Natural Resources Canada

Ressources naturelles Canada

Concrete Incorporating SCMs: Properties and Current Specifications

N. Bouzoubaâ

Materials Technology Laboratory / Laboratoire de la Technologie des Matériaux

Canada

Definition

- Supplementary Cementing Materials (SCMs) are materials that when used with Portland cement contributes to the properties of hardened concrete through hydraulic or pozzolanic activity or both.

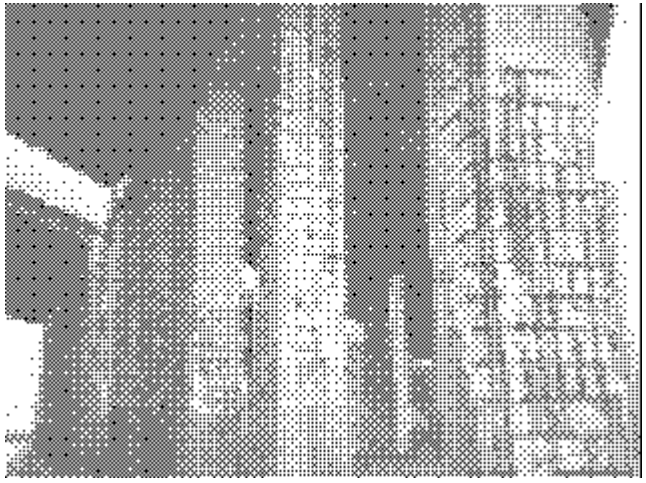
- The most commonly used SCMs are:
  - fly ash,
  - GGBFS and
  - silica fume.

Fly Ash Concrete Properties: Benefits

- Reductions in:
  - Water Demand
    - The water reduction decreases with increasing fineness and carbon content of fly ash
  - Bleeding
    - Generally reduced and pumpability is improved
  - Autogeneous temperature rise
    - Generally reduces the risk of thermal stress and cracking (especially type F and CI).
  - Permeability
    - Reduces water and chloride-ion permeability, especially at later ages, if well cured

Fly Ash Concrete Properties: Benefits

- Improvements
  - Workability
    - The spherical particle shape assists in improving workability
  - Corrosion Resistance
    - Increases the protection of reinforcing steel from corrosion if well cured
  - Sulphate Resistance
    - The use of low calcium fly ash (CSA Class F and Cl with CaO content < 20%) increases resistance to sulphate attack



Fly Ash Concrete Properties: Benefits

- Improvements
  - ASR resistance
    - The use of 25 to 35% fly ash would normally be effective in controlling ASR expansion with most alkali-silica reactive aggregate if the CaO content of the fly ash used is below ~20% and its alkali equivalent is below 4.5%. For fly ash with higher CaO and alkali contents, the exact amount required should be determined following the approach described in CSA A23.2-28A.

Fly Ash Concrete Properties

- ± Compressive Strength
- ± Flexural Strength
- ± Modulus of elasticity

Decreases the mechanical properties at early ages (especially at 1-d and in cold weather). The long-term mechanical properties such as compressive and flexural strengths, and the modulus of elasticity are typically superior to those of Portland cement concrete of similar 28-day compressive strength.

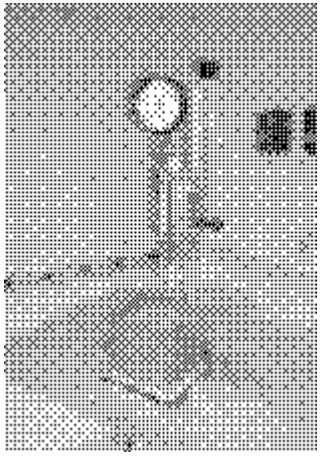
Fly Ash Concrete Properties

- ± Drying shrinkage
- ± Creep

The long-term drying shrinkage and creep of fly ash concrete will be similar to, or lower than that of Portland cement concrete of similar 28-day compressive strength.

Fly Ash Concrete Properties: Limitations

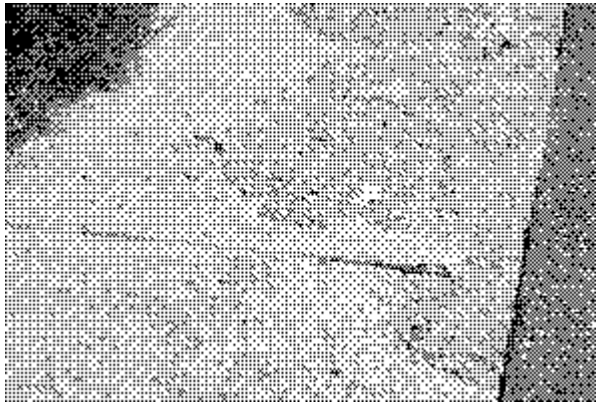
- Increased Setting time
  - Longer setting times compared to normal concrete may affect finishing schedule.
  - Cold weather conditions may further slow setting times.



Fly Ash Concrete Properties: Limitations

± De-icing salt scaling resistance

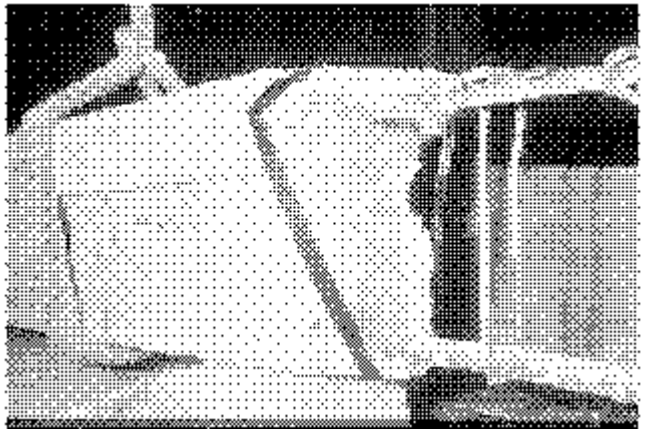
Lab data have shown that fly ash (>25%) decreases the scaling resistance of concrete, but this has not been confirmed by field data. Recent field data of sidewalk sections in Montreal have shown concrete with 35% fly ash (placed in Spring) and concrete with 25% fly ash (placed in Fall) both cured with curing compound, developing acceptable scaling resistance after 4 winters.



Fly Ash and Concrete Properties: Limitations

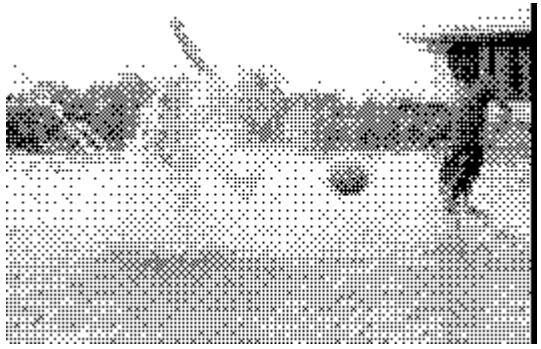
± Carbonation resistance

Lab data have shown that concrete resistance to carbonation decreases with increasing fly ash content, unless the curing period is increased and/or the w/cm is reduced. CSA A 23.1 recommends for reinforced concrete elements exposed to moisture and air, with depths of cover less than 50 mm, a w/cm not greater than 0.40 for concrete with fly ash > 40% and not greater than 0.45 for concrete with fly ash > 30%



Environmental Benefits

- For every tonne of Portland cement replaced by fly ash, there is a reduction in the environmental impact of concrete, including GHGs and air pollutants.
- Waste reduction.
- Enhanced sustainability in the construction industry.
- Contribution to achieving several LEED credits



Current Specifications

- **City of Winnipeg**
  - **Fly ash should be added as a separate ingredient. The use of blended cement is not permitted.**
  - **Class CI fly ash shall not replace portland cement by more than 15% by mass of total cementitious content in the mix.**
  - **The use of fly ash as partial replacement for portland cement shall not be permitted between October 1 and May 15 unless authorized in writing by the city of Winnipeg.**

Current Specifications

- **Manitoba Highways**
  - **Median barriers, slabs, curbs etc: Minimum 360 kg/m^3 Type GU Cement for a 30 MPa at 28 days, 0.40 maximum w/c concrete (effectively precludes use of fly ash)**
  - **Overlay slabs, shoulder barriers, abutment etc: Type 10E-SF silica fume portland cement, and shall not contain fly ash.**

Current Specifications

- **City of Edmonton**
  - **Fly ash is not permitted in curb, gutters, sidewalks, walkways, swales, medians…from September 30 to May 15.**
  - **From May 16 to September 30: no more than 10% of the specified minimum cement content may be replaced with fly ash.**
  - **In most of the structures designed by the city of Edmonton, minimum 28-d compressive strength of 30 MPa, maximum w/cm of 0.45, and minimum cement content of 335 kg/m^3 in Spring and Fall and 302 kg/m^3 in Summer is specified.**

Current Specifications

- **City of Calgary (Guidelines for Bridges and Structures)**
  - **The use of fly ash to reduce minimum cement contents is not permitted. Supplemental fly ash to a maximum of 15% of the cement content will be permitted, provided the w/c does not exceed 0.40.**
  - **Class F fly ash up to 20% is allowed in Bridge Deck, Barriers, Curbs, Median Substructures, Sidewalks Bridge Deck, but the cement content should range from 370 and 400 kg/m^3, the scaling residue according to ASTM C 672 should be less than 0.4 kg per 30 cycles.**

Current Specifications

- **Alberta Transportation – *Specifications for Bridge Construction***
  - **The use of fly ash is not permitted in bridge decks, curbs, medians, approach slabs and deck overlay concrete.**
- **Alberta Transportation – *Standard Specifications for Highway Construction***
  - **Unless otherwise approved by the Department, the use of fly ash is not permitted**

Current Specifications

- **Alberta Infrastructure – *Specifications for Concrete Paving.***
  - **Fly ash is not permitted in precast and prestressed products.**
  - **Fly ash should not be used in concrete subjected to freeze-thaw cycles, or deicing salts.**

Current Specifications

- **City of Toronto (sidewalk, curb and gutter etc.)**
  - **Slag cement up to 50%; fly ash up to 25%; silica fume up to 10%; a mixture of slag cement and fly ash up to 50% except that the amount of fly ash shall not exceed 25%.**
  - **The minimum total cementing materials content shall be 355 kg/m^3.**
  - **If SCMs are to be used, certification and documentation signed by a professional engineer, stating that the quality and durability of the concrete with SCMs will equal or exceed those of the concrete without SCMs. Specific documentation relating to deicer chemical scaling resistance and rate of strength gain shall also be submitted.**

Current Specifications

- **Ministry of Transportation of Ontario (MTO)**
  - **Up to 70% GGBFS and 40% fly ash is allowed by OPSS 1820 for circular concrete pipe, and by OPSS 1351 for precast reinforced concrete components, maintenance holes, catch basins etc.**
  - **Up to 40% GGBFS is allowed by MTO (118SO3) in dry cast culverts.**
  - **Up to 25% fly ash or slag is allowed in MTO's high performance concrete.**

Current Specifications

- **Ministry of Transportation of Ontario (MTO)**
  - **For conventional concrete in highway structures, MTO does not allow the use of OPSS 1350 dated November 2006, but the one dated January 1995, which limits GGBFS to 25% and fly ash to 10%.**
  - **For concrete exposed to De-icing chemicals, MTO specifies a mass loss of not more than 0.8 kg/m^2 of concrete slabs subjected to 50 cycles of freeze/thaw according to ASTM C 672.**

Current Specifications

- **City of Ottawa**
  - **Public Works and Services refers to Ontario Provincial Standard Specifications (OPSS). OPSS limits SCMs to 25% of the total cementing materials.**
  - **City of Ottawa is currently reviewing the last version of OPSS 1350, which allow the use of high volume SCMs into concrete.**
  - **HPC and sulphate resistant concrete applications utilize higher SCM contents.**
  - **Most other works refer to CSA concrete specifications**

Current Specifications

- Hydro Québec
  - Dans le cadre des aménagements hydro-électriques comportant du béton de masse, le ciment Portland type LH-HQ (20M) doit être utilisé et être conforme au devis technique normalisé, à moins d'indication contraire dans le devis technique.

Current Specifications

- Transports Québec (MTQ)
  - Ciment ternaire du type GUb-F/SF ou GUb-S/SF peut être utilisé dans le béton normal, sauf que la masse totale des ajouts ne doit pas être >30% de la masse totale du liant.
  - L'usage des ciments ternaires est interdit du 15 octobre au 31 mars.
  - Pour le béton projeté par procédé humide ou à sec, le ciment hydraulic composé du type GUb-SF, GUb-F/SF ou GUb-S/SF est spécifié.

Current Specifications

- Ville de Montréal
  - Pour le BHP, le ciment hydraulic composé de type GUb-SF, GUb-F/SF ou GUb-S/SF est specifié.
  - Pour le béton de trottoir ou de bordure, l'utilisation d'un liant consistant en 70 à 80% de ciment type GU et en 20 à 30% de ciment type GUb-SF, GUb-F/SF ou GUb-S/SF est specifié. Le ciment type HE sear utilisé du 15 octobre à la fin de la période de construction automnale. Il est aussi exigé pour ce type de béton un Max. 1500 Coulombs à 28 jours et un Max de 500g/m^2 de débris après 56 cycles de gel-dégel suiavnt la norme NQ 2621-900.

Current Specifications

- Nova Scotia Transportation and Public Works
  - Concrete Pavement: Low calcium (less than 10% CaO) Class F fly ash may be used at an addition rate not to exceed 15% by mass of total cementing material; minimum cementing materials content shall be 360 kg/m^2, and maximum w/c of 0.45.
  - Roller Compacted Concrete: The fly ash content must be less than 20%.
  - Cast in Place Concrete: Fly ash and silica fume may be used, however, the department reserves the right to limit their proportion to 20% and 10%, respectively in the mix.

Current Specifications

- Ministry of Transportation (British Columbia)
  - Bridge Construction: Both Type F and CI ashes are allowed, but the application rates shall not exceed 15% by mass of Portland cement.
  - Highway Construction: Fly ash application rates shall be limited to a maximum of 25% by mass of Portland cement in substructure concrete. Fly ash shall not be used in bridge deck concrete without the acceptance of the Ministry Representative. Upon such acceptance the maximum application rate shall be 15% by mass of Portland cement.

Conclusions: Benefits

- The incorporation of fly ash into a concrete mixture generally tends to:
  - improve workability
  - reduce the water requirement at a given consistency.

- It can be used to
  - enhance the ultimate strength of concrete
  - improve the impermeability,
  - improve the durability of concrete to chemical attack.
  - to mitigate thermal cracking by lowering the heat of hydration

Conclusions: Barriers

- Limitations
  - ✍ Reduction of early age strengths (7 day) of concrete, often resulting in increasing sensitivity to curing, finishing and scaling.
  - ✍ Carbonation may increase, resulting in rebar corrosion.

- Current specifications are still considered as a policy barrier to the increased use of fly ash in concrete.