Troubleshooting

Concrete Concerns

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Lafarge (A Division of LafargeHolcim)
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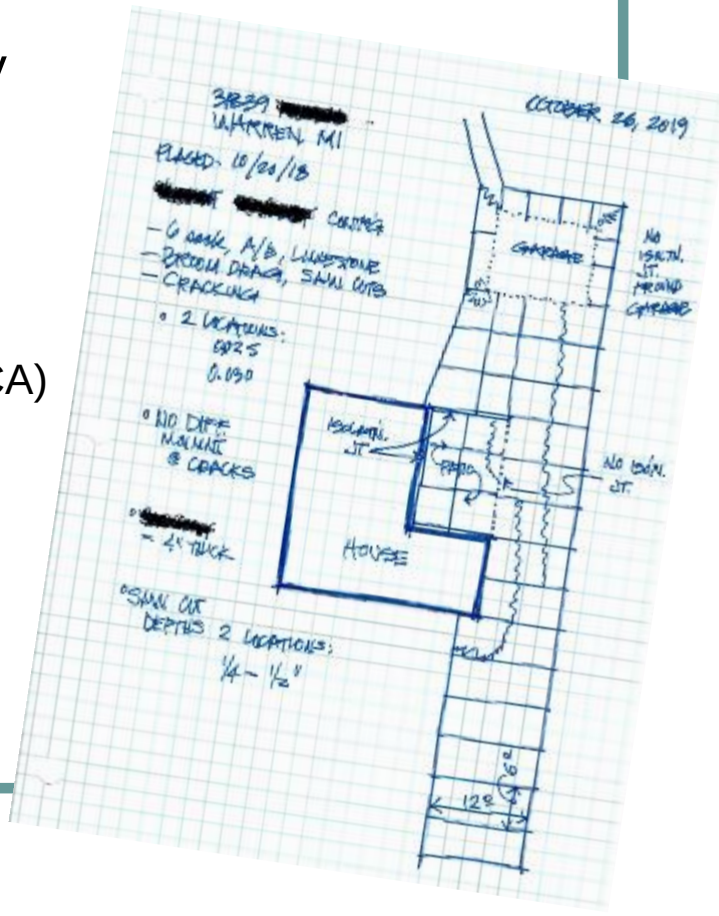
Troubleshooting Basics

- Investigating Procedures
  - Sketch out observations
  - Take measurements
  - Take photographs to help tell your story
  - Perform basic testing
- Drawing conclusions
  - *Concrete in Practice* (CIP), NRMCA
    - Rely on industry associations (MCA, ACI, PCA) for your conclusions



Popouts

- Conical voids observed in the surface of concrete wherein a portion of the aggregate remains intact
- Popouts typically result from soft or deleterious aggregates near the surface of the concrete

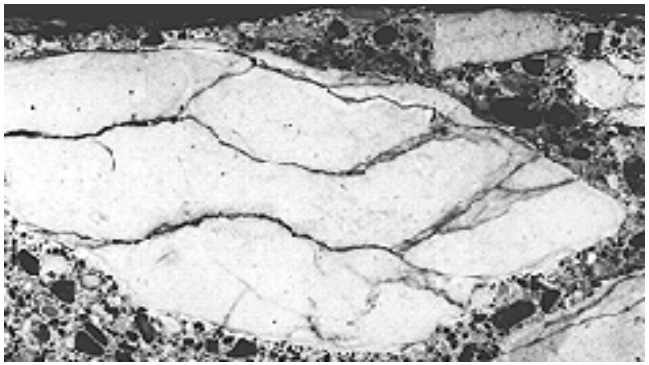
Popouts

- Although economics prohibit the complete removal of all deleterious aggregates from concrete
- A limited amount are allowed
  - American Society for Testing and Materials (ASTM C 33)
  - Michigan Department of Transportation (MDOT)

D-Cracks

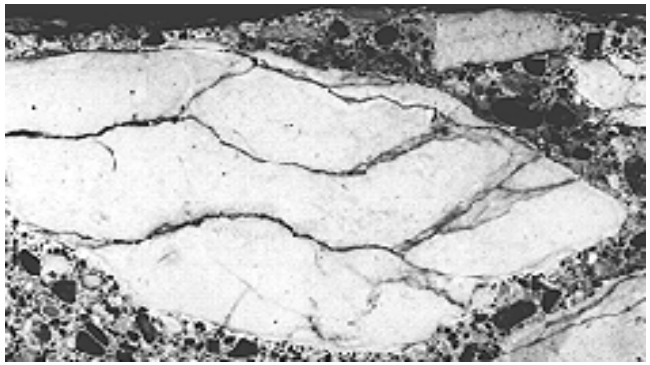
Cracking of pavements caused by freeze thaw deterioration of the aggregates within the concrete

- Typically after 3 or more years of service
- Function of the pore properties of certain types of aggregates
  - The aggregate may absorb so much water that the particle can not accommodate the expansive stresses put on it when that water freezes
  - The result is an expansion of the aggregate and possible disintegration of the concrete



D-Cracks

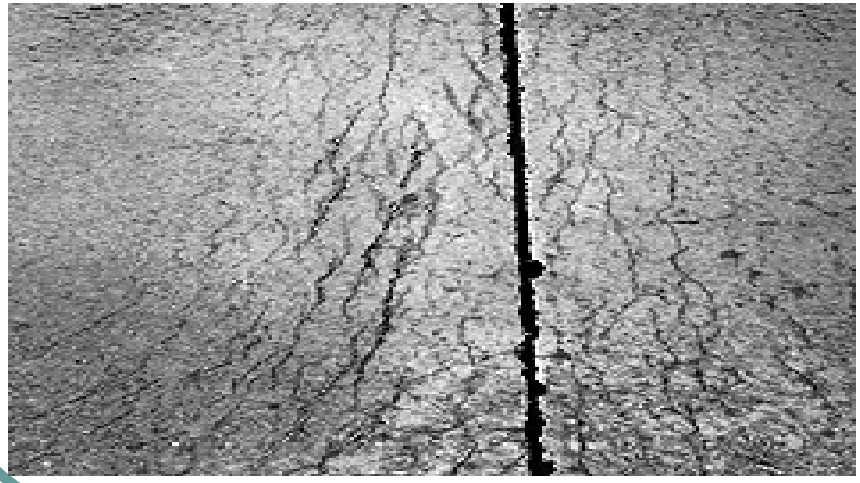
- The cracks are closely spaced formations parallel to the transvers and longitudinal joints and multiple out toward the center of the panel
- Due to the natural accumulation of water under the pavement, the aggregate becomes saturated
- Freezing/thawing damage occurs in the aggregate at bottom half of the slab and slowly works up



D-Cracks

Tips:

- Select aggregates with good freeze/thaw test records or past history
  - ASTM C 666 (AASHTO 161)
- Design and construct pavements with effective drainage systems for carrying free water out from under the pavement



Slab Moisture Concerns

- Warping, buckling, peeling, and staining of floor coverings
- Deterioration of floor covering adhesives
- De-bonding of coatings
- Odors and other air quality problems
  - Mold
  - Mildew

Blisters

- Blisters are hollow, low profile, bumps on the concrete surface, typically ranging from the size of a dime up to several inches in diameter

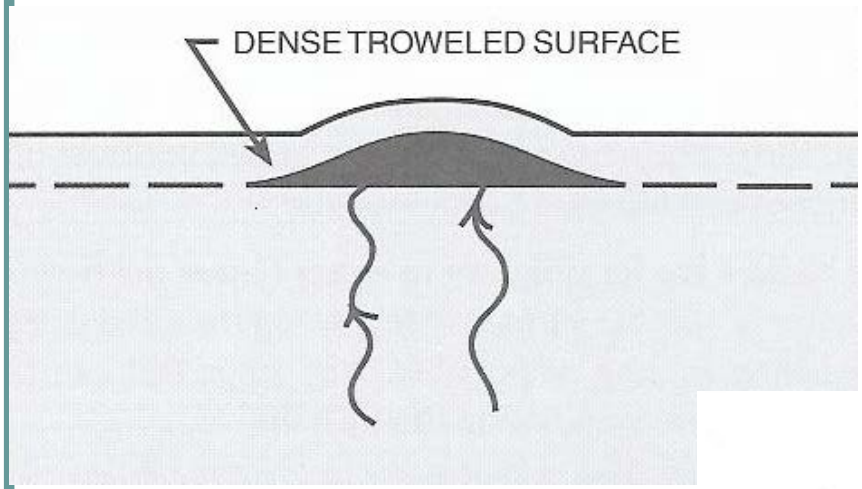
Blisters

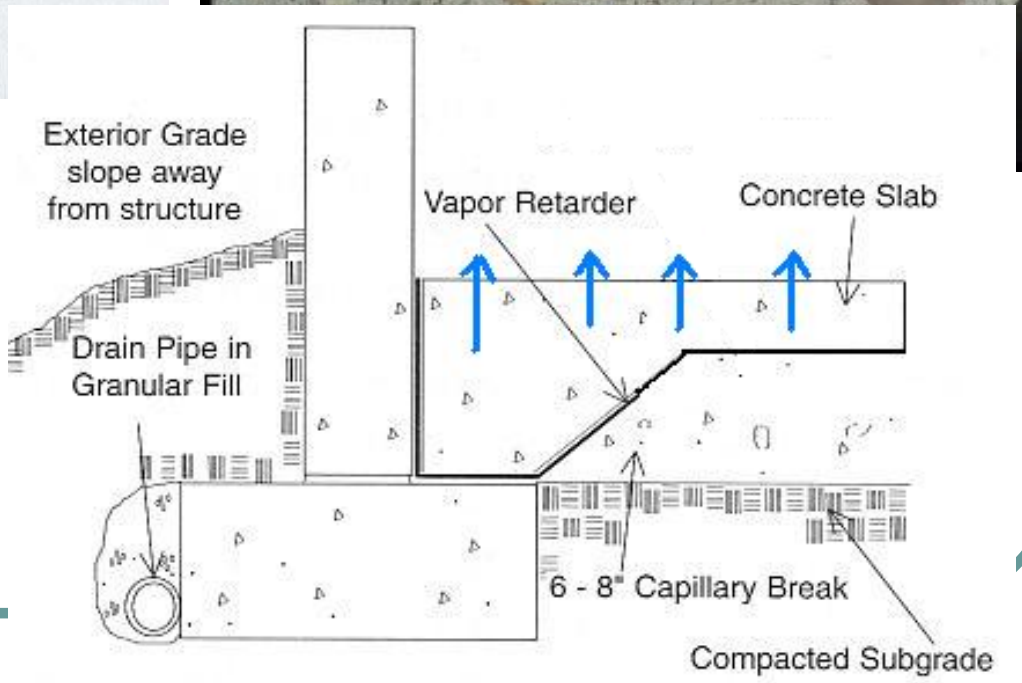
Likely to form if:

- The subgrade is cool and the concrete in the bottom portion of the slab sets slower (vapor retarder)
- Air entrainment (AE) is used at a higher than normal dosages*
- Dry shake used over AE concrete
- Mix is rich in fines
- Mix is lean in cementitious content
- The slab is exceptionally thick
- Excessive use of a vibrating screed,

which will result with excess cream

Blisters


DENSE TROWELED SURFACE

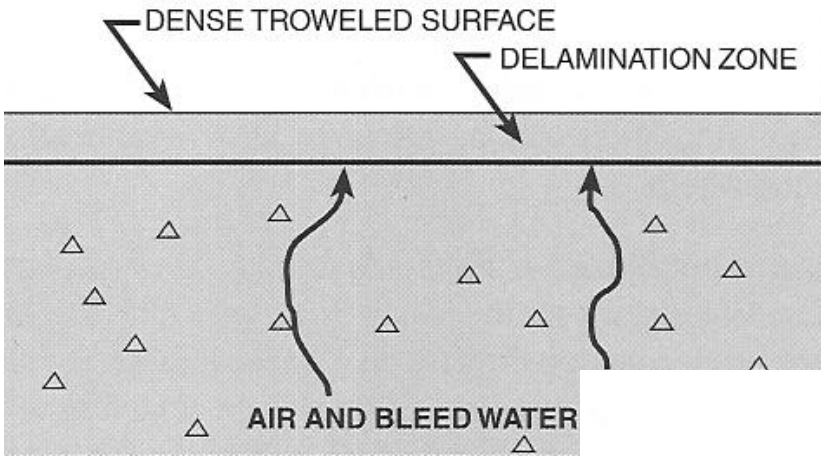

Exterior Grade
slope away
from structure
Vapor Retarder
Concrete Slab
Drain Pipe in
Granular Fill
6 - 8" Capillary Break
Compacted Subgrade

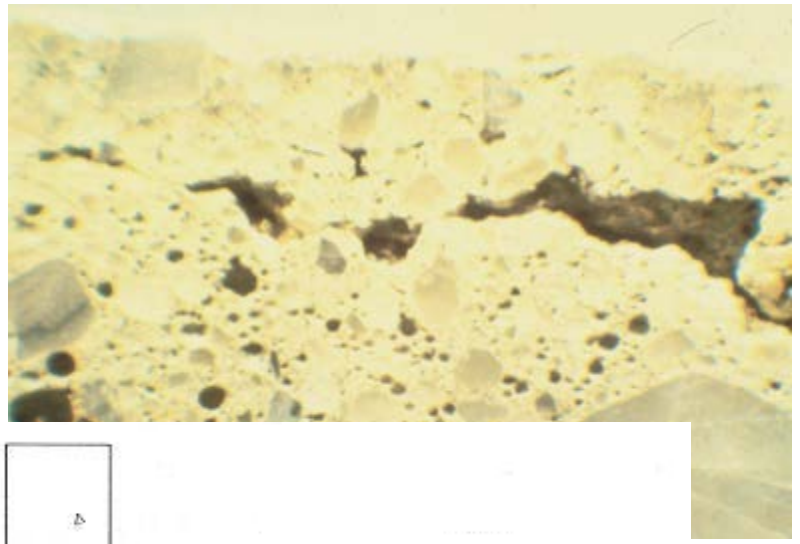
Blisters

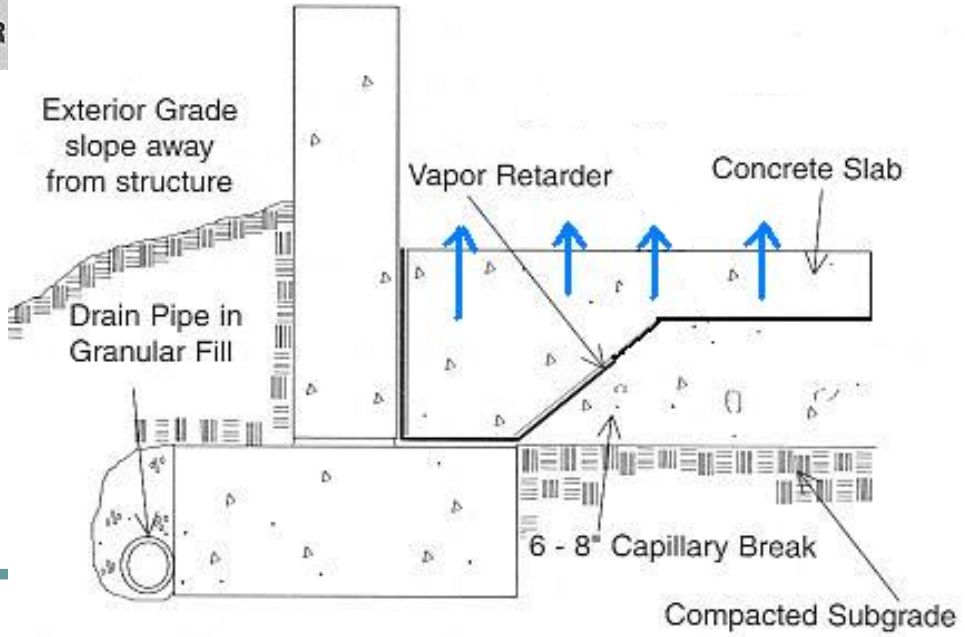
Blisters have an ugly cousin:

- Delamination
- Delamination is when the top portion of the cream is densified and separates from the base slab by a thin layer of air or water
- Can range from several square inches to several square feet

Delamination







Blisters & Delamination

Tips:

- Do not seal surface too early
  - Before air and bleed water has chance to escape
  - Emphasis should be placed on placing, striking off, and bull floating as fast as possible without working up too much mortar
  - After these operations, further finishing should be delayed as long as possible

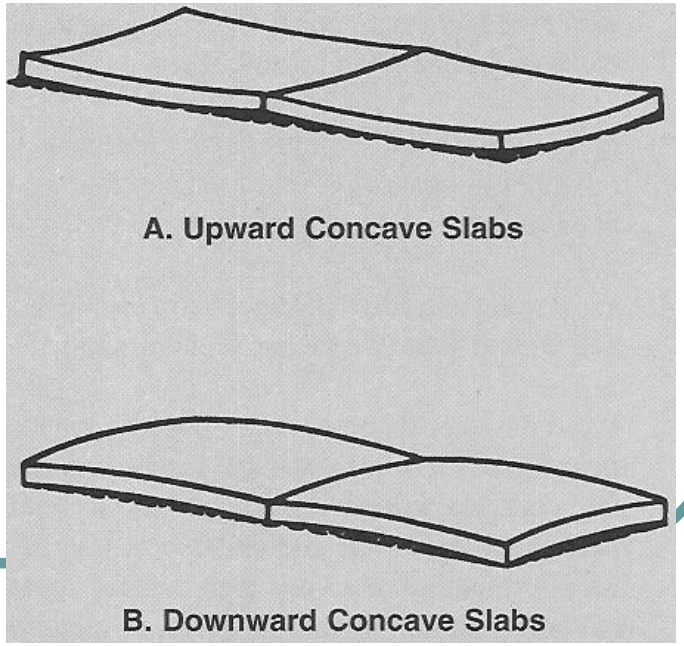
Blisters & Delamination

Tips:

- Do not use AE unless it will be subject to deicing salts*
  - Especially if the interior floor is to be steel troweled
  - Avoid dry shakes on AE concrete
- Avoid placing concrete on subgrade < 40°F
- Protect surface from premature drying

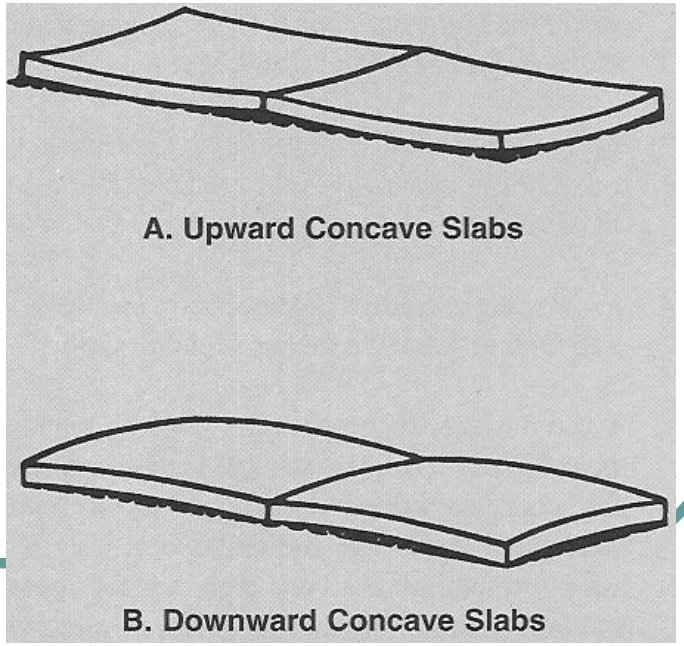
Curling

- The distortion of a slab into a curved shape by upward or downward bending
- Typically caused by the shrinkage or contraction of one portion of the slab in relation to the other portion of a slab
- Changes in slab dimensions which lead to curling are most often related to **moisture** and **temperature gradations** between the top and bottom of the slab

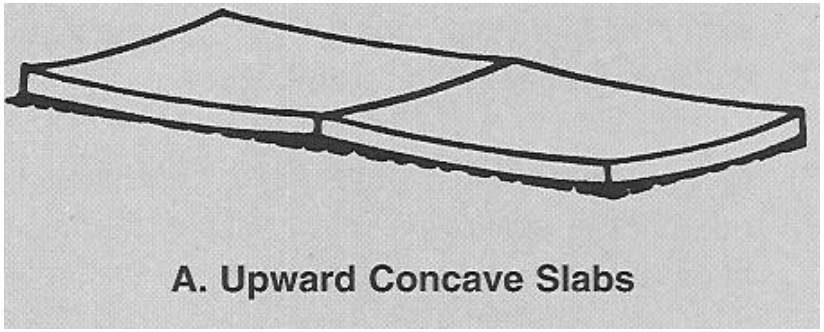


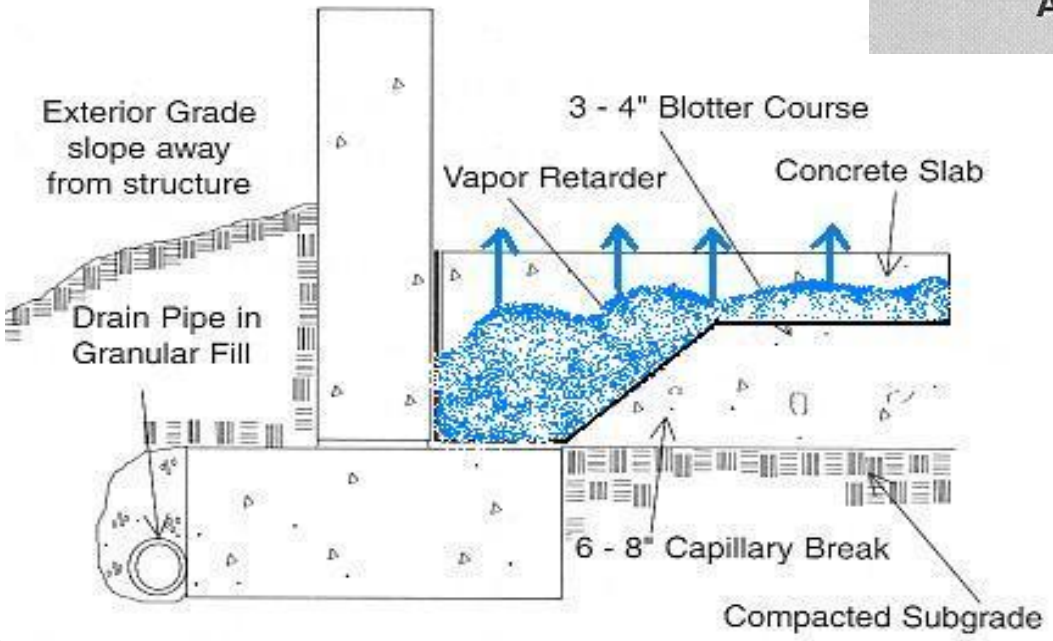
Curling

- It is most noticeable at the joints, edges and corners of a slab
- Drying shrinkage is what most impacts curling
- Drying shrinkage increases with:
  - An increase in water content
  - An increase in volume paste
  - Aggregate type can also promote curling
  - Thin slabs and long joint spacing

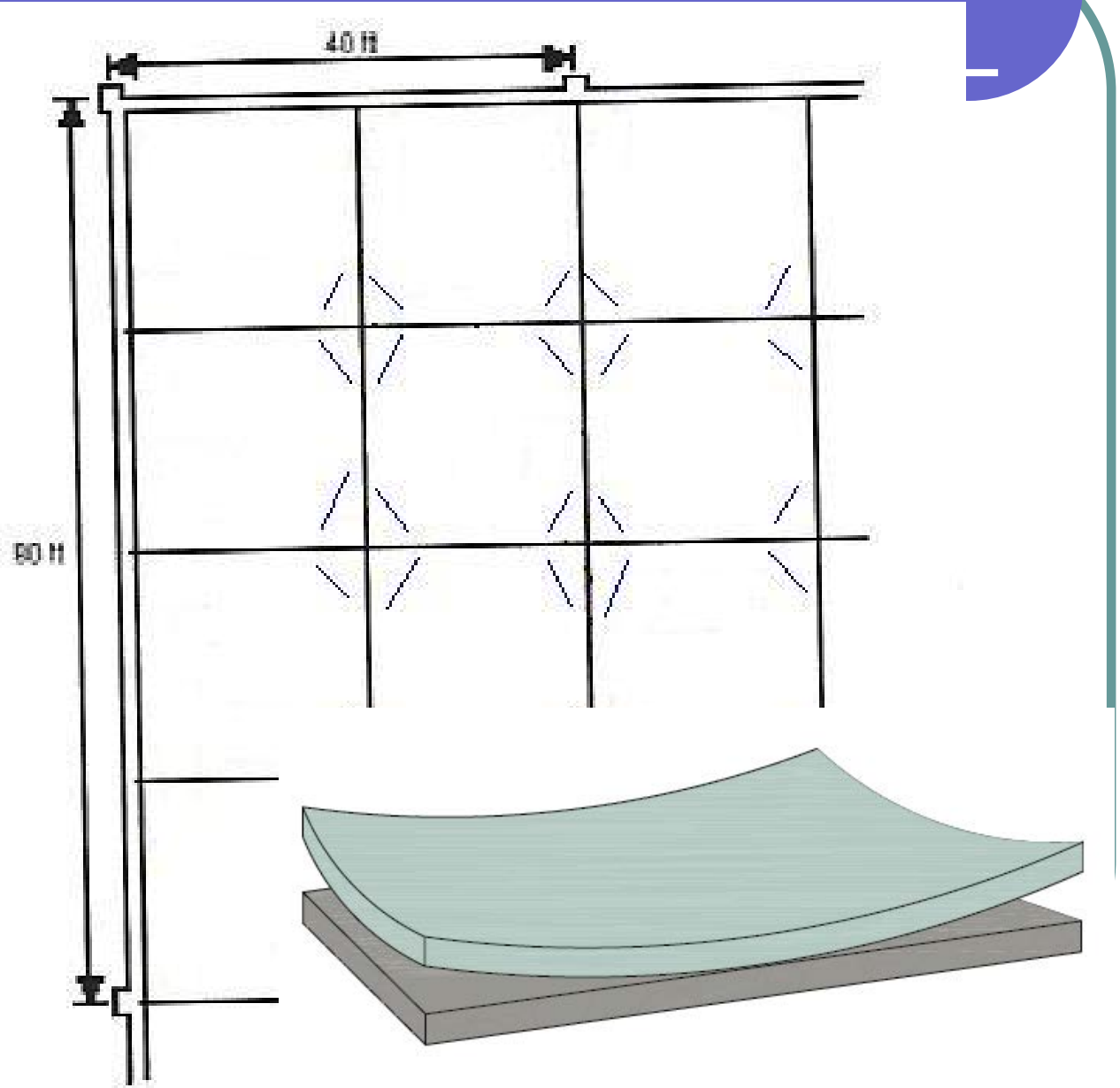


Curling

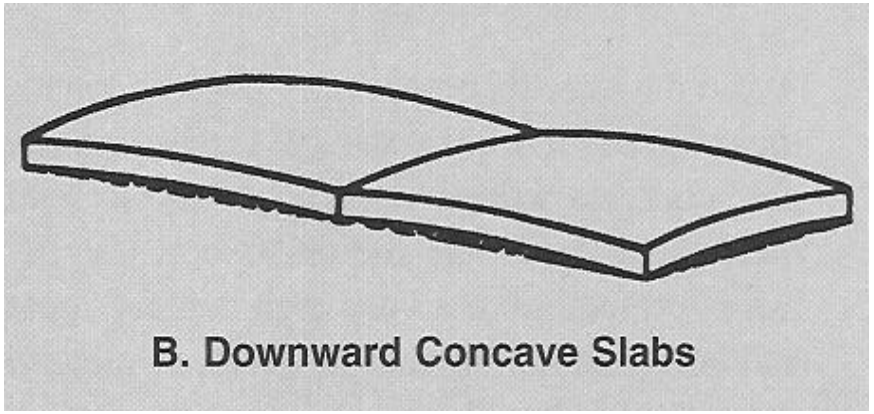

A. Upward Concave Slabs

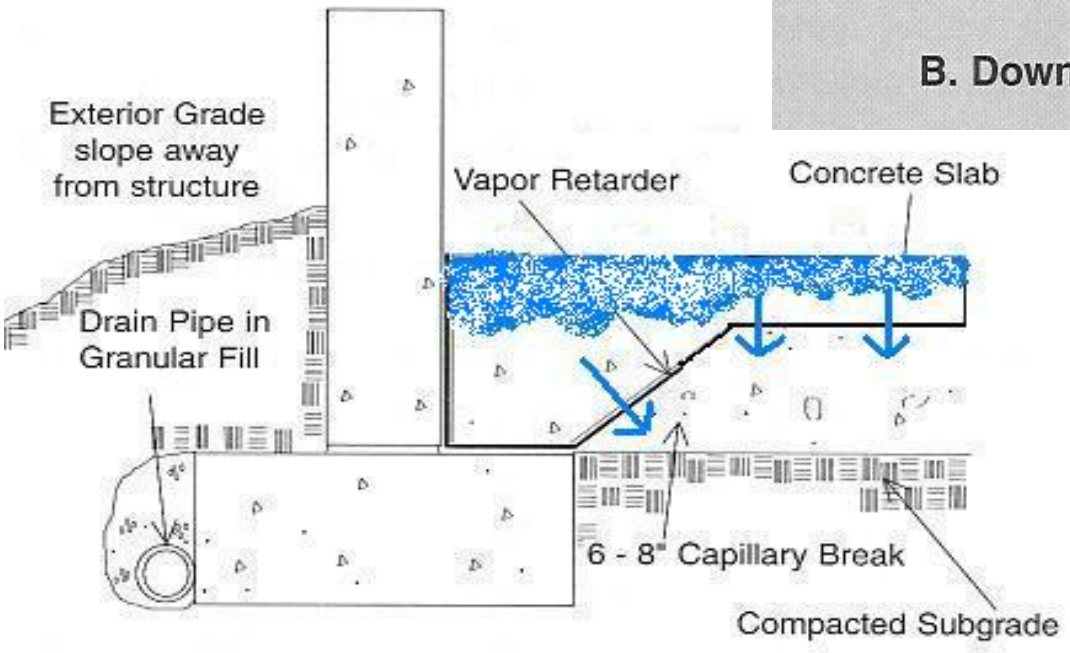

Exterior Grade
slope away
from structure
3 - 4" Blotter Course
Vapor Retarder
Concrete Slab
Drain Pipe in
Granular Fill
6 - 8" Capillary Break
Compacted Subgrade

Curling



Curling


B. Downward Concave Slabs


Exterior Grade slope away from structure
Vapor Retarder
Concrete Slab
Drain Pipe in Granular Fill
6 - 8" Capillary Break
Compacted Subgrade

Curling

Tips:

- Use lowest slump practical
- Avoid re-tempering
- Use the largest practical maximum size aggregate to minimize drying shrinkage
- Use a damp absorptive subgrade
- Proper strategy when using vapor retarders

Curling

Tips:

- Avoid higher than necessary cementitious contents (this will increases paste)
  - Higher compressive strengths does not assure lower shrinkage or less curling
- Avoid excessive bleeding
- Proper jointing techniques
- Use thickest slab practical
- Proper slab reinforcing
  - Upper 1/3 of the slab
  - Load transfer devices
- Cure thoroughly

Dusting

- Formation of powder or chalk resulting from disintegration of the hardened concrete surface
- Powders under foot traffic
- Can be easily scratched with a key, etc.

Dusting

Some causes:

- Finishing in the presence of bleed water
  - Increases w/cm at the top ¼ in producing a surface with low durability
- Poor finishing practices
  - Blessing the surface
  - Floating/troweling condensation of moisture from warm humid air on cool concrete
- Insufficient curing
- In adequate protection after the slab is finished
  - Allowing the surface to freeze, get rained on, drying winds will even promote dusting
- Inadequate ventilation of heaters
- (Carbon dioxide settling on the surface of fresh concrete will produce a reaction termed *carbonation)*

Dusting

Some causes:

- Inadequate ventilation of heaters
  - Carbon dioxide from open salamanders, gas engines or generators, power buggies, etc., may cause the exhaust gasses to settle on the surface of the fresh concrete
  - The carbon dioxide can cause a chemical reaction known as carbonation
  - Carbonation greatly reduces the strength and hardness at the surface of the concrete

Dusting

Tips:

- Use 5-in slump concrete
- Do not start finishing operations while concrete is bleeding
- Do not bless the surface prior to finishing
- Ensure adequate ventilation of gas fired heaters
- Cure the concrete and protect it from freezing and extreme ambient conditions

Dusting

Tips (*continued*) if it is dusted:

- Commercially available chemical floor hardeners
  - sodium silicates, metallic zinc, or magnesium fluosilicate
- Apply per manufacturers directions
- Grind surface to substrate or topping

Commonly Observed Cracks

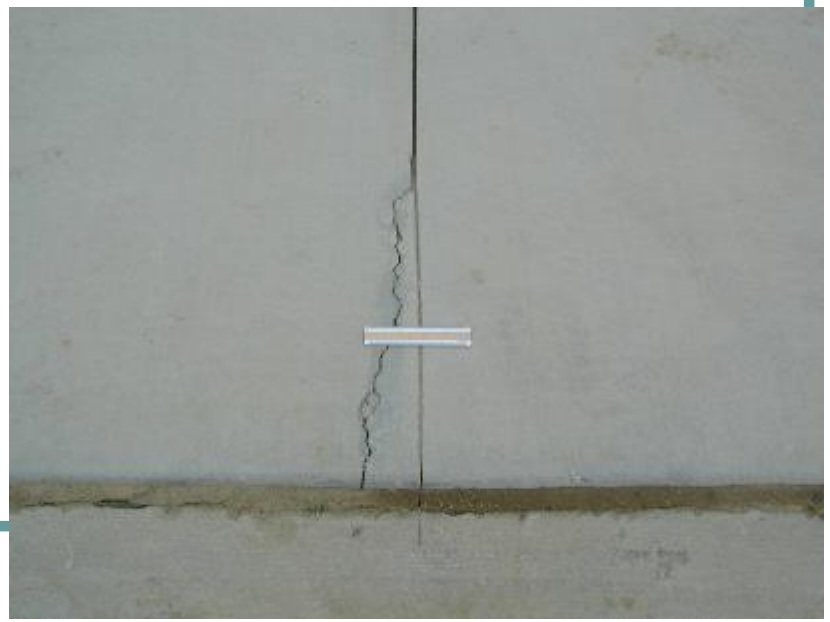
Why do cracks occur?

- Concrete, like other construction materials contracts, expands and deflects under load
- Cracks will result when this movement is not accounted for

Commonly Observed Cracks

Why do cracks occur?

- Freshly placed concrete is at its largest volume right after its first placed, as it hardens and dries it will continue to shrink in volume
- Variations in temperature will also cause concrete to expand and shrink
  - When all of these volume changes are restrained, the concrete will crack



Cracks in Basement Walls

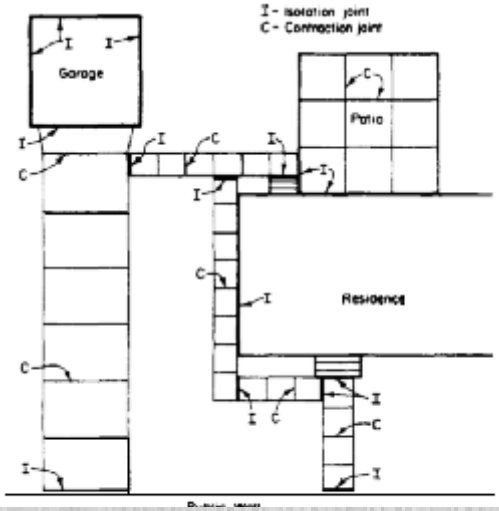
Cast-in-place walls provide durable, quality living space however, at times may crack:

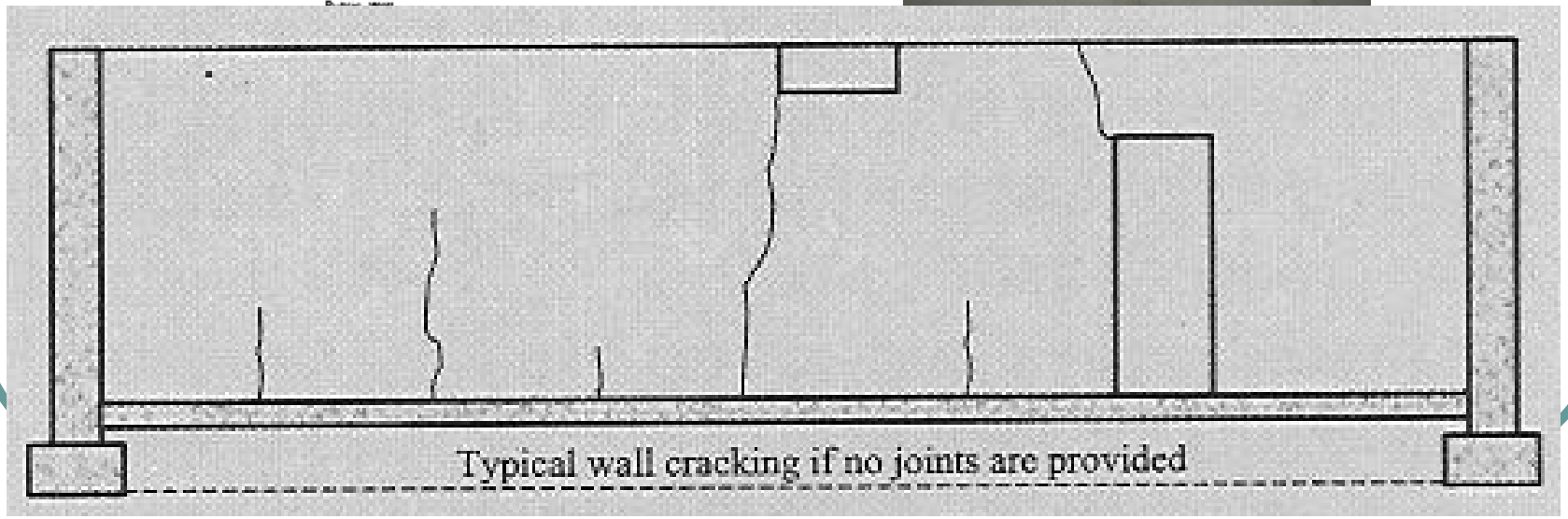
- Temperature and drying shrinkage: Can provide significant swings resulting with cracking
- Settlement: Non-uniform support of footings or expansive soils

Cracks in Basement Walls

- Other: Backfilling too early / heavy equipment near the perimeter of the wall too soon may yield structural cracking
- Lack of joints or improper use of joints in a wall
- National Association of Home Builders (NAH) requires repair or corrective action when cracks in basement walls allow exterior water to leak into the basement

Cracks in Basement Walls



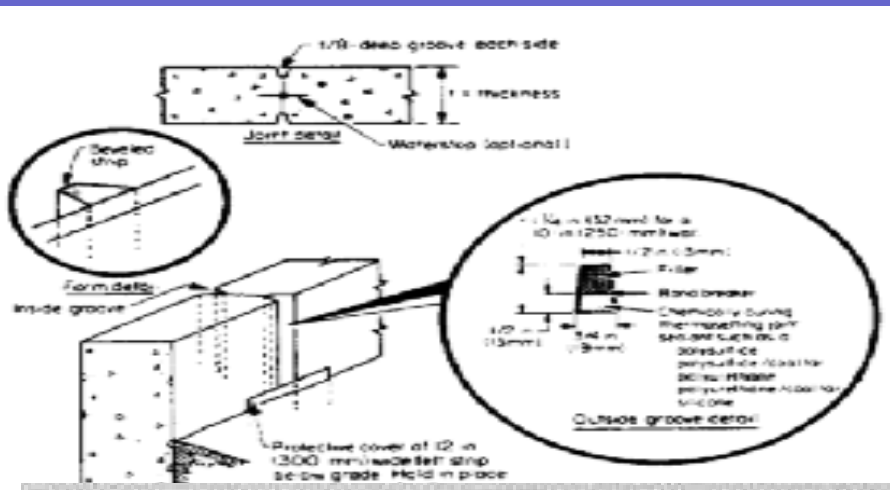


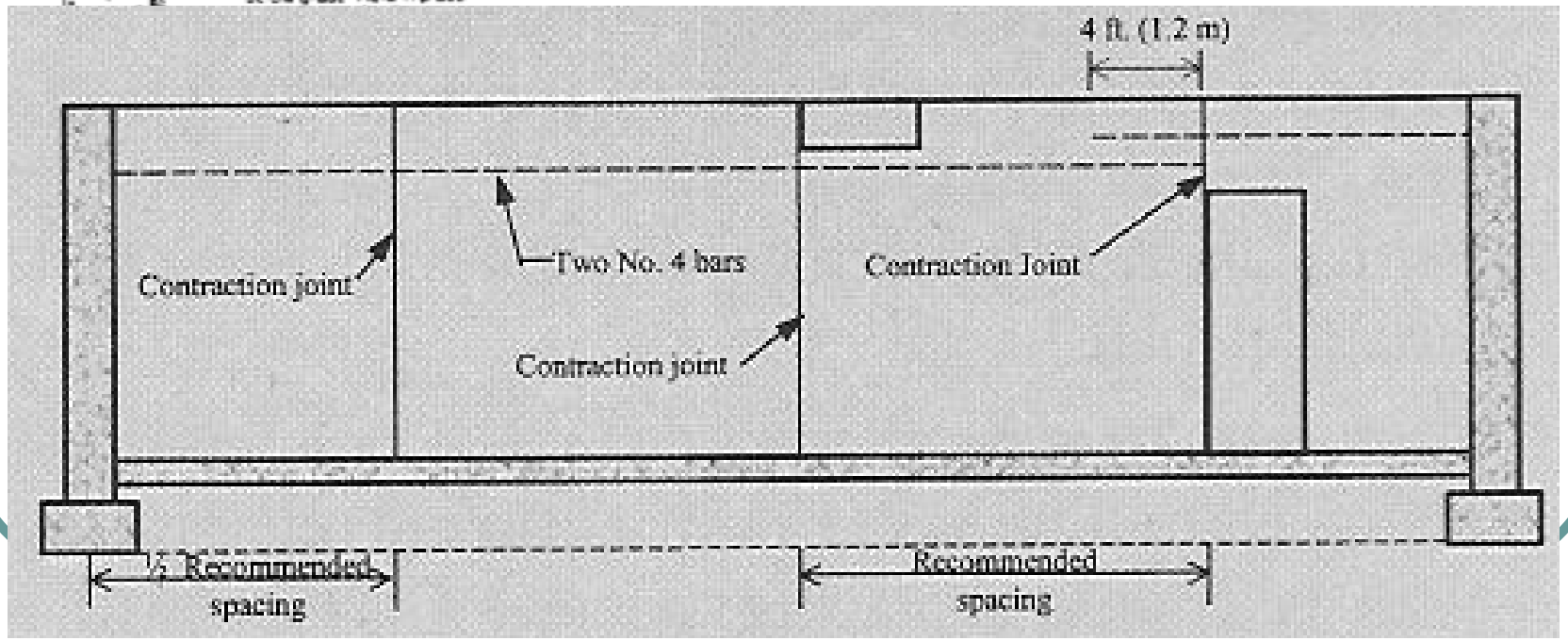
Cracks in Basement Walls

Tips:

- Consider control joints
  - 8 foot tall x 8-inch thick walls should contain vertical joints at a spacing that are 30 times the wall thickness
  - The depth of the joints should be min. ¼ the wall thickness
  - The joints should be sealed
  - Horizontal reinforcement should continue thru the joints

Cracks in Basement Walls





Cracks in Basement Walls

Tips (continued):

- Uniform soil support
- Moderate slump (5-in)
- Follow proper construction practices
  - Placement and consolidation
- Caution when backfilling, if possible after first floor decking is in
- Follow proper curing practices
- Crack repair
  - A basement wall crack does not necessarily mean poor workmanship, materials or structural failure
  - If the crack leaks, there are many ways to repair the crack
    - Epoxy injection, dry packing, routing and sealing, etc.

Plastic Shrinkage Cracks

- Appear soon after the concrete was placed, finished and still plastic
- Appear mostly on horizontal surfaces
- Parallel to each other (1 – 3 feet apart)
- Relatively shallow and typically do not penetrate the depth of the slab, or intersect to the perimeter of the slab

Plastic Shrinkage Cracks

Why do they occur?

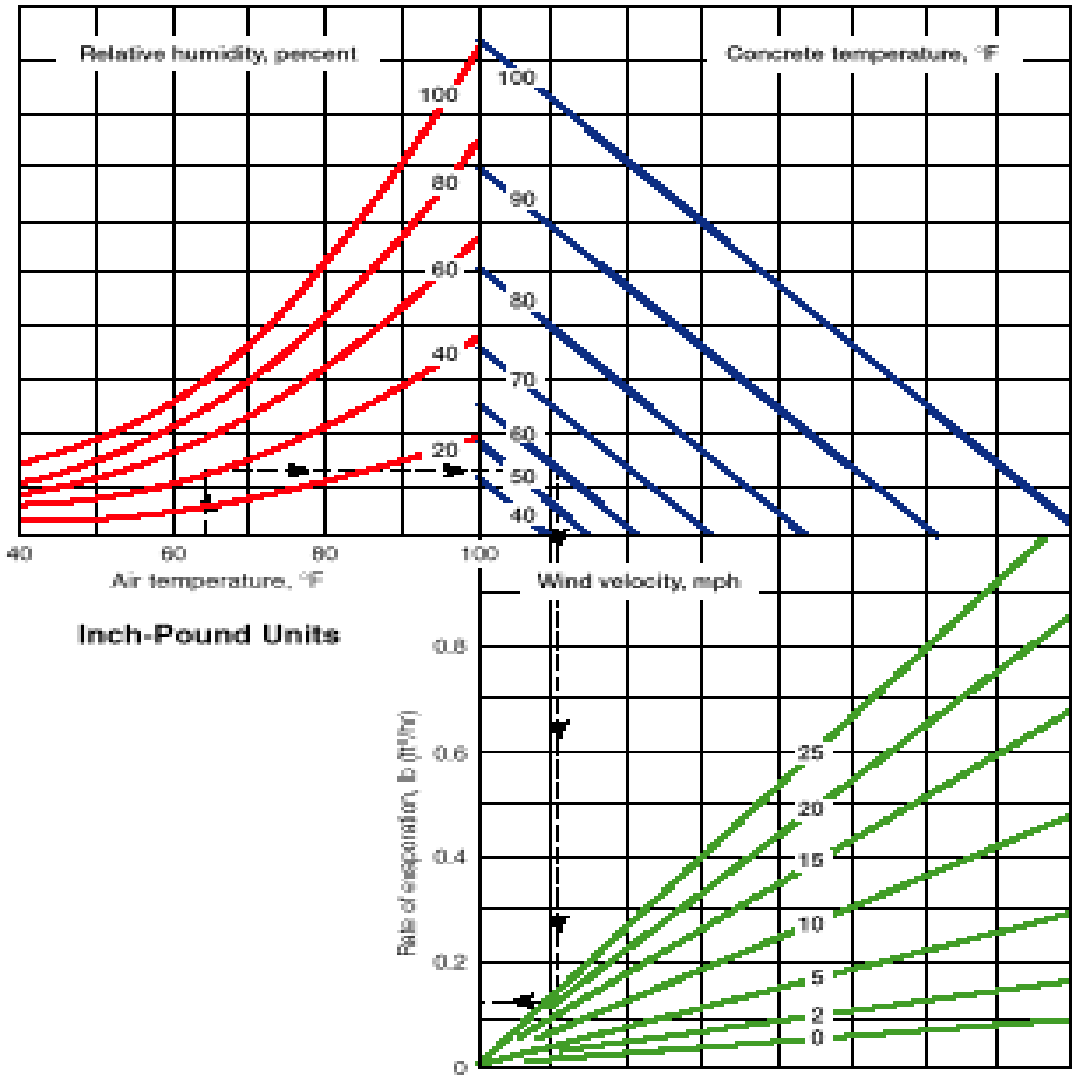
- Rapid loss of water from the concrete's surface before it has set
- Critical condition is when the rate of evaporation exceeds the rate at which rising bleed water can replace it
- If the surface dries quickly, the concrete may still be plastic and weak, and the cracks will form as the concrete slowly stiffens

Plastic Shrinkage Cracks

Conditions which cause:

- High evaporation rates, which increase opportunity for plastic shrinkage cracking are:
  - Wind in excess of 5 mph
  - Low relative humidity
  - High ambient and/or concrete temperatures

Plastic Shrinkage Cracks



> 0.2 lb/ft²: (*Trouble*)

- Precautionary measures are necessary (windbreaks, etc.)

> 0.1 lb/ft²:

(0.1 – 0.2 *Questionable*)

- Cracking is possible, depending on the constituents of the mix

- May - Lansing, MI
  - Temperature: 75˚F
  - Humidity: 10%
  - Wind: 10 mph

Plastic Shrinkage Cracks

Factors that reduce rate or quantity of bleed in the mix:

- High cementitious content
- High fines content
- Reduced water content
- Entrained air
- High concrete temperature

Plastic Shrinkage Cracks

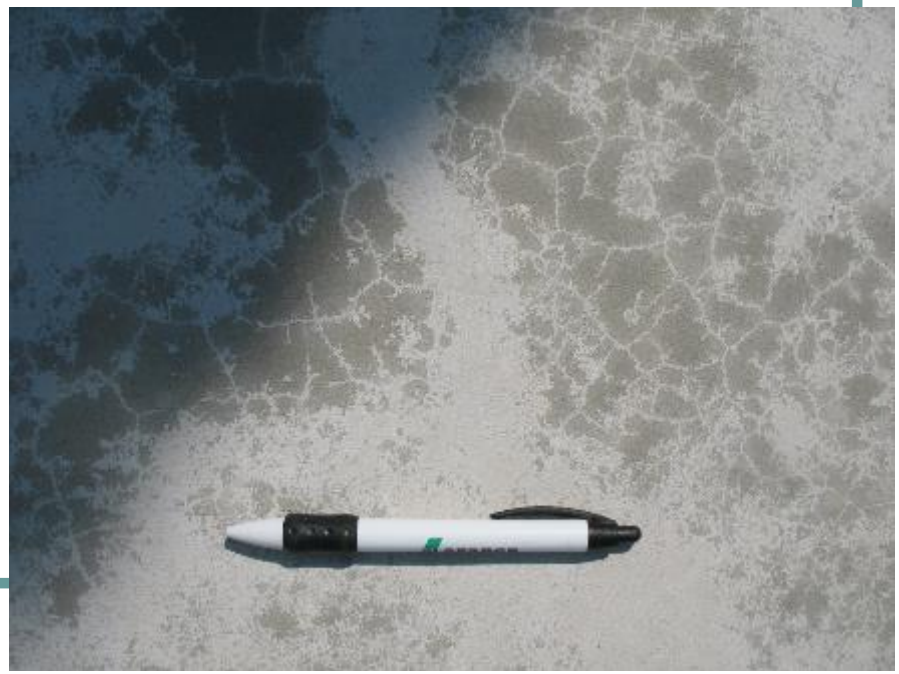
Tips:

- Dampen the subgrade and forms when conditions for evaporation exist
- Prevent moisture evaporation with fog sprays and wind breaks
- Cover concrete with:
  - Wet burlap
  - Polyethylene sheets between finishing operations*
- Use cooler concrete in hot weather
- Cure as soon as finishing is completed

Crazing

(*Shallow Map* or *Pattern Cracking*)

- Fine network of random cracks on the surface of concrete
- Approximately 1/8-inch depth
- Most noticeable on steel/over troweled surfaces
- Cause: Shrinkage of the surface layer
  - Most noticeable on wet surfaces



Crazing

(*Shallow Map* or *Pattern Cracking*)

- Rarely affect the
  - Structural integrity
  - Durability
  - Wear resistance of the concrete
- However, unsightly
  - Especially when wet, or when the concrete contains calcium chloride (for accelerating purposes)

Crazing

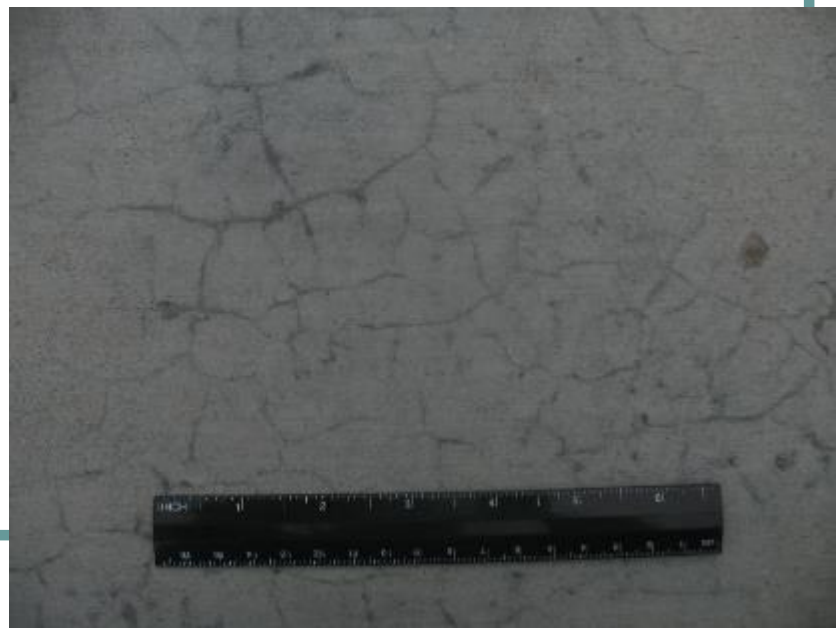
Tips:

- Hard troweled surface often craze due to shrinkage of the concentrated dense paste layer at the surface of the slab
- Use moderate slump

Crazing

Tips:

- Often proper finishing practices were not observed pertaining to:
  - Timing
  - Excessive manipulation, which may depress coarse aggregate and increase paste at the surface
  - Too wet of a mix
  - Finishing in the presence of bleed water, blessing the concrete
  - Cure as soon as finishing is completed



Settlement Cracks

Result from inadequate support

- Poor subgrade preparation
  - Subgrade should provide uniform support throughout
  - Topsoil and soft spots should be removed
  - If subgrade is not uniform, a subbase of sand, gravel, crushed stone or another granular material should be employed
- Sloped for drainage
- Free of frost, ice and snow
  - Damp, but no free standing water

Settlement Cracks

Cracks Due to Improper Jointing

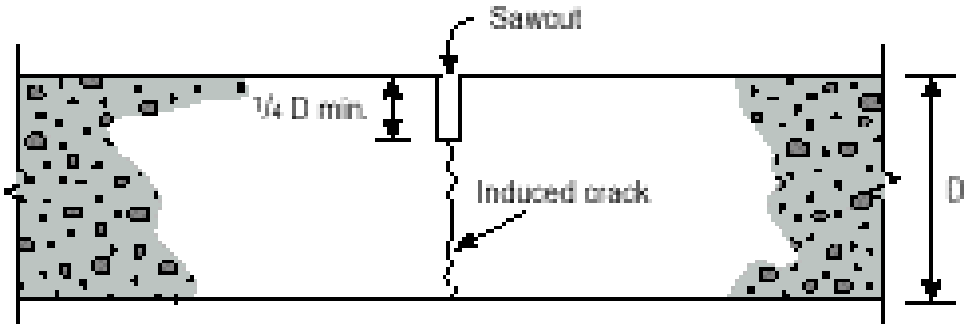
Concrete expands and shrinks with changes in moisture and temperature

- The overall tendency is to *shrink*
- Joints are predetermined, aesthetically pleasing cracks, placed into the concrete to accommodate shrinkage and other movement
- Placed by:
  - Forming
  - Tooling
  - Sawing

Cracks Due to Improper Jointing

Contraction (*or Control*) Joints:

- Create a weakened plane in the concrete and regulate where the cracks, from dimensional changes, will occur

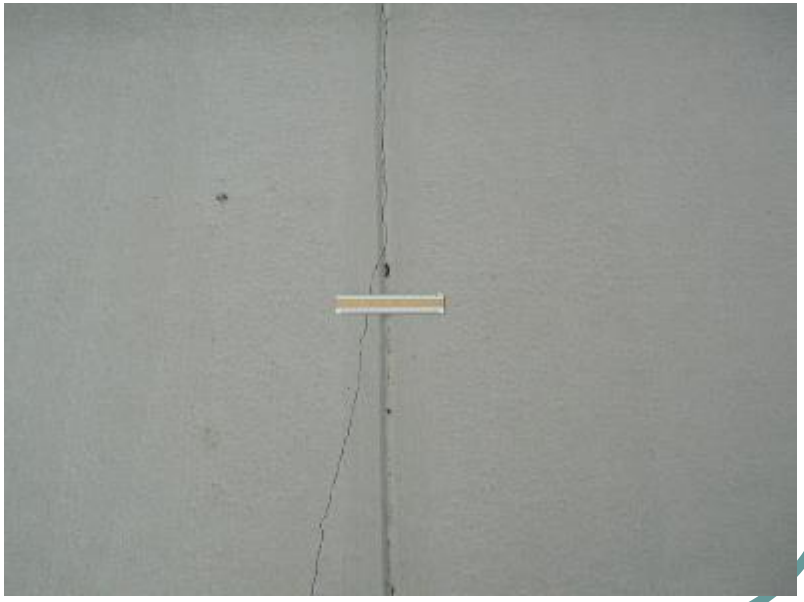


Cracks Due to Improper Jointing

Depth of Contraction (*or Control*) Joints:

- The grove should be a minimum 1/4 the thickness of the slab
- **But not less than 1-inch**

Cracks Due to Improper Jointing



Cracks Due to Improper Jointing

Cracks Due to Improper Jointing

Contraction (*or Control*) joints pattern:

- Maximum joint spacing should be 24 – 36 times the thickness of the slab (4-in slab should be jointed into 8 – 12 foot panels)
- All panels should be as square as possible (avoid sharp corners)
- Length should not be > 1.5 times the width

Cracks Due to Improper Jointing

Cracks Due to Improper Jointing

Isolation Joints:

Joints which separate slabs from other parts of a:

- Structure
- Wall
- Footing
- Column
- Other existing slabs

Cracks Due to Improper Jointing

The Big Ones

Scaling

rs plan to sue supplier

bility to our residents."

As of today, Parma city officials are refusing to grant new building

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Pavers meet to plan lawsuit

Say supplier is to blame

By BILL SAMMON
PLAIN DEALER REPORTER

INDEPENDENCE

Concrete, like people, can die without enough air.

An autopsy on concrete that gave up the ghost just months after being poured into driveways has revealed a striking lack of tiny air bubbles necessary to absorb the expansion of water during freezing. The concrete also might have contained too much fly ash, which is used as an aggregate in some concrete.

At least that's the assessment of lawyer John Manos, who is acting as a kind of concrete coroner in the failure of some 1,500 new driveways across Northeast Ohio. Manos is representing 22 people who poured $1 million worth of concrete last year, only to see it turn to rubble.

The contractors, bull-necked, big-biceped, gathered in a room of the Harley Hotel in Independence last night in an effort to save their small business. They smoked as they spoke, and worry crept into the

Bridge crumbling blamed on poorly mixed concrete

By BILL SAMMON
PLAIN DEALER REPORTER

CLEVELAND

When scientists broke open a chunk of concrete taken from the Main Avenue Bridge's crumbling new guardrails, they were hit by a strong smell of oil.

The presence of oil in concrete may cause several problems, including

A $10 million class-action lawsuit is filed over defective concrete driveways

Owners raising shale in University Oaks

The culprit is the ingredients of cement, particularly shale

concrete," Ray said. The concrete containing shale shouldn't have been used for anything outdoors, he said.

Ray analyzed the sample after a Hampton Estates resident complained to builder Dale Yost. Yost agreed to replace the slab and agreed to

of crumbling concrete across northern Ohio. Roads, bridges, sidewalks and driveways

Jeff Simmons
The Chronicle-Telegram

ELYRIA —

says he has filed ways are crumbling developer

Roads to ruin: New pavement falling apart

By BILL SAMMON
PLAIN DEALER REPORTER

CLEVELAND

The Ohio Department of Transportation is investigating why

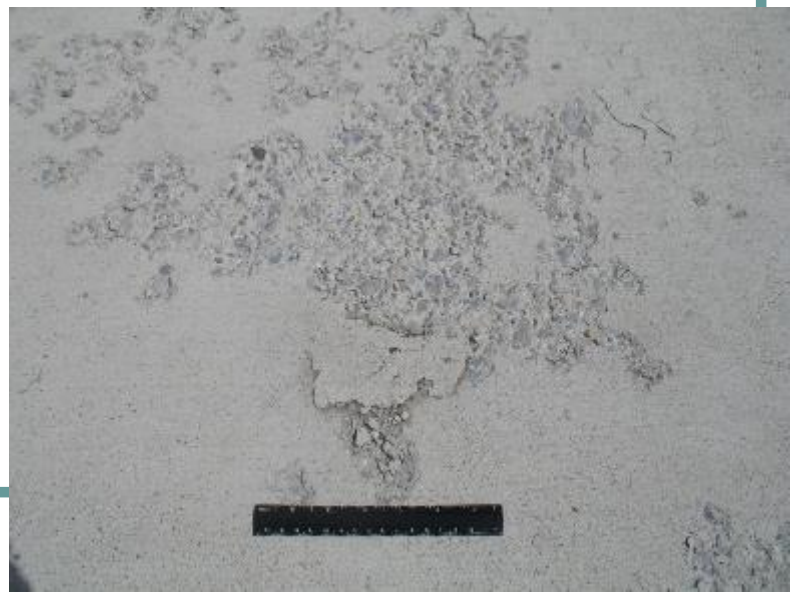
CRUMBLING ROADWAYS

PROJECT | LOCATION | ORIGINAL COST

Scaling

Scaling

- Is the loss of the concrete's surface mortar surrounding the aggregate particles
- The aggregate is exposed and hardened mortar peels away from the surface of the concrete
- It is primarily a physical action caused by hydraulic pressures from water cyclically freezing and thawing within the concrete
- When the pressures exceed the internal tensile strength of the concrete, scaling will result



Scaling

Air-entrained (AE) concrete

- Adequate air entrainment is required to protect against freeze/thaw damage

Scaling

- The extremely strong and expansive forces caused by the formation of ice within the concrete are often exacerbated by deicing salts and chemicals, which increase both the saturation of the concrete and the number of freeze thaw cycles the concrete endures
- Especially problematic with concrete with inadequate:
  - Strength
  - Air entrainment
  - Curing

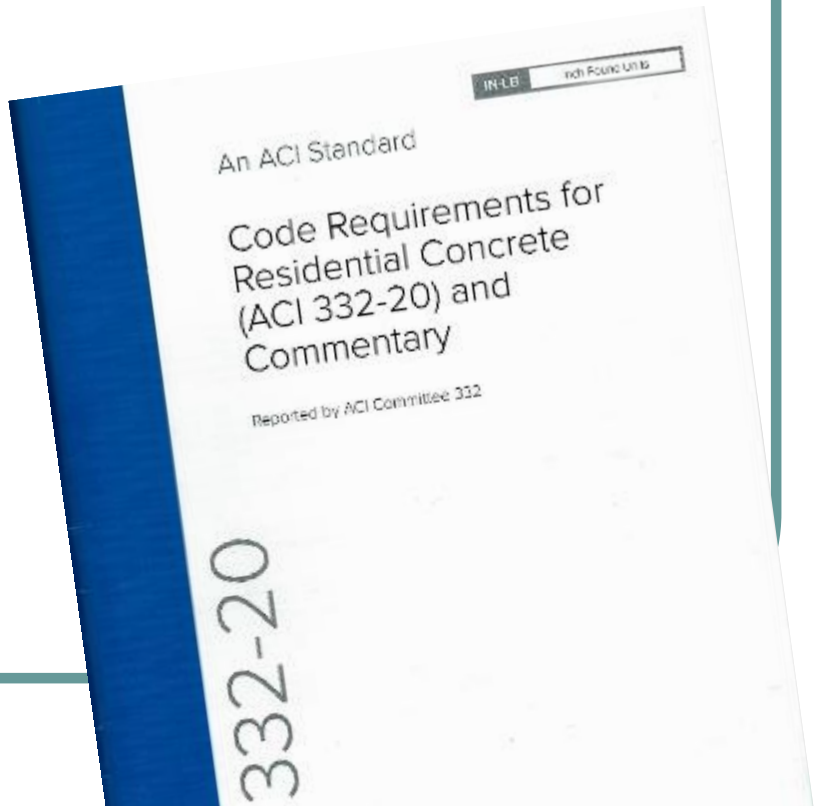
Scaling

- The extremely strong and expansive forces caused by the formation of ice within the concrete are often exacerbated by deicing salts and chemicals, which increase both the saturation of the concrete and the number of freeze thaw cycles the concrete endures
- Especially problematic with concrete with inadequate:
  - **Strength**
  - **Air entrainment**
  - **Curing**

Scaling

American Concrete Institute (ACI) 332, *Code Requirements for Residential Concrete,* Chapter 5: *Concrete Requirements* for

- ‘Very Severe’ environment (RF3 Exposure Category)
- Specified compressive strength of the concrete (f′c) shall be a minimum 4500 psi

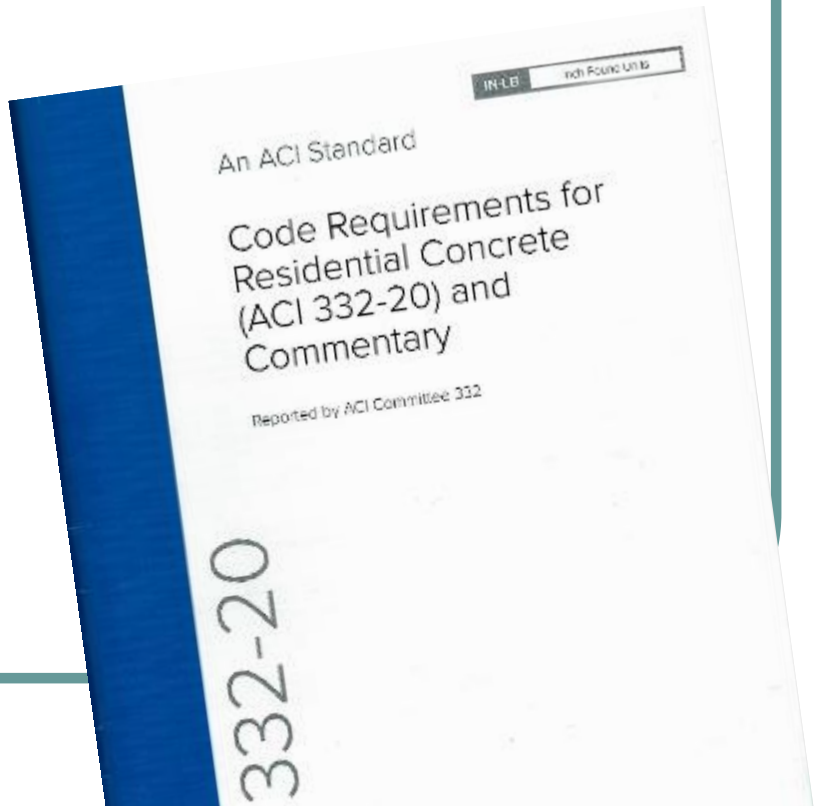


Scaling

American Concrete Institute (ACI) 332, *Code Requirements for Residential Concrete,* Chapter 5: *Concrete Requirements* for

- w/cm less than 0.45. Achieving a w/cm less than 0.45 reduces the concrete's permeability to water and deleterious chemicals, while enhancing durability
- Also in accordance with the Code,

the maximum slump shall be 4 inches*



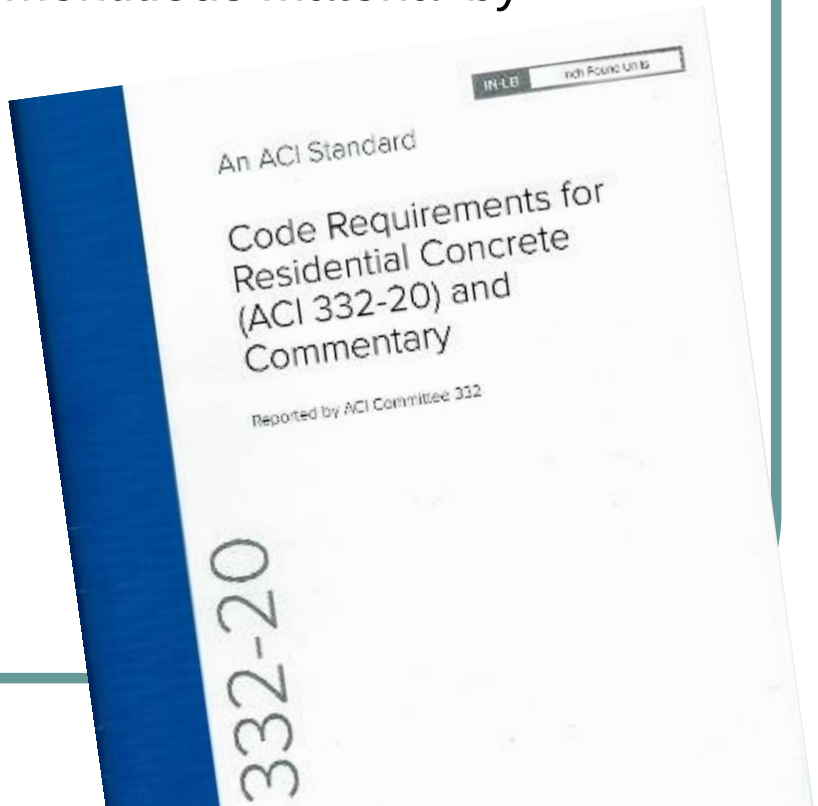
Scaling

- The use of supplementary cementitious materials (SCM) such as fly ash or Ground Granulated Blast Furnace Slag (GGBFS), or slag cement, also reduces the permeability of concrete while improving its durability
- The maximum percent of the total cementitious material by weight shall not exceed the values

listed in ACI 332 Table 5.4.2

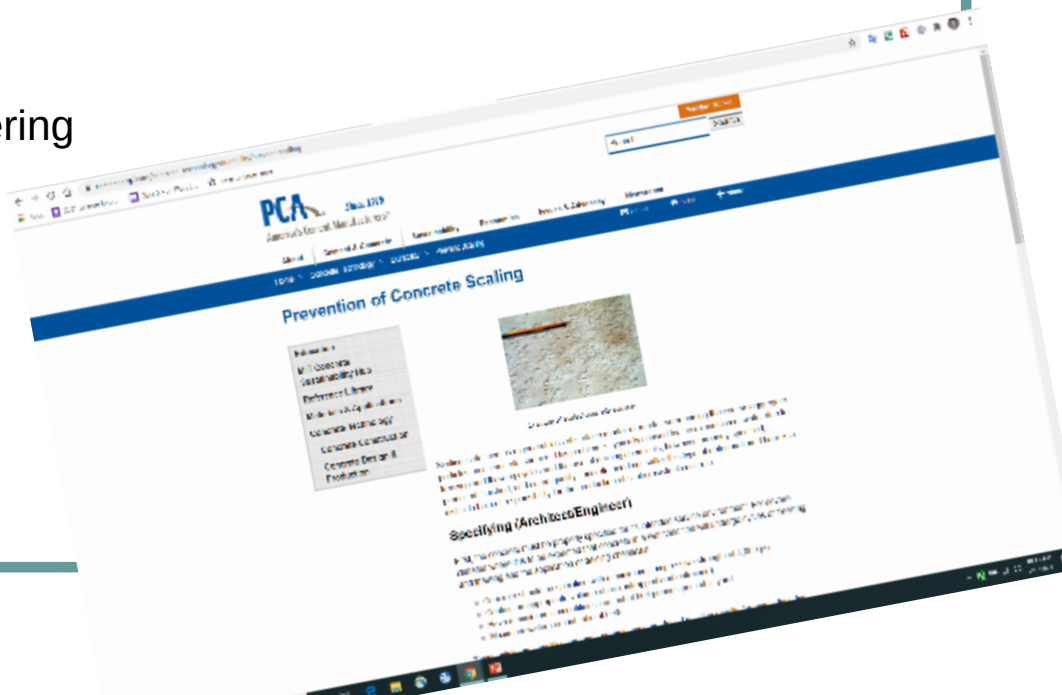
Requirements for Concrete

Subject to Exposure Class RF3



Scaling

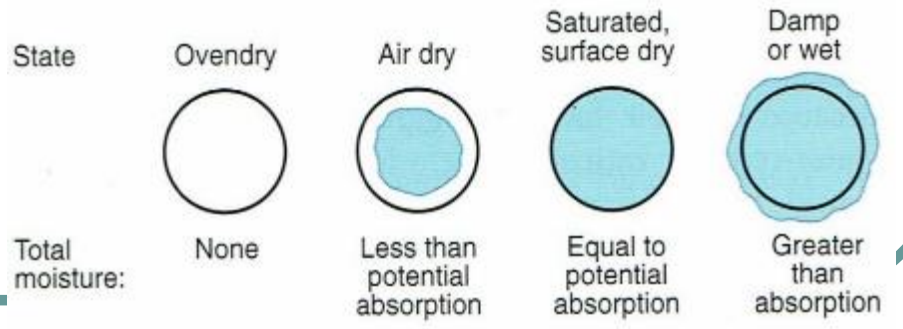
- According to the Portland Cement Association (PCA), the mix should contain a minimum cementitious factor of at least 564 pounds per cubic yard (lbs/yd^3)
- A cementitious factor of at least 564 lbs/yd^3 improves the mixes ability to provide other desirable characteristics of quality concrete such as:
  - Lower permeability
  - Greater durability
  - Increased resistance to weathering
  - Improved wear resistance



Scaling

Tips:

- 'Very Severe' environment (RF3 Exposure Category), ACI
  - 4500 psi = ACI, 332 Residential Code
  - 4000 psi = PCA, *Prevention of Concrete Scaling* & NRMCA, *CIP No. 2*
  - 564 lbs minimum of cementitious
- Total air content when utilizing a nominal maximum sized aggregate between ¾ – 1 inch is 6 ± 1.5%
- Slump: 3 – 5 inches
  - Consider a WRDA (5 – 10% reduction in water)
  - Understand water may be brought into the mix, or taken away from the mix, via aggregates understand
    - Oven Dry
    - Air Dry
    - Saturated Surface Dry (SSD)
    - Damp/Wet



Scaling

Tips:

- Proper finishing techniques
  - Do not finish in the presence of bleed water
  - Do not bless the surface
  - Do not use steel trowels on exterior flatwork

Scaling

Tips:

- PROPERLY CURE THE CONCRETE
  - Maintaining a satisfactory ***temperature*** is an important factor when curing because temperature affects the hydration process
  - The temperature of freshly placed concrete should be maintained above 50º F for 3 – 7 days.
  - Maintaining a satisfactory ***moisture content*** may often be accomplished by applying liquid membrane-forming curing compounds
    - Wax or resin b… …evaporation of moisture during the curing peri…

Scaling

Tips:

- PROPERLY CURE THE CONCRETE
- 21 day air cure or drying period is required to develop the strength and durability characteristics of the concrete
  - Exposure to freezing and thawing cycles and deicing salts within this time period is not recommended
- A sealer should be applied to all new concrete in a ‘Very Severe’ environment
  - A sealer helps protect concrete from absorbing moisture and being damaged from cyclic freezing and thawing
    - For example, a penetrating silane solution that penetrates deeply and chemically reacts with the cementitious surface has been shown to offer adequate protection from moisture penetration

Scaling

Tips:

- The ambient temperature at the time of placement during the first 72 hours after placement are critical to the concrete's strength and durability
- It is also important that the concrete be protected from freeze thaw cycles during its air dry period which includes the concrete's first 30 days
- In a 'Very Severe' environment planning and protection must be considered for concrete placed after September 15, knowing that the first several weeks of October can often contain temperatures below freezing at night

Scaling

Tips (Homeowner / Building Owner):

- Care for flatwork in a ‘Very Severe’ environment often consists of broadcasting deicing salts and chemicals to remove ice
- Although it would be best to avoid deicers all together, the need to reduce slip and fall hazards is paramount

Scaling

Tips (Homeowner / Building Owner):

- Sodium chloride (NaCl), commonly termed rock salt, when used as directed, has proven to be the safest deicer for melting ice and not adversely affecting the durability of the concrete
- **Once the NaCl has turned the ice to slush, it is recommended that it be shoveled up and disposed**
- **All forms of de-icing salts and chemicals should be avoided during the flatworks first year of service, and other means of snow and ice removal should be considered**
    - Other deicers such as magnesium chloride acetate, calcium chloride or products which combine these chemicals have been found to be detrimental to the surface durability of concrete

Scaling's Ugly Cousin

- Loss of mortar directly over the coarse aggregate particle
- Caused via hydraulic pressures directly over the coarse aggregate

Mortar Flaking

- Is the peeling away of the concrete's mortar directly over the flat surface of a coarse aggregate found very close to the surface of the slab
- Mortar flaking resembles a scaled surface or a surface with aggregate popouts, however, it does not result with fractured aggregate particles embedded in the concrete and there are fewer, if any, conical voids as is the case with popouts

Mortar Flaking

- *Bleed-water* (free water in the mix that is pushed upward to the surface due to the settlement of heavier solid particles such as cement and aggregates), can become blocked just below the coarse aggregate particle

Mortar Flaking

- As bleed-water beneath the aggregate cannot readily migrate to the slab's surface to replenish evaporated water; this combination of:
  - Bleed-water blockage
  - Lack of moisture necessary for cement hydration just above the coarse aggregate particle
  - Results in a thin, dry, mortar layer of poor durability, high shrinkage, and poor bond with the underlying aggregate causing the mortar directly over the coarse aggregate particle to become compromised

The Concrete Industry

Quality is never an accident but the result of good intentions & sincere efforts

Eli & Edythe Broad Art Museum – Michigan State University

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Quality is never an accident but the result of good intentions & sincere efforts

Bagley Pedestrian Bridge – Detroit, MI

The Concrete Industry

Thank You

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