Cold Weather Concrete Mix Design for the Beneficial Use of Coal Fly Ash as a Supplementary Cementitious Material

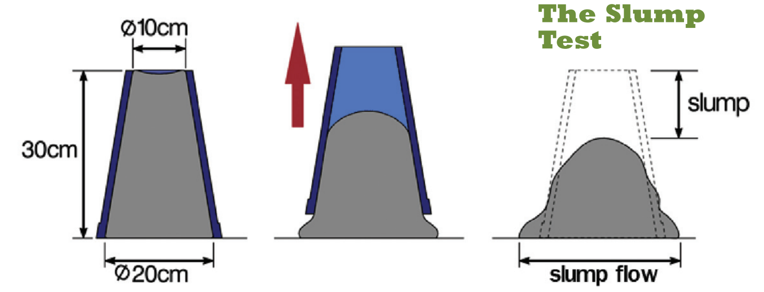
This fact sheet provides information on cold weather mix design considerations for the use of coal fly ash as a supplementary cementitious material (SCM). Cold weather poses special considerations for the beneficial use of coal fly ash as an SCM. Cold weather increases the curing time and decreases the rate of strength gain of concrete. Concrete containing coal fly ash is generally slower to cure than concrete without fly ash, and this effect is exacerbated by cold weather.

Table 1 Minimum temperatures recommended by ACI for fresh concrete as placed and maintained

55° F	Most slabs, pavements, sections less than 12 in. thick.
50° F	Most beams, columns, walls, sections 12 to 36 in. thick
45° F	Large columns, footings, pedestals, mats, sections 36 to 72 in. thick.
40° F	Sections over 72 in. thick

The first consideration for the use of fly ash as an SCM is the type of fly ash to be used. There are two predominant types of fly ash used as SCMs: these are Class C and Class F ashes, as defined by ASTM C618. They are both pozzolanic-that is, they are compounds that exhibit cementitious properties when combined with calcium hydroxide in water. Class C ash also has self-cementing properties and tends to cure faster than Class F ash, so its use may be preferable in cold weather. For more information about the differences between Class C and Class F ashes, and about the use of fly ash as an SCM, the Federal Highway Administration web site may be helpful: *http://www.tfhrc.gov/hnr20/recycle/waste/cfa53.htm.*

The Slump Test



Another consideration for cold weather mix design is that cold weather can actually be helpful, as long as care is taken to prevent freezing and other problems. Concrete set in cool temperatures, while generally slower to cure and gain strength, will typically have higher ultimate strength. Fly ash used as a cement replacement and used in conjunction with liquid admixtures will further enhance the ultimate strength of concrete in cooler weather.

The American Concrete Institute (ACI) defines cold weather as a period of three or more consecutive days that have an average daily air temperature of less than 40°F and in which the air temperature does not exceed 50°F for more than half of any 24-hour period.

Table 1 shows the benefit of concrete mass on reducing the effect of lower temperatures on concrete setting and strength. The larger mass of concrete is more resistant to damage at somewhat lower temperatures.

Strategies to Deal with Fly Ash Concreting in Cold Weather

There are two general strategies to use to ensure good performance of fly-ash concrete in cold weather: one is to adjust the concrete mix to account for weather's effects, and the other is to protect the concrete from the cold. Using one or more of the following methods will allow the user to achieve the typical benefits of fly ash concrete, while mitigating the negative effects of the cold.

Reduce water/cement ratio. The slower setting times and reduced rate of strength gain that result from decreased hydration can be counteracted by having a higher cement content, less water, or a lower slump. Replacing a certain percentage of cement with fly ash decreases water requirements so concrete can be placed at a lowered slump.

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Slump is the relative tendency for concrete to "sag" or "slump" after a special conical form is removed from a sample of the concrete being tested. Slump characteristics are important to proper handling and compaction of concrete.

Require a less-fluid (low-slump) concrete mix. Lower slump properties are easier to attain when using fly ash because its spherical shape results in higher workability even in mixes with less water. Lower slump will also reduce bleed water, which is the water that can emerge on the concrete surface during curing, and that can result in structural weakness.

Increase portland cement content up to 100 lbs. per cubic yard to help develop early strength, or replace normal cement with rapid-setting Type III Portland cement.

Add chemical accelerators such as calcium chloride at a maximum of two percent by weight to the cement mixture, or add proprietary, non-chloride accelerators according to specification. Accelerators increase the rate of hydration, leading to a shorter set time.

Use air-entrained concrete when exposure to moisture, freezing, and thawing are expected. Air entrainment is the deliberate incorporation of tiny air bubbles into the concrete mix to improve resistance to freeze-thaw damage. This is typically accomplished by incorporating special admixtures into the concrete.

Keep concrete from freezing. If concrete freezes while still plastic, its potential strength and durability can be severely affected. Fresh concrete must be protected from freezing until the concrete attains a compressive strength of about 500 pounds per square inch. Concrete should be protected for a minimum of two days. Protection methods include:

- Provide insulation blankets and plastics to help the curing process. Leave for approximately 7-10 days.
- Provide triple insulation thickness at corners and edges of walls and slabs.
- Heat the mix by (1) using hot water in the concrete mix, (2) providing a heated enclosure for concrete, (3) heating subgrades before placing concrete, or (4) heating the concrete framework.
- Do not expose concrete surfaces to a sudden temperature drop; gradually reduce insulation or enclosure temperature to control concrete cooling (no more than a 50°F drop in 24 hours).
- Allow concrete to air dry before exposing it to freezing temperatures.
- After a sufficient protection period, cool concrete gradually.

These methods may be used alone or in combination to reach the setting and strength gain characteristics required. The appropriate decision will afford an economically viable solution with the least impact on the ultimate concrete properties.

For more information about C2P2 and the use of coal fly ash, go to: www.epa.gov/c2p2, or contact the EPA coordinator at RCC-Challenge@epa.gov.

References

ACI (2002) "Cold Weather Concreting." American Concrete Institute, Committee 306,ACI 306R-88.

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