Department of Climate Change, Energy, the Environment and Water

Supplementary Cementitious Materials

Fact sheet

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NSW GOVERNMENT

Acknowledgment of Country

We acknowledge that Aboriginal and Torres Strait Islander peoples are the First Peoples and Traditional Custodians of Australia, and the oldest continuing culture in human history.

We pay respect to Elders past and present and commit to respecting the lands we walk on, and the communities we walk with.

We celebrate the deep and enduring connection of Aboriginal and Torres Strait Islander peoples to Country and acknowledge their continuing custodianship of the land, seas and sky.

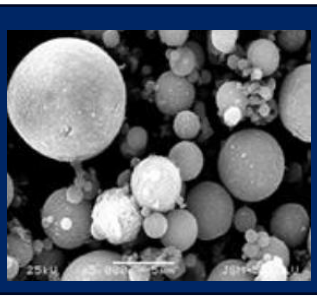
We acknowledge the ongoing stewardship of Aboriginal and Torres Strait Islander peoples, and the important contribution they make to our communities and economies.

We reflect on the continuing impact of government policies and practices, and recognise our responsibility to work together with and for Aboriginal and Torres Strait Islander peoples, families and communities, towards improved economic, social and cultural outcomes.

Artwork:
Regeneration by Josie Rose

Fly Ash (FA)

Fly Ash is a pozzolan, by-product of coal burning in power plants.



Suitable use: Structural concrete, non-structural concrete, concrete pavement, pavement base and subbase.

Benefits

- Good workability and pumpability.
- Higher ultimate strength.
- Improved resistance to chloride ingress.
- Alkali–silica reaction (ASR) mitigation (minimum 20-25% replacement).
- Reduced heat of hydration and risk of early age thermal cracking.
- **Embodied carbon**: Fly ash is in the range of 14-27 kgCO2e/kg compared to ~970 kgCO2e/tonne for OP cement[1].

Considerations

Durability

- Can impact carbonation resistance, but additional cover or coating can mitigate the risk.

Program

- Can have slower setting time and slower strength development, but modern admixtures can address the issue.

Implications

Designer/ Specifier

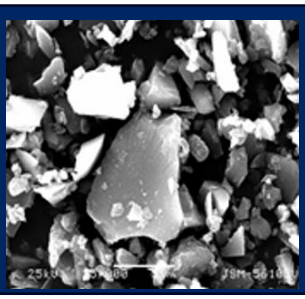
- Requires accelerators to achieve high early age strength requirements.
- For replacement levels above 35% may need to consider additional cover for external elements at risk of carbonation.
- For precast and prestressed concrete, select replacements levels to achieve strength development requirements.
- Specifier to understand performance requirement (i.e., early age strength, heat of hydration).
- AS 3600 is silent, however there is no restriction to the application.
- Required for certain exposure conditions as per AS 5100.

Construction team

- Can increase setting and curing time if accelerators not used.

Ground Granulated Blast Furnace Slag (GGBFS)

Ground Granulated Blast Furnace Slag (GGBFS) is a by-product of iron smelting, grounded to suitable fineness.



Suitable use: Structural concrete, non-structural concrete, concrete pavement, pavement base and subbase.

Benefits

- Improved resistance to sulphate attack.
- Higher ultimate strength.
- Alkali–silica reaction (ASR) mitigation (minimum 50% replacement).
- Reduced heat of hydration and risk of early age thermal cracking.
- **Embodied carbon**: GGBFS is in the range of 130-192 kgCO2e/kg compared to ~970 kgCO2e/tonne for OP cement[1].

Considerations

Durability

- Can impact carbonation resistance, but additional cover or coating can mitigate the risk.

Program

- Can have slower setting time.
- Can have slower strength development if accelerators not used.

Implications

Designer/ Specifier

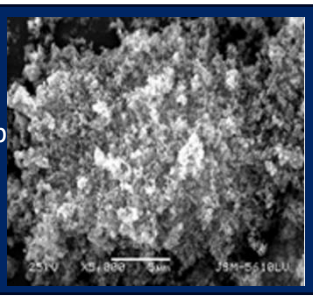
- Requires accelerators to achieve high early age strength requirements.
- For replacement levels above 60% may need to consider additional cover or coating for externa elements at risk of carbonation
- For precast and prestressed concrete, select replacements levels to achieve strength development requirements.
- Specifier to understand performance requirement (i.e., early age strength, heat of hydration).
- AS 3600 is silent, however there is no restriction to the application.
- Required for certain exposure conditions as per AS 5100.

Construction team

- Can increase setting and curing time if accelerators not used.

Silica Fume

Silica fume, which is finer than cement, is a by-product obtained from the smelting p
silicon and ferrosilicon alloys.



Suitable use: Structural concrete, non-structural concrete, shotcrete applications, concrete pavement, pavement base and subbase.

Benefits

- Higher early and long-term strength.
- Improved abrasion resistance.
- Improved chemical resistance (low permeability).
- Alkali–silica reaction (ASR) mitigation (minimum 8% replacement).
- Reduce concrete bleeding.
- Used in ternary mixes with fly ash or GGBFS to improve durability.
- Typically, 3-10% replacement of cement
- **Embodied carbon**: Silica fume is typically similar to fly ash.

Considerations

Durability

- Can impact carbonation resistance, but additional cover or coating can mitigate the risk.

Implications

Designer/ Specifier

- For high replacement levels may need to consider additional cover or coating for externa elements at risk of carbonation.
- Can require more water due to its fineness, but an adequate mix design would enable compliance with the fresh property requirements.

Construction team

- Can decrease workability and finishability if high replacement is used and admixtures are not specified

Calcined clay, also known as Metakaolin

Calcined clay often consists of clay heated to a temperature between 650°C and 850°C and Metakaolin is the most commonly available calcined clay on the market.

Calcined clay is not currently readily available in the Australian Market. Suppliers, universities and others in the industry are collaborating to bring it to the market.

Benefits

- No changes in setting times.
- Decreased heat of hydration.
- Increased finishability.
- Increased early and long-term strength.
- Improved chemical resistance (low permeability).
- Alkali–silica reaction (ASR) mitigation.
- For metakaolin, typically, up to10% replacement of cement.
- **Embodied carbon**: Calcined clay is ~16-24% of the embodied carbon of an OP cement. Note that calcined in not generally available in industry at this time, however this is expected to change over the next couple of years.

Considerations

Durability

- Can impact carbonation resistance, but additional cover or coating can mitigate the risk.

Implications

Designer/ Specifier

- For high replacement levels may need to consider additional cover or coating for externa elements at risk of carbonation.
- Can require more water due to its fineness, but an adequate mix design would enable compliance with the fresh properties requirements.

FACT SHEET: Supplementary Cementitious Materials (SCMs) in Concrete

Application of supplementary cementitious materials in concrete

Blends	Replacement levels		
	Traditional Usage	**To be used on Projects**	**Ambitious Targets**
Binary blends: Fly ash + GP	Fly ash: 10-25% (Overall 10-25% embodied carbon savings)	Fly ash: 35% cast in situ 30% precast and prestressed (Overall 30-35% embodied carbon savings)	Fly ash: >35% (>35% embodied carbon savings)
Binary blends: Slag + GP	Slag: 30%~50% (Overall 25-40% embodied carbon savings)	Slag: 50% (overall) (~40% embodied carbon savings) 60% cast in situ 45% precast and prestressed	Slag: >70% (>55% embodied carbon savings)
Tertiary blends: Fly ash + Slag + GP	Fly ash + Slag: 20-30%	Fly ash + Slag: 25% + 25% (or 20% plus 30 %) **A range of combinations are possible**	Fly ash + Slag: 50-65% **A range of combinations are possible**
Observations	No impact to early age performance requirements.	• Minor or no reductions for 1 to 5 day concrete strength. • No negative impact on 28 days strength • Cost neutral if minor early age strength reductions can be accommodated (minor cost impacts if no early age strength reductions permitted).	• 1 day to 5 days strength reduction. • No negative impact on 28 days strength • Cost increase if higher early age strength is required. • Longer curing (>7 days) • Increased carbonation risk may require additional cover if exposed to the atmosphere and moisture
Implementation actions	No extra actions are required.	• Include replacement levels and maximum cementitious content in concrete specification. • Engage with local suppliers two months in advance in order for them to ensure local plants can accommodate requirements. • Contractor can use either high performance low shrinkage concrete, high early age concrete **or** lower performance concrete with slight early age strength reduction. • Concrete supplier to provide verification documents demonstrating compliance with the designer's requirements (such as compressive strength, early age strength, and performance in certain exposure conditions etc), % of SCM replacement, concrete mix design (including admixtures and accelerators).	• Include replacement levels and maximum cementitious content in concrete specification and drawings. • Engage with local suppliers two to four months in advance in order for them to identify if trials are required and to ensure local plants can accommodate requirements. • Authority approval for infrastructure projects is typically required to demonstrate compliance with performance requirements against authorities' concrete specification (such as RMS B80) or Australian Standards (such as AS3600, AS5100). • Inform construction team on the possible impact of early strength delay. • Concrete supplier to provide verification documents demonstrating compliance with designer's requirements, % of SCM replacement, concrete mix design.

Future pathways for supplementary materials in concrete

Technology	Main components	Status	Supply chain
High SCMs concrete mixes	Black coal fly ash and slag	Easy wins, available now, temporary solution	• Subject to local fly ash supply, will be available until the closure of coal-fired power stations (e.g., close-down between 2028 - 2048) • Slag mostly sourced from Japan, Port Kembla slag also available in NSW
Pond ash	Mixture of black coal fly ash and bottom ash which is collected in ash ponds	Researched but not field trialled	• Major concrete suppliers and NSW government are conducting research and establishing the supply of pond ash. Supply and use expected to be available after the closure of coal-fired power stations (e.g., close-down between 2028 - 2048)
Geopolymer concrete or Geopolymer with GFRP bars	Black coal fly ash	Researched and field trialled SA TS 199:2023 provides requirements and guidance for the design and construction of geopolymer concrete (GPC) and alkali-activated binder concrete (AABC) building structures and members that contain reinforcing steel or tendons, or both.	• Subject to local fly ash supply, will be available until the closure of coal-fired power stations (e.g., close-down between 2028 - 2048) • Limited suppliers.
Alkali activated concrete	Slag	Researched and field trialled SA TS 199:2023 provides requirements and guidance for the design and construction of geopolymer concrete (GPC) and alkali-activated binder concrete (AABC) building structures and members that contain reinforcing steel or tendons, or both.	• Subject to slag availability • Suppliers are currently performing trials • Limited suppliers
Geopolymer concrete (calcined clay based)	Calcined clay[1]	Researched but not field trialled	• Major concrete suppliers are conducting research and establishing the supply of calcined clay. Supply expected to be available in 5 years
Concrete with pozzolans cement replacement (calcined clay based).	Calcined clay	Researched but not field trialled	• Major concrete suppliers are establishing the supply of calcined clay. Supply expected to be available in 5 years
Concrete with calcined Clay Cement LC3[2]	Calcined clay, clinker and limestone	Researched but not field trialled	• Major concrete suppliers are conducting research and establishing the supply of calcined clay. Supply expected to be available in 5 years

Note:
1.Calcined clay, also known as Metakaolin, is produced by heating kaolin, which is a widely available natural clay mineral, to a temperature between 650°C and 800°C
2. Approximately 30% calcined clay, 50% clinker, 20% limestone)

[1] Greenhouse gas intensity factors based on AusLCI (V1.42). See ‘How to calculate embodied carbon of a concrete mix of a concrete mix’ Fact Sheet for further detail.

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