DEVELOPMENT AND INTRODUCTION OF A LOW CLINKER, LOW CARBON, TERNARY BLEND CEMENT IN CUBA (2005-2014)

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22 June 2015
CIDEM’s Experience in housing programs in Cuba

- Center for R&D of Structures and Materials, founded in 1991
- Develops appropriate technologies for the manufacture of materials
- Each development an innovation loop which includes fundamental and applied research
- Implements the technologies at grassroots level through partnerships with international donors

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<td>UCLV:</td>
<td>MINFAR: first ideas on appropriate technologies for building materials</td>
<td>MINAZ: participation in the program “production of alternative materials”</td>
<td>Sagua la Grande: First experience local production</td>
<td>Villa Clara: replication throughout the province</td>
<td>Production of ecomaterials at grassroots level</td>
<td>hurricanes emergency response projects</td>
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<td>The center was found</td>
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Agriculture Wastes as Pozzolans (1994-2004)

1. Ashes burnt without control
   *Sugar cane bagasse and straw*


Martirena et al. Rudimentary, low tech incinerators as a means to produce reactive pozzolan out of sugar cane straw, CCR, 36 (2006) 1056-1061

2. Ashes burnt under control
   *Sugar cane straw burnt undr 700 oC*

3. Ashes from the solid fuel block
   *Sugar cane straw and clay mixed and burnt at 800-900 oC*
Low Grade Clay available where they are needed (developing & emerging economies)

Regions in yellow and pale green
Timeline of cooperation CIDEM & LMC-EPFL

2005-2008
SDC-SNSF Project
Calcined clays for pozzolans

2009-2012
SDC-SNSF Project
Ternary blend cement calcined clay-limestone

2013
SDC-Climate Change
Low Carbon Cement

Pursuit of sustainable alternatives to replace clinker through the use of calcined clays…

Understanding clay activation and pozzolanic reactivity

Thesis R. Fernandez, 2009
Simulation of Solid-Fuel Block

Pre-heating Transition period

SFB burning

Recuperation of the ashes

Ashtray Burning conditions
Focus on Low Grade Kaolinitic Clays alone

Cuban Soil (Manicaragua, Cuba)

Water / stones / sand / Organic matter / Non-clayey minerals / Clay minerals

- Limestone / Quartz
- Quartz
- Feldspath
- Pyrite
- Dolomite
- illite
- Kaolinite
- Montmorillonite
- Gypsum

Air

Thesis R. Fernandez, 2009
Importance of correct firing window

Safe zone  Danger zone

Thesis A. Alujas, 2011

Thesis R. Fernandez, 2009

Median diameter (d50)

Temperature (°C)
Clay activation vs. firing temperature

![Graph showing clay activation vs. firing temperature](image-url)
Hypo-sulphation of systems with MK

The quick CH consumption on the cement paste made with 30% MK could indicate that the system was under sulphated... so that there was a higher demand for sulphates...
SDC-FNS Project EPFL-UCLV: synergy between calcined clays and limestone (2009-2012)

Assumption that combined addition of limestone and calcined clays contribute to the formation of monocarboaluminate hydrate

- Metakaolin “MK”
  - \((\text{Al}_2\text{O}_3) : 2 \cdot (\text{Si}_2\text{O}_2)\) 222 g/mol

- Limestone “LS”
  - \(\text{CaCO}_3\) 100 g/mol

- Formation of monocarbo aluminate “Mc” (AFm)
  - \(3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{CaCO}_3 \cdot 11\text{H}_2\text{O}\) or \(\text{C}_4\text{ACH}_{11}\)

- Assuming the reaction in excess of \(\text{Ca}^{2+}\) and \(\text{OH}^-\)
  - \(\text{Al}_2\text{O}_3 + \text{CaCO}_3 + \text{Ca}^{2+} + \text{OH}^- \Rightarrow \text{C}_4\text{ACH}_{11}\)

⇒ MK:LS weight ratio of 2:1

Thesis M. Antoni, 2013
The cementitious system OPC-calcined clay-limestone

- Combined addition gives better strength than OPC at 7 & 28d for replacement of 45%
- ~90% for 60% addition

Fast synergetic effect between metakaolin and limestone

![Graph showing compressive strengths relative to OPC and compressive strengths [MPa]](image)
From pure clay systems to Low Grade Clay

» B45 with 50% kaolinite clay still gives very interesting results

Thesis M. Antoni, 2013
SDC Climate Change Division Project, Project Entry Phase (2013)

(August 2013) Production of 130t of cement

(2014) Validating cement with various builders

(2014-2015) Initiate durability studies
First industrial trial, 2013, Cuba

- 118 tonnes of original material with 18% moisture content were fed to the kiln.
- 65 tons of calcined material were obtained.

First batch: 3-5 tonnes (discarded)
2nd batch: 8-10 tonnes
5th batch: 17-20 tonnes
First industrial trial, 08-2013

10 In bags

120 t in silo
SDC Climate Change Division Project, (2014-2017)

2.5 t in bags
Concrete casting Cayo Santa María
Exposure site cayo Santa María
LCA results. OPC & PPC vs. LC3 (improvement potential)

Lívia Sánchez
Path toward a standard covering LC3

ASTM C595
Pozzolan content: ≤ 40%
Limestone content: ≤ 15%
Minimum clinker content: 45%

LC3 50% clinquer
LC3 65% clinquer

M. Schnaider 7th International VDZ Congress
2013

(**) tests carried out by Lafarge (France)
Concluding remarks

» Low grade kaolinite clay is a good source for pozzolans thought calcination

» The synergy between calcined clay and limestone enables higher clinker substitution (more than 50%)

» The new ternary cementitious system has proven to be robust in trials at lab scale, but also through industrial trials carried out in Cuba

» It becomes a suitable solution for developing countries with growing economies.

» OPEX 9-15% lower than traditional OPC and PPC

» CO2 reduction between 25-35% less than OPC-PPC

» A path established for standardization