Ternary cement blends based on metakaolin and limestone

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SUSTAINABILITY OF CEMENT AND LOW-COST HOUSING

With 1 m³ produced per year per capita, concrete is the most widely used material in the world and accounts for 5-8% of man-made CO₂ emissions. It is possible to reduce its environmental impact by substituting cement with supplementary cementitious materials (SCMs) like fly ash, slag, silica fume and natural pozzolan. Calcined Cuban clayey soils are an interesting SCM for low-cost housing projects which promote the use of locally produced and affordable “ecofriendly” materials in developing countries, where the energy costs of producing cement make it disproportionately expensive.

THEORETICAL

1. Limestone “LS”. CaCO₃ – widely available & inexpensive material, mainly composed of calcite
   - **Filler**: Finely ground LS is used up to 3% as a filler in OPC (negative impact over 10-15%)
   - **Reactive additive**: Induces the formation of Hc and Mc Afm phases (hemi- and monocarboaluminates) at the expense of Ms (monosulfoaluminate) and stabilises Ettringite (AFT) [2]. Formation of these phases is influenced by carbonate, aluminates and hydroxide ion activity [3].

2. Metakaolin “MK”: (Al₂O₃) : 2 (SiO₂) – natural pozzolan thermally activated by calcination of clayey soils containing kaolinite
   - In OPC, when 30% of cement is replaced by reactive clay, MK reacts with Portlandite (Ca(OH)₂) or CH to form C-A-S-H hydrates and improves mechanical strength after 1 day. The more kaolinite the clay contains, the more reactive it is [1].

AIM OF THE STUDY

- Achieve higher substitution by replacing cement with blends of metakaolin clay and limestone and characterisation of these novel blends (benefit from MK and LS?)
- Reproducing results found with Cuban cement, limestone and kaolinite-containing pozzolans for potential field application

MECHANICAL PERFORMANCE

Reference system (MK-LS)

Blends ("MK-B") show high reactivity with significant improvement of strength over OPC at 7 and 28 days up to 45% substitution.

The MK-B45 (30% MK and 15% LS) shows similar properties to MK30 (30% clay), with 15% less cement.

Cuban materials

Blends with coarser clays containing 40% kaolinite ("A"") and "Cu") show an increase in strength at 7 and 28 days, but remain mostly under OPC.

SIG-B45 blend, with finer clay containing 58% kaolinite, produces an increase in strength similar to the MK-LS system.

CONCLUSIONS

- A synergistic effect was observed in blends of MK and LS through an increase in strength at 7 and 28 days compared to OPC, for cement substitution of 15-45%.
- These novel blends show finer and more homogeneous microstructures than OPC and benefit from the presence of both MK and LS.
- It was observed the formation of Hc and Mc Afm phases and stabilisation of AFT. Accurate prediction of their formation may be possible in accordance with [3].
- All blends show high pozzolanic activity due to the presence of clay. The effect is enhanced by the presence of limestone with higher CH consumption at early age.
- Results from Cuban materials show that blending is applicable to less reactive materials. Such blends are extremely interesting for low-cost housing applications.

REFERENCES


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