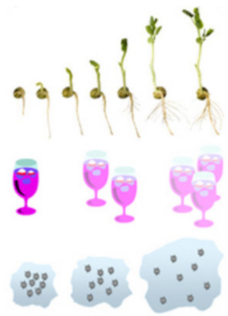
CCI Webinar

How Concrete Works



What tomato seedlings, Kool-Aid and snowballs have to do with concrete,

and how they can help you avoid problems like cracking and curling

December 10, 2011

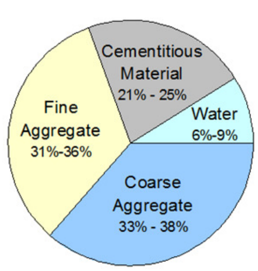
Fundamentals of Concrete

- Essential to selecting or designing a mix
- Valuable in working with the concrete
- Key to troubleshooting

If you don't know how concrete works, how can you make a high quality product?

Primary Ingredients:

- Cement
- Water
- Aggregates
  - Fine (sand)
  - Coarse (gravel)



Secondary Ingredients:

- Pozzolans
- Pigments
- Fibers
- Admixtures

Ingredient Selection and Proportion

The relative proportions of the primary and secondary ingredients influence:

- strength
- stability
- workability
- durability
- aesthetics
- ease of manufacture
- forming techniques
- cure times
- and more

Primary Ingredients

Basic elements of concrete; without one of these you don't have concrete.

- Aggregates are structural filler
- Cement + Water = Paste (binder)

Aggregate

Aggregate

- Make up the bulk of concrete volume
- Important to durability, stability, appearance and strength of concrete
- Can be fine or coarse
- Can be stone or glass
- Strongly influences **Workability**
- **Gradation** is very important in mix design
- Can be the most complex part of mix design
- Most often overlooked or underestimated

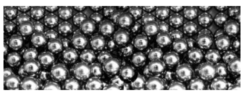
Aggregates and Workability

Workability influenced by:

- Particle shape
- Particle roughness
- Gradation/packing
- Aggregate to paste ratio
- Surface area

Coarse Aggregates

- Max. particle size 3/8" for 1.5" thick countertops
- Smoother, rounder particles boost workability
- Rough, angular particles inhibit workability but increase flexural strength

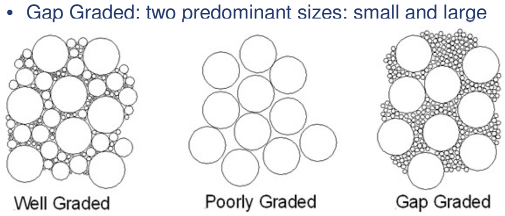


Fine Aggregates

- Sands have greater influence on workability, paste content and water demand than coarse aggregates
- Use more coarse sands (#8, #16, #30 sieve)
  - Finer sands increase trapped air (#50, #100)
  - Excessive fines (smaller than #100) can cause loss of workability and a potential for higher w/c ratios to compensate

Types of Aggregate Gradation

- Well Graded: broad range of sizes
- Poorly Graded: all one size
- Gap Graded: two predominant sizes: small and large



Recycled Aggregates

- Crushed bottles
- Crushed window glass
- Tempered glass
- Scrap stained glass
- Crushed porcelain (sinks, tubs, toilets)
- Crushed concrete
- Crushed granite/marble scrap

Stiff Mix

Hand packed

- Often all-sand mix concrete (uniform graded)
- Stiff, zero-slump concrete
- Variegated, hand-pressed or solid
- Always has pinholes and air voids

Fluid Mix

Wet cast

- Often aggregate-based mix concrete (gap graded)
- Fluid, highly workable
- Often vibrated
- Crisp, tight surface, none or few pinholes

Cement

- Portland cement
- Type I, II or III
  - Type I: normal
  - Type II: moderate sulfate resistant
  - Type III: high early strength
- White or gray

Cement

- Broadly similar but subtly different: fineness, set time, chemistry
- Different brands have different colors
- Portland most common, but other types are used (calcium sulfo-aluminate CSA cement)
- Different cement chemistry has different rules

Water

- Use sparingly when designing mix
- Use precisely when making concrete
- Use liberally during curing

  - The less water used to make the concrete, the better the concrete.

Water

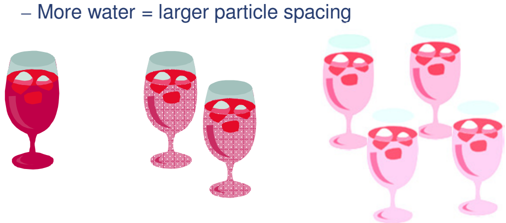
Water is an important ingredient that must be dosed carefully.

It is not used like salt and pepper are to “season” the concrete to “taste”.

The Role of Water: During Mixing

Grape Kool-Aid®

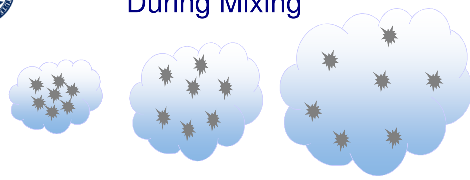
- Too much dilutes strength, color
- More water = larger particle spacing



Water to Cement Ratio (w/c)

- Determines strength and durability of concrete
- Lower w/c ratios yield richer colors; higher w/c ratios yield paler colors
- High w/c ratio (more water) results in weak concrete
  - This is because diluted cement paste is weaker and more susceptible to cracking and shrinkage

The Role of Water: During Mixing



Low w/c < 0.35 | Moderate w/c 0.35 – 0.45 | High w/c >0.45

More water = larger particle spacing
More water = longer time to set
More water = lower strength
More water = BAD

The Role of Water: During Curing

Tomato Seed

- Needs water to grow
- Dies if dries out

Cement needs to stay wet to hydrate (cure)
More water = GOOD

Secondary Ingredients

- Modify only the cement paste
- Influence fresh and hardened characteristics

Pozzolans

From left to right:

- Fly ash (Class C)
- Metakaolin
- Silica fume
- Fly ash (Class F)
- Slag
- Calcined shale

Pozzolans

- Consume weak byproducts and produce more strong binding material.
- React with (weak) calcium hydroxide liberated during cement hydration and convert it to form additional (strong) cementitious materials
- May be natural, manufactured or derived from waste products from industrial processes
- Include metakaolin, silica fume, fly ash, slag, glass and vitreous calcium aluminosilicates (VCAS)

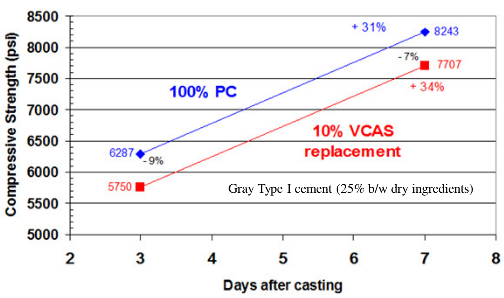
Reasons for using pozzolans

- **Improve strength (long term)**
- Improve workability (some pozzolans)
- Improved microparticle packing
- Reduce porosity
- Reduce bleedwater
- **Reduce or eliminate ASR & efflorescence**
- Make concrete “greener”
- Cement replacement or addition

Pozzolans' effect on early strength

- Less cement generates less calcium hydroxide
- <u>High replacement doses often yield *lower* early strengths due to less cement</u>
- Full effectiveness is achieved through long term wet curing (28+ days)

CCI early compressive strength development tests:
Straight portland cement
versus 10% VCAS replacement



Factors affecting pozzolans:

- Particle shape
- Particle size
- Chemical makeup
- Reactivity

- Dosage
- Curing conditions
- Temperature

VCAS
(vitrified calcium aluminosilicate)

Benefits
- White
- High reactivity
- Enhances workability
- Contains post industrial recycled content

Cons
- Manufactured, has some carbon footprint
- Expensive

Bottle Pozz
(powdered glass)

Benefits
- Nearly white
- Fairly high reactivity
- Enhances workability
- 100% post consumer recycled content

Cons
- Relatively expensive

Metakaolin

Benefits
- White (or very nearly white)
- Very high reactivity (similar to silica fume)
- Enhances paste stability

Cons
- Decreases workability
- Manufactured using mined kaolin clay
- Has carbon footprint
- Expensive

Other Pozzolans

Fly ash, slag and silica fume are less commonly used for concrete countertops.

Typical Dosages

- Metakaolin 10% to 20%
- VCAS 10% to 25%
- Bottle Pozz 10% to 25%
- Fly ash
  - Class C 15% to 40%
  - Class F 15% to 25%
- Slag 30% to 45%
- Silica fume 5% to 10%

Fibers

- Types:
  - Steel, **AR glass**, Carbon, Synthetic (nylon, polypropylene, **PVA**, etc)

Fibers

- Generally added to concrete as *plastic shrinkage control*, also known as **secondary reinforcement.***
- This is different from structural reinforcement – that is **primary reinforcement**.

*Except for GFRC

How Fibers Work

- Matrix of fibers helps to stabilize the wet concrete and distribute the plastic shrinkage stresses so that large cracks are minimized or eliminated as concrete begins to harden
- Fibers help keep larger aggregate from sinking

Fibers

- Regular fibers **DO NOT** replace structural reinforcement in ordinary concrete
- Not all fibers add strength or toughness
- Fibers ONLY provide strength benefits AFTER the concrete cracks
- Fibers *do* provide crack <u>control</u>
  - If your client can't see a crack, is it really there?

Fibers: GFRC

- Glass fiber reinforced concrete (GFRC)
- Large volume of AR glass fibers (3 lbs in 100 lbs of GFRC)
- Ordinary concrete uses 1-5 lbs in 4000 lbs of concrete
- Mix designed tailored for fiber volume
- Only large volumes of structural fibers can replace light steel reinforcing

Fibers in GFRC

Chemical Admixtures

- Water reducers/Superplasticizers
- Accelerators
- Retarders
- Air entrainers
- Shrinkage reducers
- Corrosion inhibitors
- Defoaming agents

Water Reducing Admixtures

- Low range (5% - 12% reduction)
- Mid range (8% - 15% reduction)
- Best for flatwork, troweled concrete

- High range (12% - 40% reduction)
  - a.k.a. superplasticizers

Water Reducing Admixtures

Can be used either to:

- Reduce w/c ratio to maintain a given slump, or
- Increase slump for a given w/c ratio

Superplasticizers

- Use for highly workable concrete with low w/c ratio
- Typically used with precast concrete or when troweling won't be performed
  - can make concrete sticky
  - length of time it remains effective can vary
  - influence on set time can vary

Polycarboxylates

- Powerful superplasticizers
- Often used for self consolidating concrete (SCC), where very high flowability and long duration are desired
- Concrete very sticky, difficult to trowel
- SCC often also uses viscosity modifiers

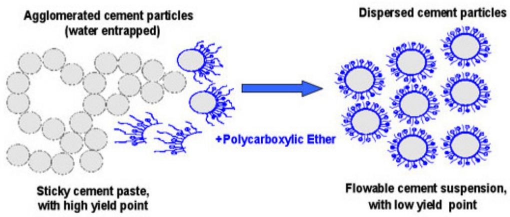
How Water Reducers Work

- Cement particles cling together from electrostatic attraction of opposite charges
- Water reducers make all particles have the same electrical charge
  - Like charges repel each other
- Water reducers "reduce static cling".

Static Cling

Water + Cement particles = Static Cling

How Water Reducers Work



Summary

You learned about:

- Aggregates
- Cement
- Water
- Pozzolans
- Fibers
- Admixtures

How these ingredients work together in your mix design

Summary

Important points:

- Use well-graded aggregate and coarse sands if possible
- Measure water precisely
- Use a low w/c ratio (remember the Kool-Aid and snowballs)
- Keep concrete wet while curing (remember the tomato seedlings)
- Use pozzolans to reduce ASR & efflorescence, but be aware they can reduce early strength and affect workability
- Fibers do not replace steel for primary reinforcing, except in GFRC
- Use superplasticizers to increase workability without increasing w/c ratio (remember the static cling cat)

More Resources

More information about mix design:

- "Precast Mix Design 101"

Mix calculator:

- "Precast Mix Calculator"

Find these self-study courses in our Online Store.

Contact: info@concretecountertopinstitute.com or 888-386-7711