

TESTING OF SUTABILITY OF SUPPLEMENTRY MATERIALS MIXED IN TERNARY CEMENTS

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Outline

- » Introduction to Ordinary Portland Cement (OPC)
- » Supplementary Cementitious Materials (SCMs)
- » Pozzolanicity
- » Methods of pozzolanicity and their problems
- » Modification suggested
- » Summary



Introduction to OPC

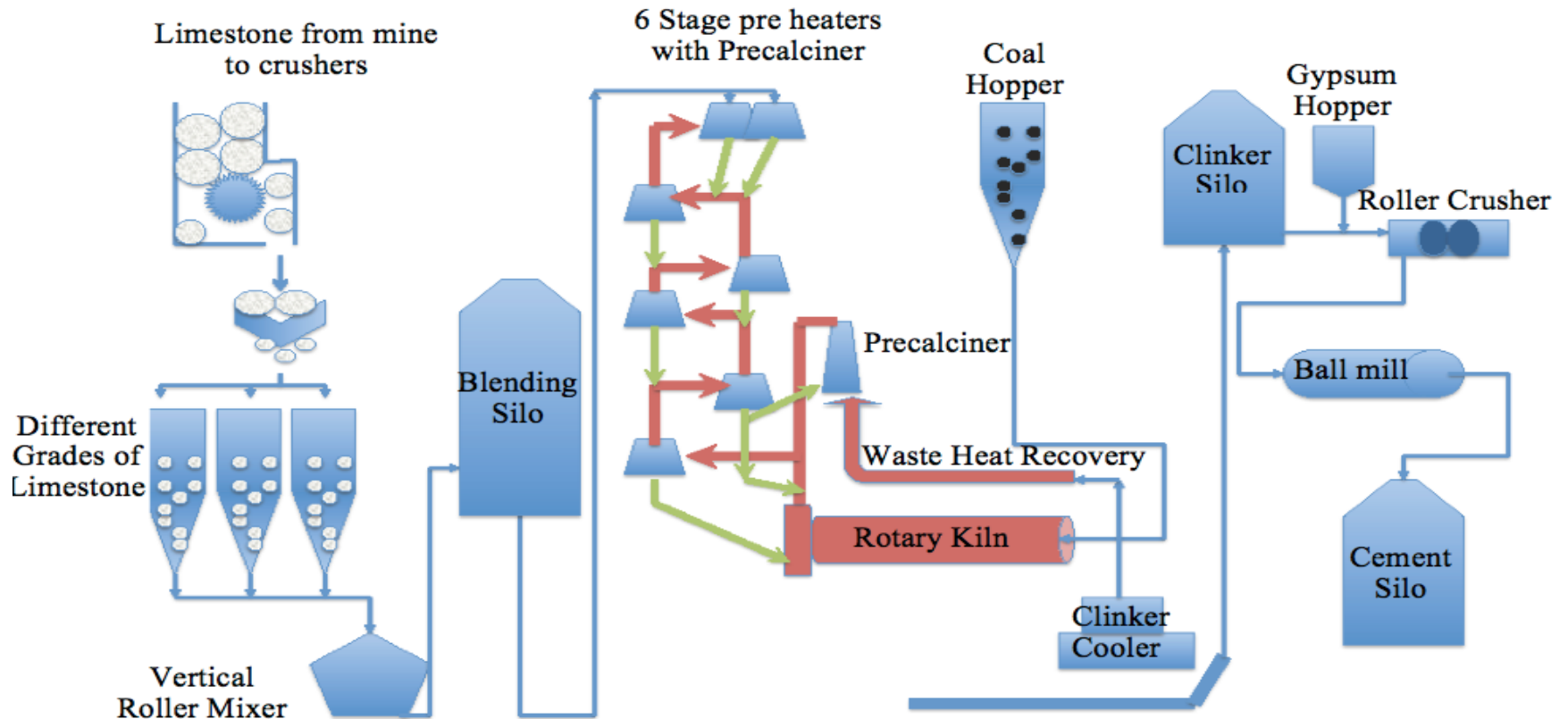
- » Most important binder for concrete
- » Around 200 years old
- » Major problem: CO₂ emission
- » 60% of total CO₂ emission is only due to decomposition of raw material in rotary kiln





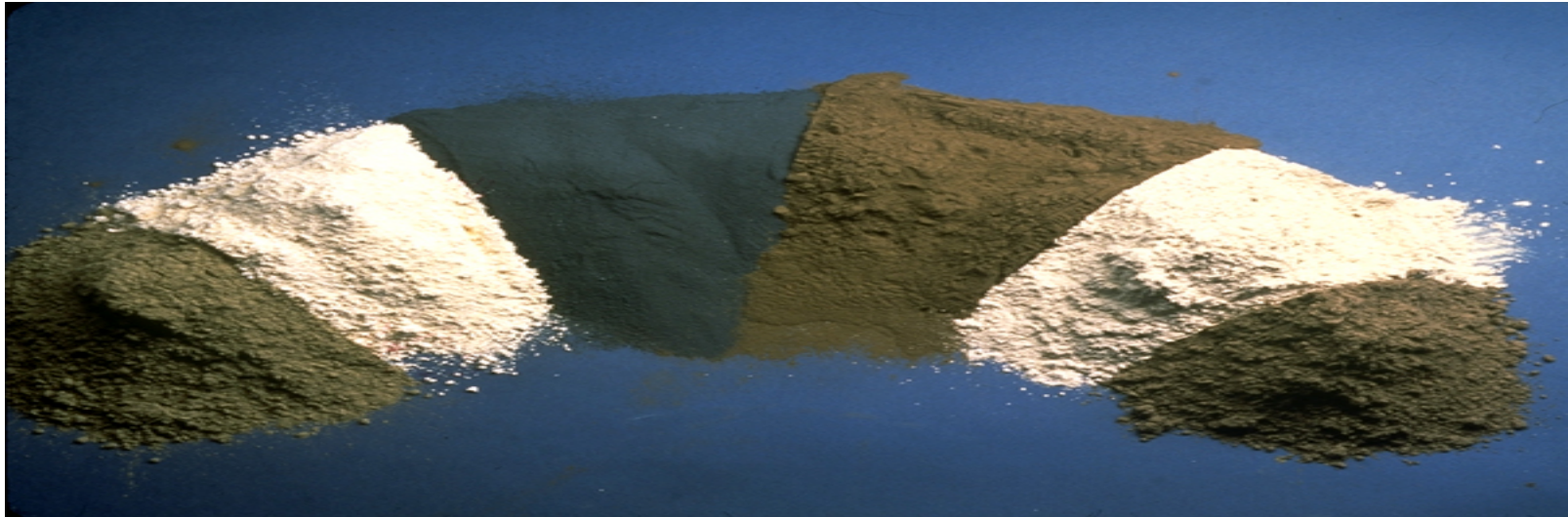
Introduction to OPC

Cement production (Dry Process)





Solution to the problem: (SCMs)

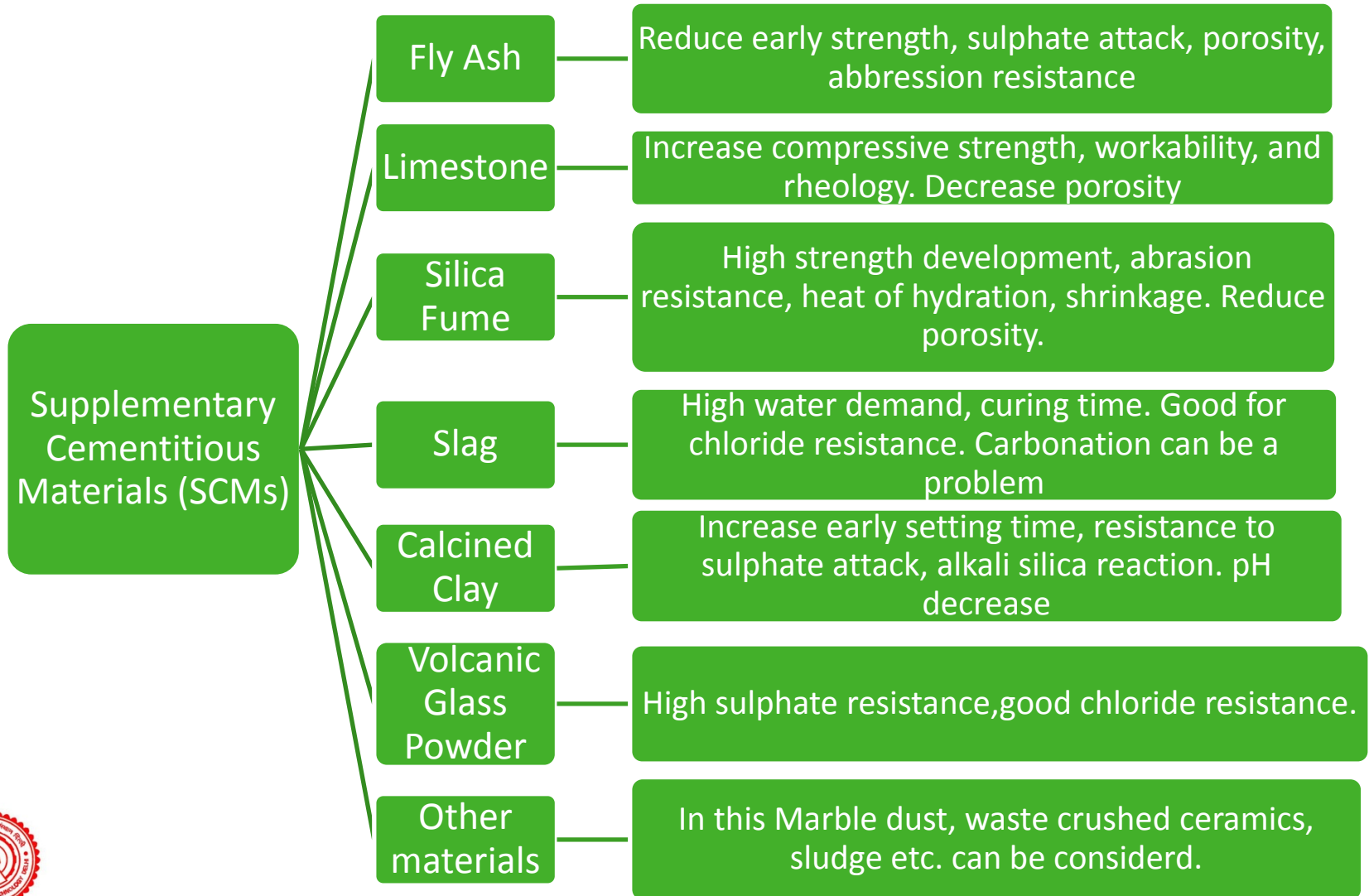


Source: PCA

- » Mainly contain reactive silica and some part of reactive alumina
- » Provide same hydration product as OPC and give many positive effects



Solution to the problem: SCMs



Pozzolanicity

- » Measurement of the degree at which lime (CH) react with pozzolanic material to form calcium silicate hydrate (CSH)
- » Tells about efficiency of SCMs that contributes to the strength
- » Depends of huge no. of factors
- » Fast and reliable method is not yet found
- » Existing methods classified based on the direct and indirect observation of reactivity



Methods of pozzolanicity and their problems

» Direct methods: mainly focus on CH consumption in hydrated paste

XRD

- Sophisticated and costly
- Not applicable on amorphous phase

TGA and DTA

- Composition and heating rate effect results

Chapelle test

- High temperature effect reaction kinetics

Frattini test

- Blended cement paste is tested
- Time consuming and leaching of Ca ions affect result

Scanning Electron
Microscopy

- Polishing of sample requires experience
- Carbonation of sample



Methods of pozzolanicity and their problems

» Indirect methods: do not tells about the reaction kinetics

Lime Reactivity

- Reactivity is not defined
- w/c ratio and different rate of pozzolanic-lime interaction

Strength Activity Index

- Results based on total efficiency including cement
- Not suitable for small replacement of pozzolan

Electric Conductivity

- Measure short term activity

Calorimetry

- Not applicable for low heat emitting pozzolan

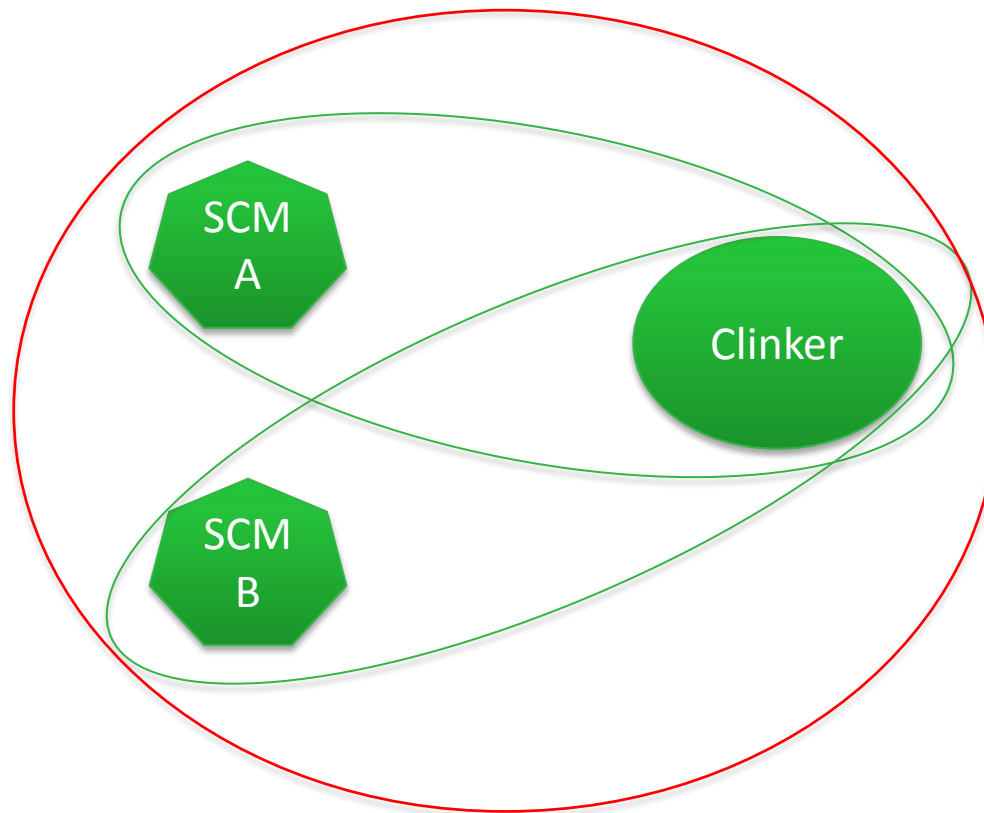
Flocculation test

- Based on visual observation and experience
- Need more study



Methods of pozzolanicity and their problems

- » No methods define interaction of two different SCMs with clinker phase



Test method: Chapelle's Test

- » Originally developed for metakaolin (MK), standardised in NF P18-513
- » 1-gm of MK with 2-gm of CaO and 250 ml of water is heated for 16 hours at a temperature of 90° C
- » Hydrated paste is titrated with 0.1N HCl and result expressed as mg. of Ca(OH)_2 consumed per gm. of MK



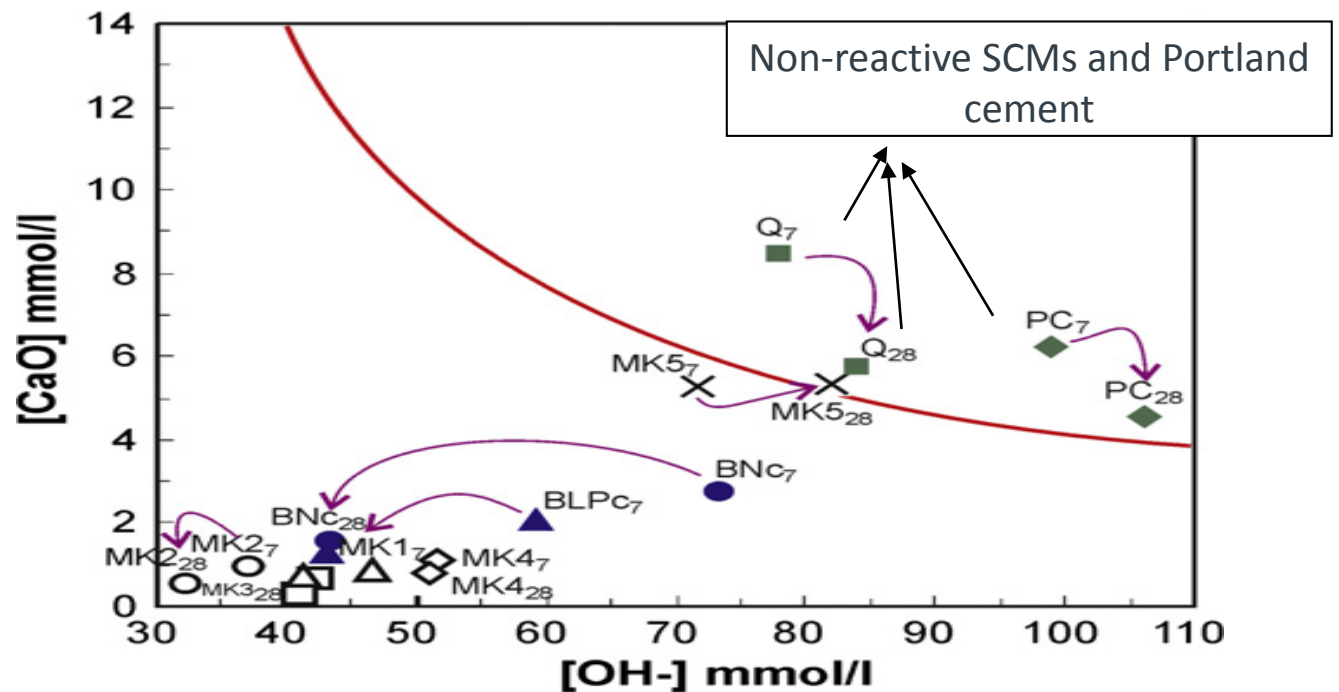
Modification suggested: Chapelle's Test

- » Already available modification suggests to perform for longer duration at lower temperature i.e. at 40° C for 90 days
- » Reducing the temperature and increasing the time for dilution using stirrer can modify this method
- » Best suitable time for the same yield in low temperatures can be find out



Test method: Frattini Test

- » Standardised in British standard BS EN 196-5:1995
- » Measures quantity difference of CH in aqueous solution (in contact with the hydration product) and CH requires saturating a solution of same alkalinity



Modification suggested: Frattini Test

- » For LC³ blend, Initially OH⁻¹ and Ca²⁺ ions can be found due to MK + clinker phase reaction.
- » Then allowed to react for some more time and then free carbonates can be calculated



Test method: Lime reactivity

- » Standardised in IS 1727 “Methods of test for pozzolanic materials”
- » Measures compressive strength development due to lime and pozzolan reaction
- » Mortar cubes are cast in a ratio of 1:2M: 9 (lime: pozzolan: standard sand) where M is ratio of specific gravity of pozzolana and specific gravity of lime (i.e. CH)



Modification suggested: Lime reactivity

- » Can be modified for ternary blends using M as given below
- » $M = (\text{Specific gravity of two pozzolanic material multiplied by their mass or volume ratios} \div \text{Specific gravity of CH})$
- » Fix water/ cement ratio can also be tried



Test method: Strength activity index

- » Standardised in ASTM C311 “Standard test method for sampling and testing fly ash or natural pozzolans for use in Portland cement concrete”
- » Compressive strength of cement mortar cubes are measured at 28 days



Modification suggested: Strength activity index

- » Slow pozzolainic reaction of some SCMs may not be observed properly
- » Accelerated curing conditions and volumetric batching of SCMs can help in observing complete hydration



Test method: Isothermal conduction calorimetry

- » Measure rise in temperature due to hydration of paste
- » Works better for cement blends
- » Not well suitable for studying low reactive pozzolans in which rise in temperature can be very less or low



Modification suggested: Isothermal conduction calorimetry

- » As per the modification suggested, test can be performed into two steps
- » In first step, ternary blend paste can be observed, and then in second step, paste of higher reactive pozzolan with calcium hydroxide can be analysed.
- » Then difference in the heat of hydration in binary and ternary blends will give the idea about synergy effect
- » The water/powder ratio should be kept constant for all the pastes



Summary

- » Till date, no standardised method is available for ternary blends
- » Test methods based on CH consumption can give nearly accurate idea of pozzolanicity
- » It is better to perform two different methods, preferably one direct and other indirect because no single method is acceptable for all SCMs



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