Hydrating mechanism of high volume-phosphorus slag blended cement via chemical-thermal synergistic activation

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1. Background

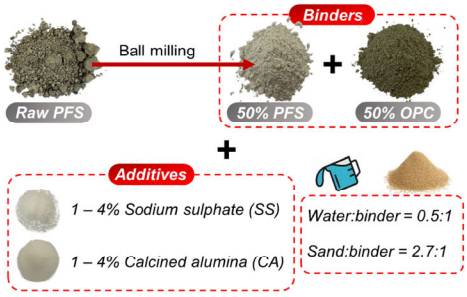
Current situation: With the **growing demand** for blended cement, introduction of a new type of supplementary cementitious material (SCM) can **alleviate** the **over-reliance** of fly ash and blast furnace slag (BFS).

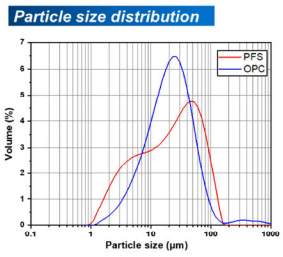
Phosphorus furnace slag (PFS) generated from the yellow phosphorus industry can be used as a **viable alternative** to commercial SCM due its similar chemical composition as BFS, but the **reactivity of PFS is lower than BFS** due to the presence of P_2O_5 residual, causing **reduced rate of hydration** in cement-based materials, resulting in **lower early strength**.

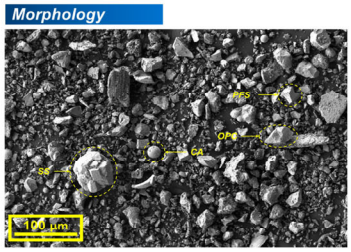
2. Approach

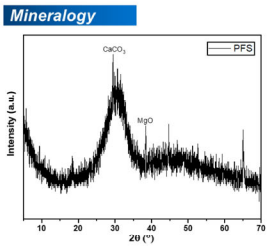
This project aims to systematically **enhance** the **reactivity** of PFS through **chemical** and **thermal** activations to improve its early age hydration, while the **reaction** mechanisms of PFS blended cement is analysed through microstructural studies, namely morphology and phase assemblages.

3. Materials & mix proportions (EN 196-1)

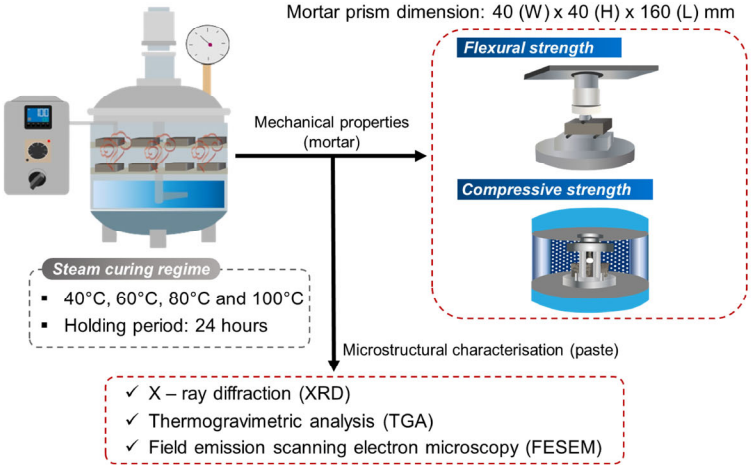








4. Sample preparation & test methods

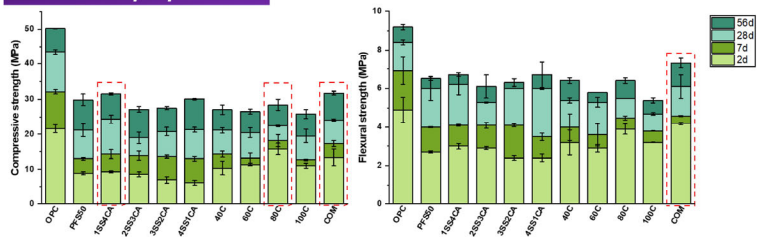


6. Conclusions

- Addition of 1% sodium sulphate and 4% calcined alumina enhances later strength of PFS blended cement mortar.
- Steam curing at 80°C increases early strength significantly but reduces later strength.
- Combination of 1% sodium sulphate and 4% calcined alumina along with 80°C offers superior mechanical properties at all ages.
- Microstructural analysis links the improved mechanical properties to hydration mechanisms.
- Changes in portlandite intensity are due to sodium sulphate reaction which expedites the hydration of alite and belite.
- Addition of calcined alumina promotes increased ettringite formation.
- Elevated temperature during steam curing increases the formation of portlandite and CSH, thus enhancing the density and mechanical properties.

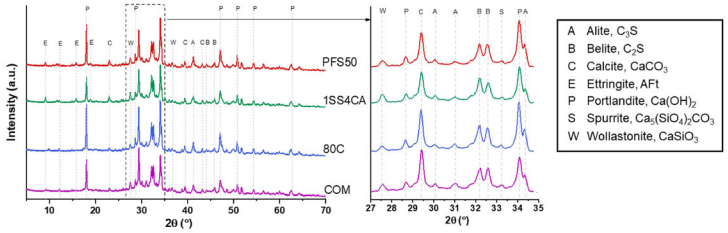
5. Experimental results and discussion

Mechanical properties

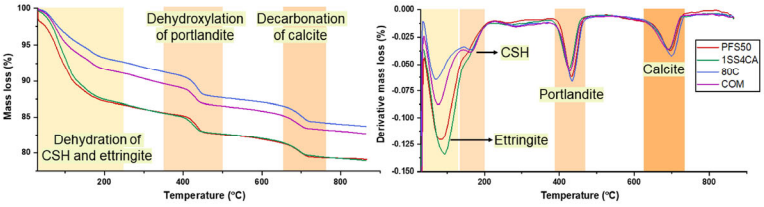


- The use of 1SS4CA as additives is the key factor for improving mechanical properties at later age.
- Steam curing is superior in enhancing early strength (especially at 80°C) compared to chemical activation, although it results in reduced later strength.
- For combined activation methods, optimal mechanical properties can be achieved at all stages of concrete development.

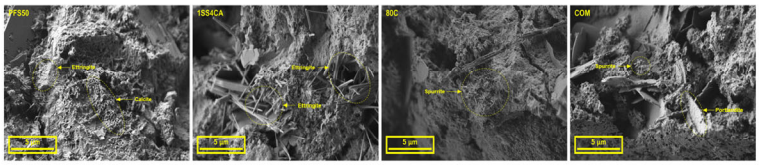
Microstructural characterisation (2d hardened paste)



- The main crystalline phase is portlandite and the secondary crystalline phases are belite, alite and ettringite. The hump in between 29° to 35° represents the presence of amorphous phase CSH.
- In chemical activation, the intensity of portlandite decreases is caused by the reaction of SS which consumes portlandite to produce NaOH and increases the alkalinity level, thereby expediting the hydration of alite and belite. The addition of CA provides sufficient alumina to form more ettringite.
- The reaction between CaO and H_2O is enhanced during steam curing and increases the intensity of portlandite. This acceleration promotes the reaction between PFS and portlandite, leading to the formation of CSH, thereby increasing the density and mechanical properties.



- The total mass loss of PFS50 is the highest, followed by 1SS4CA, COM and 80C.
- Four prominent peaks are observed, namely dehydration of CSH and ettringite, dehydroxylation of portlandite and decarbonation of calcite.
- 1SS4CA exhibits higher mass loss for ettringite, while 80°C shows the highest mass loss for portlandite and calcite.



- A large amount of calcite can be observed in PFS50.
- The amount of needle-like ettringite in 1SS4CA is higher than PFS50.
- The morphology of COM is packed with hexagonal portlandite crystals.
- The spark-like spurrite can be observed in 80C and COM.
- The FESEM images are corresponding with the XRD and TGA results.

References & Acknowledgement

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