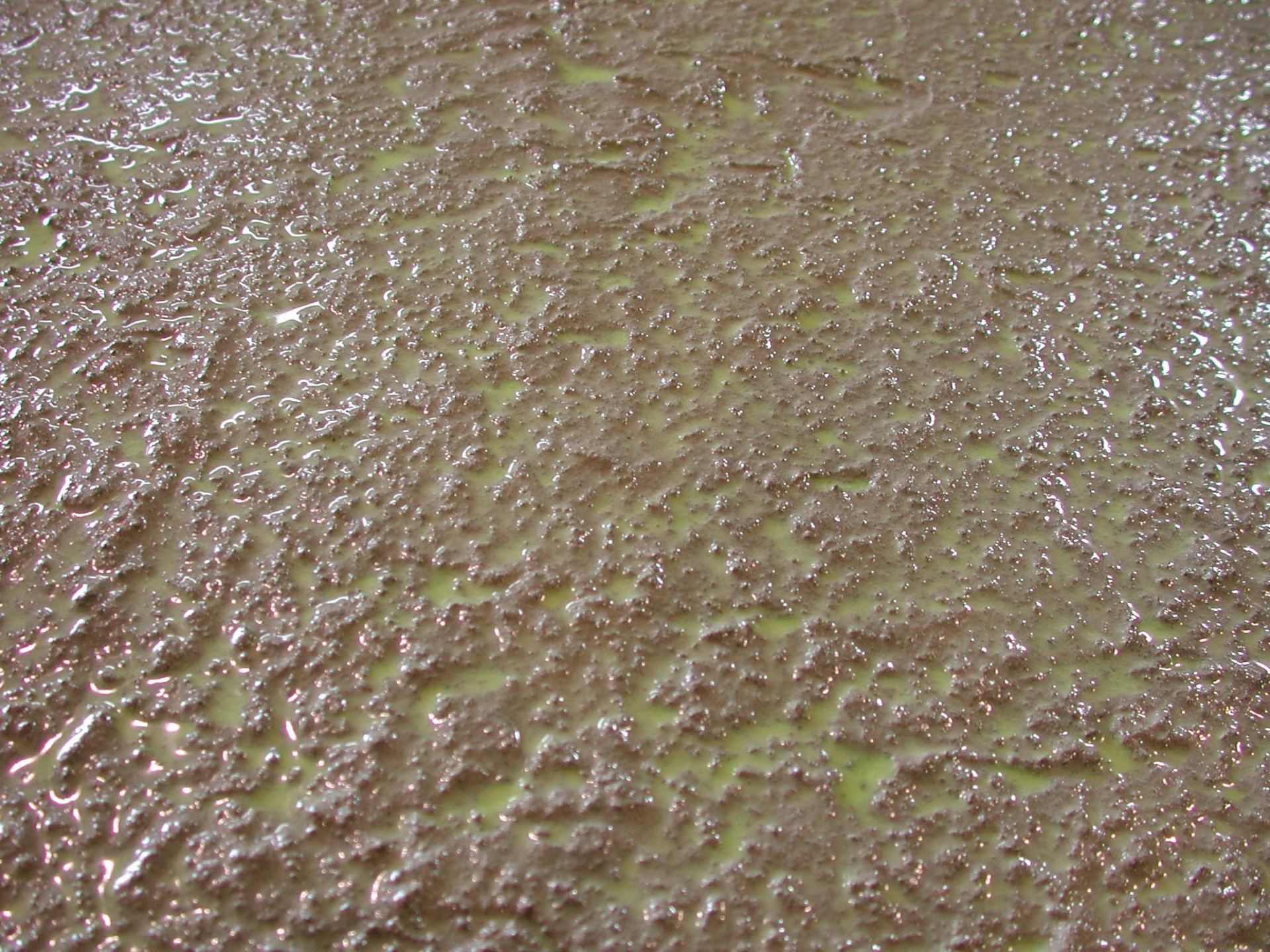
- ▶ The two best methods recommended for protection from dehydration during the initial protection period.
 - ***Fog Misting***
 - a fine mist is sprayed into the air over top of the slab, not onto the surface.
 - ***Evaporation Retardant***
 - Use at the manufacturers recommended application rates.
 - These water soluble products do not work when not applied heavily enough or diluted too much.
 - Evaporation Reducers should not be used as finishing aids.













Evaporation Retardants

- ▶ Evaporation Retardants do nothing to prevent surface drying if used as finishing aids.
- ▶ Must be applied after finishing operations and allowed to form a film that is not disturbed.
- ▶ If disturbed, they no longer protect against dehydration.

Finishing – How to Finish

Finishing - Tools

- ▶ ***Wood Floats*** do the least harm to the salt scaling resistance
 - Wood is least likely to seal bleed channels and facilitate over finishing
- ▶ ***Magnesium Floats*** can also be used but have a greater tendency to seal the surface

Finishing Tools for Salt Scaling Resistance

***Steel Trowels (power trowels),
should not be used on exterior concrete!***

Steel Trowels

- ▶ Steel trowels (power trowels) are not recommended
 - Steel trowels tend to densify and seal the surface too much trapping bleed water and creating a weak layer below the surface
- ▶ Magnesium or wood floats tend to seal the surface less than steel









Plastic Shrinkage

- ▶ Cracks can be wide, but do not go through the slab vertically or horizontally
- ▶ Cracks can form perpendicular to the wind direction, but can be random when the wind swirls
- ▶ Caused by lack of protection from rapid drying, when the concrete is still plastic







Curing

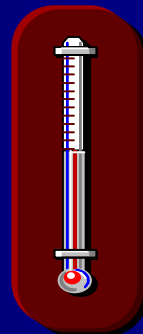


Benefits of Adequate Curing

- ▶ Greatly improves
 - ***Durability***
- ▶ Greatly improves
 - ***Abrasion Resistance***
- ▶ Eliminates
 - ***Early Cracking***
- ▶ Increases
 - ***Strength***
- ▶ Greatly improves
 - ***Water Tightness***

Curing for Additional Durability (CSA A23.1 Class C-2)

- ▶ Time **7 days minimum**
- ▶ Temperature **10 °C minimum**
- ▶ Moisture **Saturated at all times**



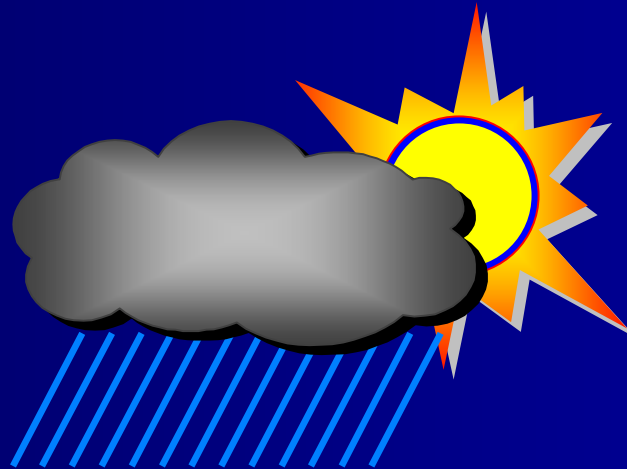
Methods of Curing

Retained Moisture

- ▶ Polyethylene sheets
- ▶ Curing compound
 - applied thick enough to work

Supply Additional Water

- ▶ Wet burlap and plastic
- ▶ Fog Spray
- ▶ Ponding



When Should Curing Start?

- ▶ Curing should begin *Immediately* after the final finishing operation
 - Unfortunately curing is often delayed with hand finished concrete, sometimes for many hours.
- ▶ Any delay in curing allows the concrete surface to dry and significantly weakens the bond of the surface to the substrate
- ▶ Concrete has to be essentially saturated for hydration to continue









Curing Compounds

- ▶ Water soluble curing compounds must not be diluted. Diluted curing compounds do not keep the water in the concrete.
- ▶ Non-water soluble curing compound must also not be diluted with water.





One Month Air Dry Period

- ▶ According to CSA A23.1,
 - “Immediately after the 7 day curing period, the concrete should be allowed to “Air Dry” for at least one month before the application of de-icing chemicals.”

References

- ▶ CSA A23.1 Concrete Materials and Methods of Concrete Construction
- ▶ NRMCA CIP #
- ▶ RMCAO Driveways Brochure

Summary

1. Order the right concrete
 - **CSA A23.1 C-2**
2. Protect against dehydration prior to final finishing and curing
 - ▶ **Evaporation Retardant**
3. ***Do not seal the surface!***
4. Cure, Cure, Cure
5. Air Dry for one month



What can a Specifier do

1. Require that the surface not be sealed
 - ▶ The contractor must know that finishing operations must not seal the surface
2. Require and enforce that curing is applied immediately after final texture
3. Prior to curing require that concrete not be allowed to dry
4. Try to schedule construction so that the one month air dry period is possible

New Mixed Mode and Capacity Increase Ideas from India

