Fly Ash for Enhanced Concrete Durability

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Fly Ash

- For the purpose of this discussion we will be discussing Class F fly ash
- Class C is not readily available in this market area and due to its chemistry does not provide some of the durability characteristics that Class F ash does
Fly Ash

- Bad press lately
  - Duke Energy – Dan River spill
  - Duke Energy – Landfills, basins and ponds
    - Legislation passed requiring discontinued use and clean up
    - 15 years to close all landfills and lagoons
    - 100 million tons in 33 open air pits at 14 sites
What is the Future of Fly Ash in NC?

- Uncertainty
  - Seasonal availability issues – Fall and Spring
  - Coal fired power plants being decommissioned or converted to natural gas
  - Power grid variations
  - Coal source and treatment variations
  - “Processing” of the fly ash in landfills and lagoons
What is the Future of Fly Ash in NC?

- Certainty
  - INCREASED COST!
Coal Burning Power Plants
Fly Ash
Fly Ash

- General Rules
  - Fly ash affects the ability to entrain air
  - Fly ash concretes have lower water demand
  - Fly ash concretes have a lower bleed rate
  - Fly ash concretes have a slower time of set
  - Fly ash concretes have lower early strength
All fly ashes are NOT equal

- Vary in:
  - Reactivity
  - Chemistry
  - Particle size/distribution
  - Inert/non-reactive materials

- Variability is due to source(s) of coal, rate of the coal feed through the boiler furnace, and the “treatment process”,
All fly ashes are NOT equal

- As EPA regulations change the quality and consistency of fly ash changes
- EPA restricts nitrogen oxides in flue gases
  - Commonly referred to as NOx limits
  - Different technologies used to meet NOx limits
    - Combustion controls (low NOx burners) usually affect the carbon content (increasing it) due to lower combustion temperatures and lower oxygen levels
    - Post-combustion controls (ammonia treatment in our area) affects the usability of the ash
Limits on % Fly Ash

- NCDOT – Section 1024 – Table 1024-1
  - 20% by weight of required cement content with 1.2 pounds of Class F fly ash per pound of cement replaced
Limits on LOI

- LOI – Loss on Ignition – the amount of unburned carbon in the fly ash
  - Specification intent is to decrease the “negative” effect of the fly ash on loss of entrained air content
  - LOI is not the only or controlling criteria
    - The fineness of the carbon particle can and in most cases has more effect on air entrainment than does the % of LOI
- Carbon “filter”
Limits on LOI

- NCDOT – Section 1024 - 5
  - LOI not to exceed 4%
Air Entrainment

- Air entraining agents can be “filtered” out
- Lower initial air content and loss of air in transit
- One of the most common issues with the use of fly ash
- Can be managed with proper quality control and communication
How Does Fly Ash Affect Durability?

- Enhanced Chemistry
- Enhanced Workability
- Enhanced Finishability
How Does Fly Ash Affect Chemistry?

- Supplemental Cementitious Materials (SCM)- Flyash, Silica Fume, Slag- no cementitious properties by itself but when combined with cement they provide added benefits to concrete
How Does Fly Ash Affect Chemistry?

- Paste structure is enhanced due to fly ash “consuming” the by-product of cement hydration and creating more C-S-H. Calcium hydroxide is the primary hydration by-product that reacts with the silica and alumina in fly ash. This additional C-S-H creates a denser paste matrix. Alkalis are also “consumed” with Class F ash.
How Does Fly Ash Affect Chemistry?

- Durability
  - Freeze-Thaw Resistance
  - Permeability
  - Chemical Attack
  - Sulphate Resistance
  - Alkali Silica Reactivity
How Does Fly Ash Affect Workability?

- Due to the spherical particle shape of fly ash, even with lower water content the result is:
  - Easier placement - particularly when pumping
    - Less air loss through the pump
  - Easier consolidation
How Does Fly Ash Affect Finishability?

- Pros and Cons with respect to finishing
  - Again, the spherical particle shape creates a mix that is easier to finish
Scanning-Electron Micrograph of Powdered Cement
Fly Ash
How Does Fly Ash Affect Finishability?

- Set times
  - Pro or Con?
Does Fly Ash “retard” the set time of concrete?

– As a general rule fly ash does not act as a retarder
  
  • Studies have shown that fly ash chemistry can delay or accelerate set times, but typically fly ash does not chemically effect set time

– The delay in set time is due to a lower Portland cement content to provide the hydration chemistry
Does Fly Ash retard the set time of concrete?

- Can be managed with chemical admixtures
  - Water Reducers, High Range Water Reducers/ Superplasticizers: Disperse the cement grains to expose more cement surface area to water to initiate hydration. HRWR use will effect set time and strength gain
  - Accelerators: Initiate the hydration process. Accelerator use will effect set time.
Problems with delayed set?

- Tendency to overwork the concrete
- Extended exposure in plastic state can aggravate plastic shrinkage cracking
- Remember, fly ash has lower water demand and lower bleed rate both of which aggravate plastic shrinkage
Plastic Shrinkage Cracks
Plastic Shrinkage

- Mix management
- Site preparation
- Environmental management
- Plastic curing
  - Fogging
  - Evaporation retarders
  - Curing membranes
Why NOT use Fly Ash?

- Availability of fly ash
  - Spring and Fall supply issues
- Quality of fly ash
- High early strengths required
In Addition to Enhanced Durability Why Use Fly Ash?

- Decrease material cost of concrete
- Decrease the environmental cost (Carbon Footprint) of concrete
Decrease Carbon Footprint

- How can a coal combustion by-product be environmentally friendly?
  - Using fly ash in concrete reduces the quantity that has to be placed in landfills or ponds
  - Reduces the amount of Portland cement used
    - Portland cement production yields about 0.9 to 1.0 tons of CO₂ per ton of cement produced
  - A recycled industrial by-product is used to decrease the amount of high carbon footprint material used per cubic yard
Fly Ash for Enhanced Durability?

- A very useful and manageable material that can:
  - Decrease material cost of concrete
  - Decrease the environmental cost (Carbon Footprint) of concrete
  - Increase durability related to:
    - Chemistry – Micro
    - Workability and Finishability - Macro
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