Concrete Hydration

DOTSC – Student Seminar

Alex Ranz

July 28, 2010

OUTLINE

HISTORY

- Origin

CONCRETE'S MAIN INGREDIENTS

7-15%
Cement

14-18%
H2O

Paste

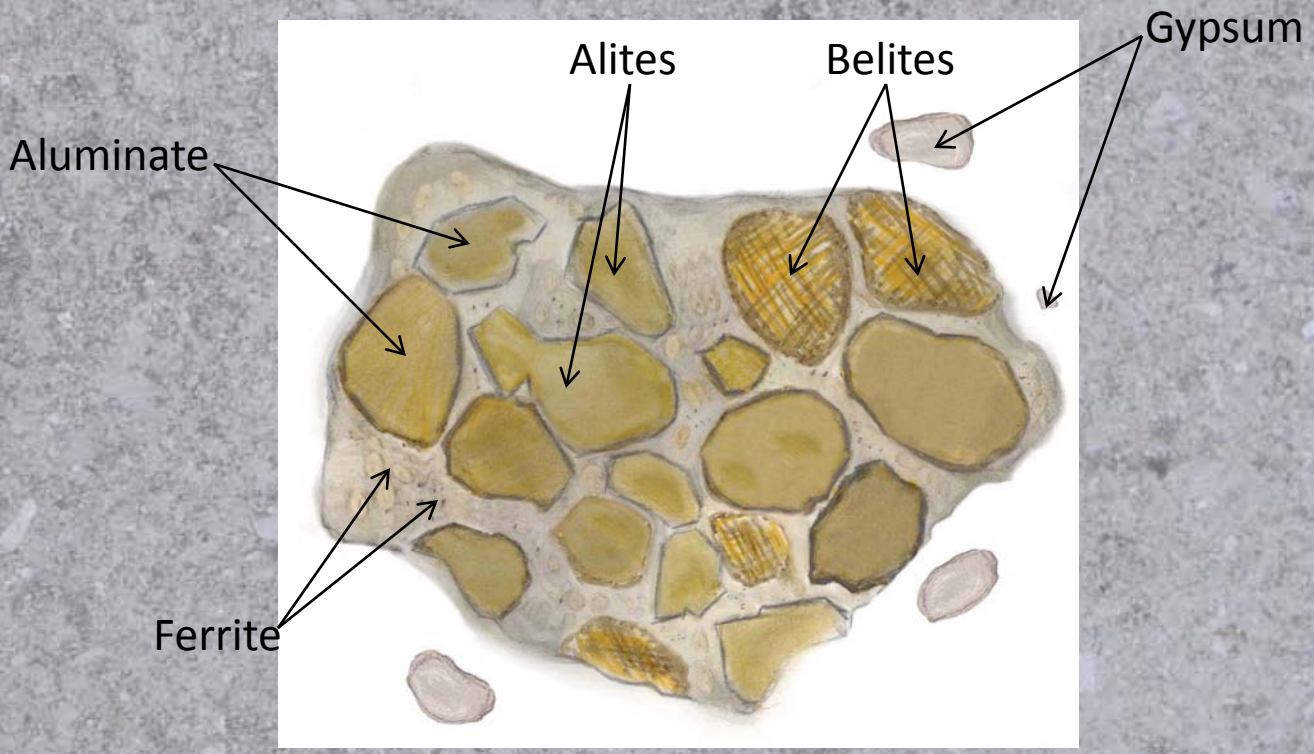
Fine
Aggregate

Course
Aggregate

Mortar

Concrete

PRIMARY HYDRATION PRODUCTS



HYDRATION PROCESS

Mixing

Dormancy

Hardening

Cooling

Densification

Mixing

Within minutes of mixing cement and water, the aluminates start to dissolve and react, with the following results:

- Aluminate reacts with water and sulfate
- C-A-S-H Gel builds up

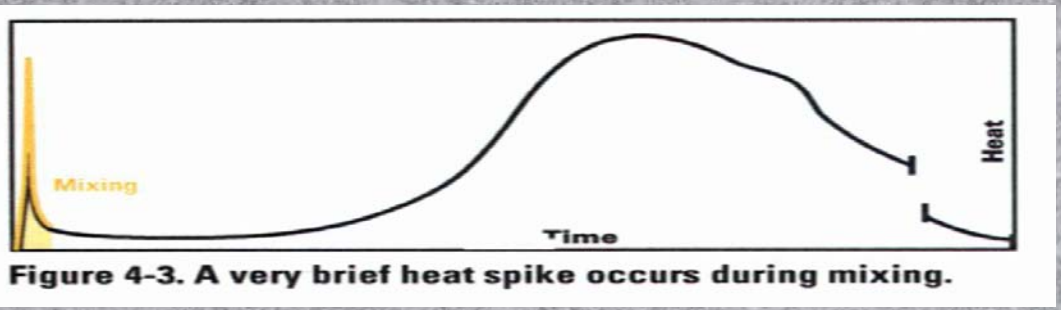


Figure 4-3. A very brief heat spike occurs during mixing.

(Integrated Materials and Construction Practices for Concrete Pavement)

DORMANCY

For about two to four hours after mixing, there is a dormant period, during which the following events occur:

- C-A-S-H gel is controlling
- During dormancy Alite and Belite dissolve

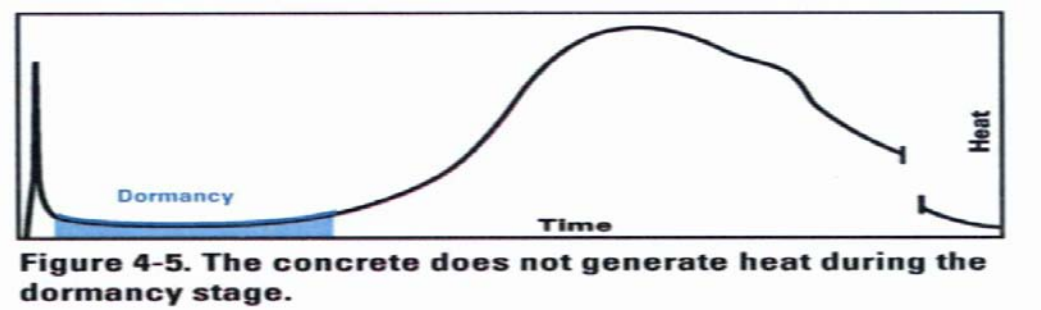
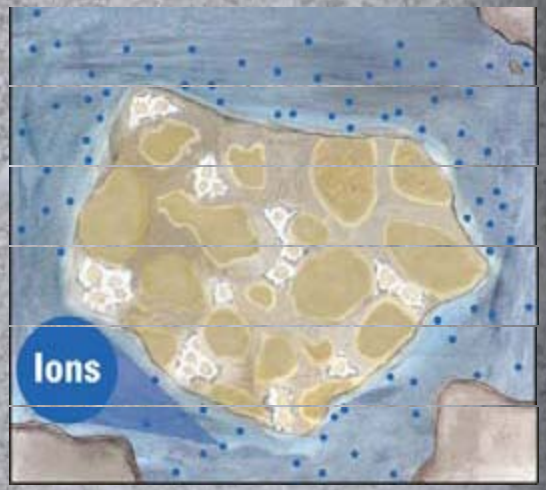


Figure 4-5. The concrete does not generate heat during the dormancy stage.



(Integrated Materials and Construction Practices for Concrete Pavement)

HARDENING

This stage is dominated by Alite hydration and the resulting formation of C-S-H and CH crystals:

- The solution becomes supersaturated
- The heat and stiffening increases
- Acceleration begins to start
- During acceleration
- Final set

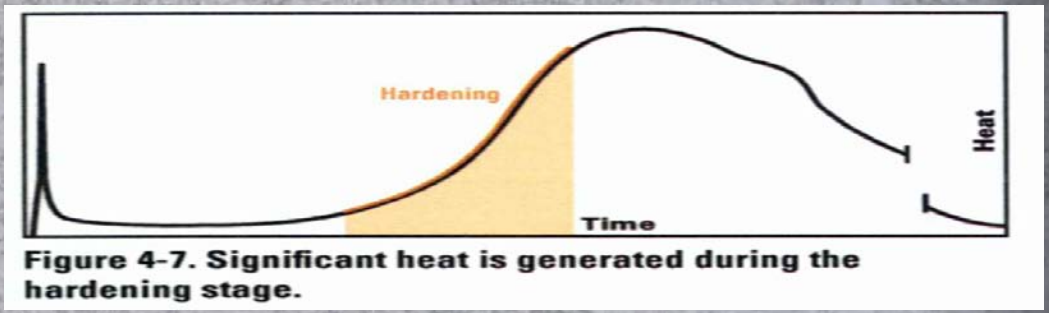


Figure 4-7. Significant heat is generated during the hardening stage.

(Integrated Materials and Construction Practices for Concrete Pavement)

COOLING

After final set, the rate of Alite reactions begins to slow, and the amount of heat generated peaks and begins to drop. This occurs because the buildup of C-S-H and CH interferes with contact between remaining water and undissolved cement grains. During this stage, several things are occurring:

- The concrete gains strength
- Tensile stresses build up faster
- Temperature peaks

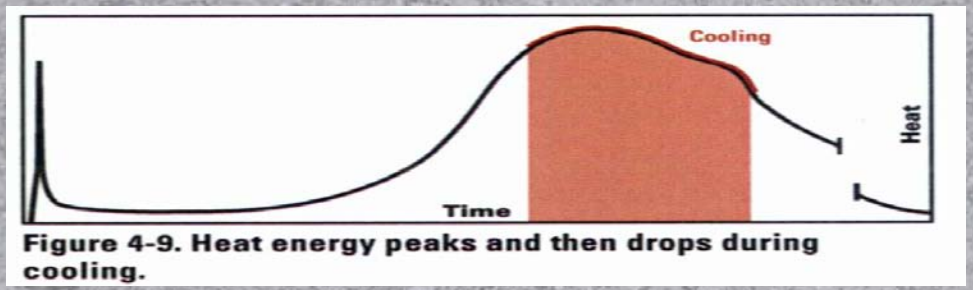


Figure 4-9. Heat energy peaks and then drops during cooling.

(Integrated Materials and Construction Practices for Concrete Pavement)

DENSIFICATION

This stage is critical for continued development of concrete strength and reduction of concrete permeability. The concrete must be kept moist as long as possible.

- When Alite makes contact with water in the concrete
- When Belite reacts more slowly than Alite
- Hydration continues

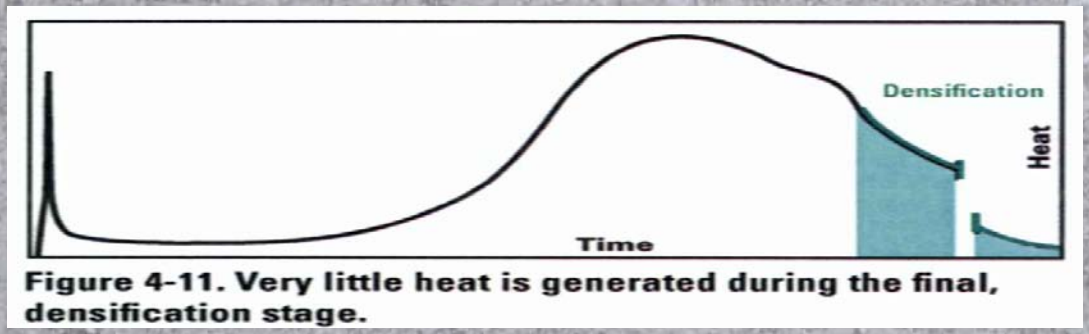
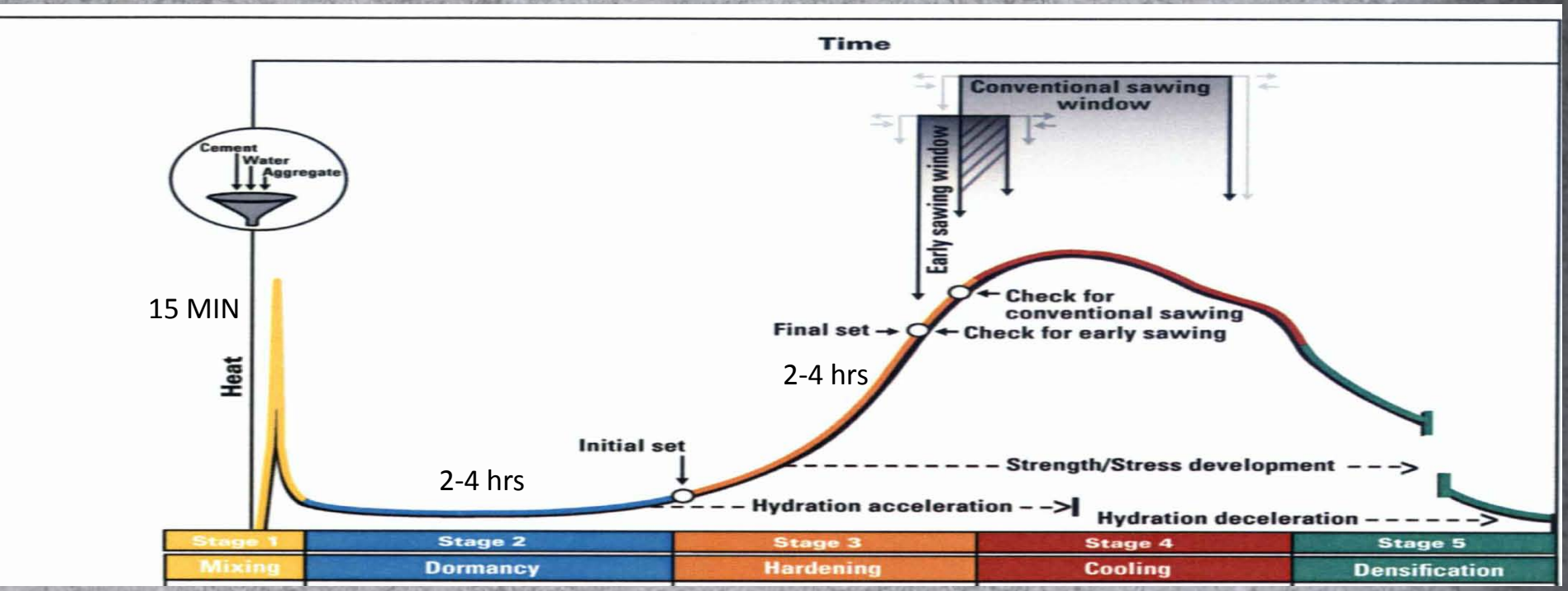


Figure 4-11. Very little heat is generated during the final, densification stage.

(Integrated Materials and Construction Practices for Concrete Pavement)

TIMELINE


Time
Conventional sawing window
Early sawing window
Cement
Water
Aggregate
15 MIN
Heat
Check for conventional sawing
Final set
Check for early sawing
2-4 hrs
Initial set
2-4 hrs
Strength/Stress development
Hydration acceleration
Hydration deceleration
Stage 1
Stage 2
Stage 3
Stage 4
Stage 5
Mixing
Dormancy
Hardening
Cooling
Densification

ENGINEERS TASKS

Ensure precise mixing

Transport, place, finishing

Curing time/compound

Saw joints

Insulation

Checklist

ENGINEERS TASKS

- Ensure precise mixing
- The concrete shall be mixed in the quantity required to provide continuous placement and finishing operations. Addition of water to re-temper concrete is not permitted. High heat is generated immediately followed by rapid cooling, which lasts about 15 minutes. If the mixing is the wrong portions the hydration process will be affected, which the reactions will be off and you won't get a gel-like paste.

ENGINEERS TASKS

Transportation

Finishing

Placing

Concrete shall be delivered to the site of placement in a truck mixer operated at agitating speed. Equipment for transporting concrete shall meet Section 153.02 B. The interval of time between introducing the cement to the mixture and the time the concrete has been completely discharged is about 60 minutes in agitating equipment. This is where the dormancy stage starts and CASH gel is taking control with little heat. The concrete shall be deposited on the roadbed so segregation and unnecessary rehandling is avoided. Placement shall be continuous between all transverse joints. Spreading and initial strike-off shall be performed by a mechanical spreader meeting Section 153.07. Concrete shall be spread uniformly across the full width of the slab being paved, and shall be struck off at a height. Other methods of spreading may be approved by the Engineer where use of a mechanical spreader is not feasible. This is the ending of the dormancy stage of the hydration process which lasts between 2-4 hrs. which makes the mixture plastic, workable and not generating huge amount of heat.

ENGINEERS TASKS

Curing time/compound

A. Burlap Cloth made from Jute or Kenaf
B. Liquid-Membrane-Forming Compounds, White Pigmented, Type 2
C. Liquid-Membrane-FormingCompounds,White Pigmented,Type 2, ClassB
D. Geotextile Fabric

This is during the hardening stage of hydration which lasts up to 4 hrs. The hydration generates significant heat and the mixture begins to set and harden and gain strength. Stress also begins to be a form.

ENGINEERS TASKS

Saw Joints

Joints in concrete pavement shall be of the design specified and shall be constructed at the spacings and locations specified. The ramp joints beyond the ramp taper shall have the same spacing sequence as the mainline. The Contractor shall establish joint locations. This is during the cooling stage of the hydration process and stress will develop to strengthen if not relieved. The engineers job is to make sure that the right joints are sawed in to the relieve stress and to control cracking of any kind.

ENGINEERS TASKS

Insulation

Checklist

Curing shall be accomplished using a wetted fabric cure or an impervious membrane cure. Any specified method of cure may be used but methods shall not be changed without approval. All concrete pavement shall be cured for a period of at least 72 hours unless high-early strength concrete is utilized. This is the densification stage of hydration and the concrete will continue to become stronger and less permeable. The engineers job is to make sure that the right insulation applied according to temp and that the curing application is protected for as long as possible.

HOT EFFECTS

Without the proper care, concrete may have reduced strength and will be very prone to cracking due to rapid drying. It also may stiffen quickly making finishing quite difficult.

Increased rate of cement hydration at elevated temperatures and the increased evaporation rate of moisture from the freshly mixed concrete are the causes of most of the problems associated with hot-weather concreting. The ability of a mix to reach its design strength is determined by the efficiency of the chemical reaction that takes place between water and cement. That reaction is responsible for solidifying the entire concrete mass. As concrete hardens, cement is said to be hydrating and the concrete is said to be curing. The curing gains strength but the rate of cement hydration is what can be adversely affected during hot weather.

➢Guides to follow

COLD EFFECTS

In order for hydration to take place, the temperature of the concrete must be 40 degrees F. If it's below 40 degrees F, the hydration process slows and at some point may stop altogether. Further more, the amount of free water in the mix will have a direct relationship to the damaging effects that freezing has on the concrete. The environment may be also altered by using enclosures and moist heat, applying insulating blankets, polystyrene sheets, or hay, and leaving the forms in place.

- Guides to follow

RAIN EFFECTS

Challenges

- Before final set
- After final set

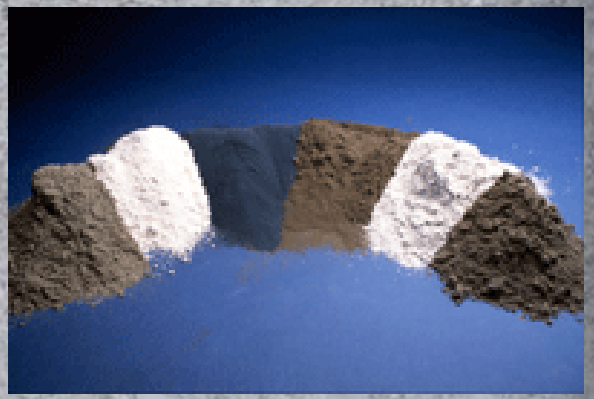
Precautions

If it starts to rain during operations, take the following actions:

- Stop batching and placing operations and cover the fresh concrete immediately with protective coverings like polyethylene sheeting or burlap, this helps the Belite reactions to occur.
- As soon as the surface has dried, apply curing membrane.
- After the curing period, diamond grinding may be required to remove surface blemishes and provide texture to any surface exposed to rain where damage has occurred and the hydration process is much weaker if this occurs.

EFFECTS OF SCMs

Supplementary Cementitious Materials



- Fly Ash
- Ground Granulated Blast Furnace Slag
- Silica Fume
- Natural Pozzolans

Why they are used for improvement

- How do these materials affect the concrete properties

EFFECTS OF CHEMICAL ADMIXTURES

Chemical admixtures are the ingredients in concrete other than portland cement, water, and aggregate that are added to the mix immediately before or during mixing.

- Why
- Effectiveness of it

Admixtures are classed according to function. There are four classes.

- Air-Entering
- Water-Reducing
- Retarding
- Accelerating

CONCRETE

Report

http://www.arch.hawaii.edu/site/fileadmin/us

http://iti.northwestern.edu/cement/monograph

http://www.nrmca.org/aboutconcrete/cips/30p.pdf

http://www.dot.nd.gov/manuals/environmental/2008-Vol01.pdf

www.youtube.com/zoomintoconcrete