Louisiana State University

Advancing Sustainable Construction:
Harnessing Louisiana's Local Resources for Low-Carbon Concrete

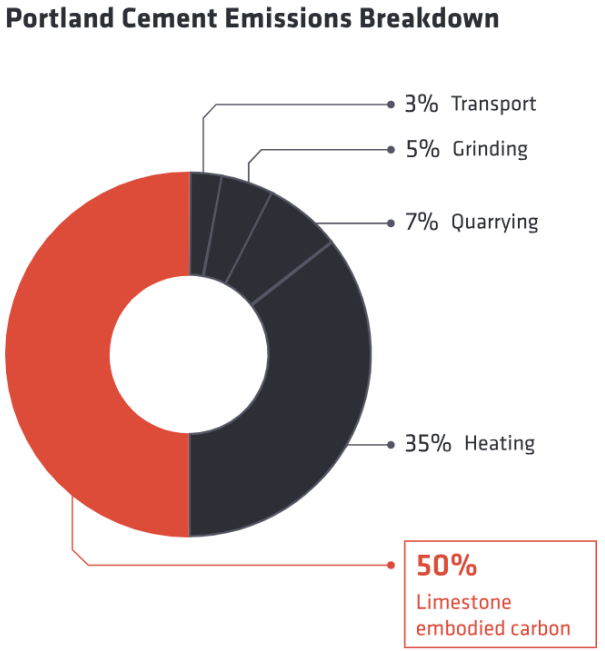
Andrew Callender, Khalilullah Taj, Dr. Yen-Fang Su

Department of Civil & Environmental Engineering
Louisiana State University and A&M College

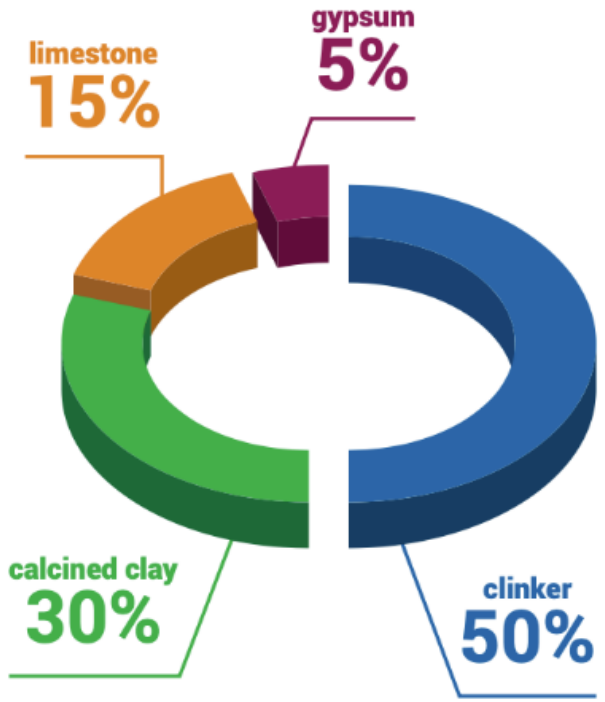



Carbon Emissions & Limestone Calcined Clay – LC3

- The cement industry is responsible for 8% of man-made carbon emissions (*COP28*)
- ACI involvement led to ACI CODE 323 Low Carbon Concrete Code
- Limestone Calcined Clay – LC3 (*Scrienver et al.,2018*)
  - Reduces CO_2 emissions by 40%
  - Limestone and Gypsum already used at plants, however Calcined Clays are not widespread



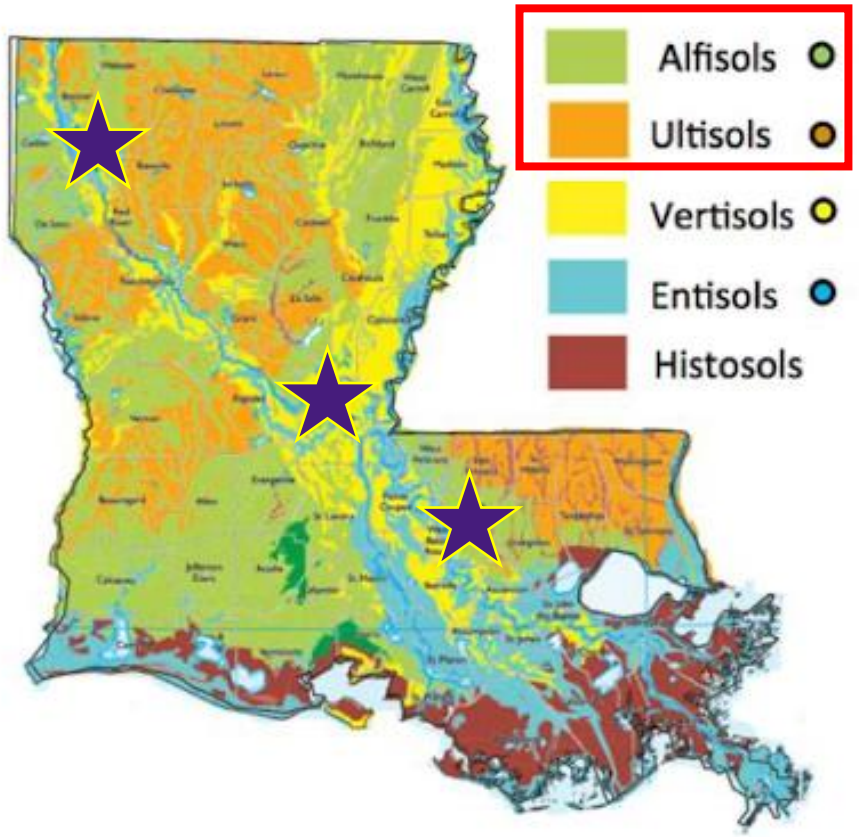
Terra. Sustainability. Retrieved from https://terraco2.com/sustainability/



LC3. Home. Retrieved from https://lc3.ch/

Clays

- Clays
  - Must have **kaolinite** present
  - Economical if low grade kaolinitic content
  - Characterized as either Alfisols or Ultisols
- Sourcing Clays
  - 6 clay samples taken across Louisiana
  - The further North, the more kaolinite found in clays



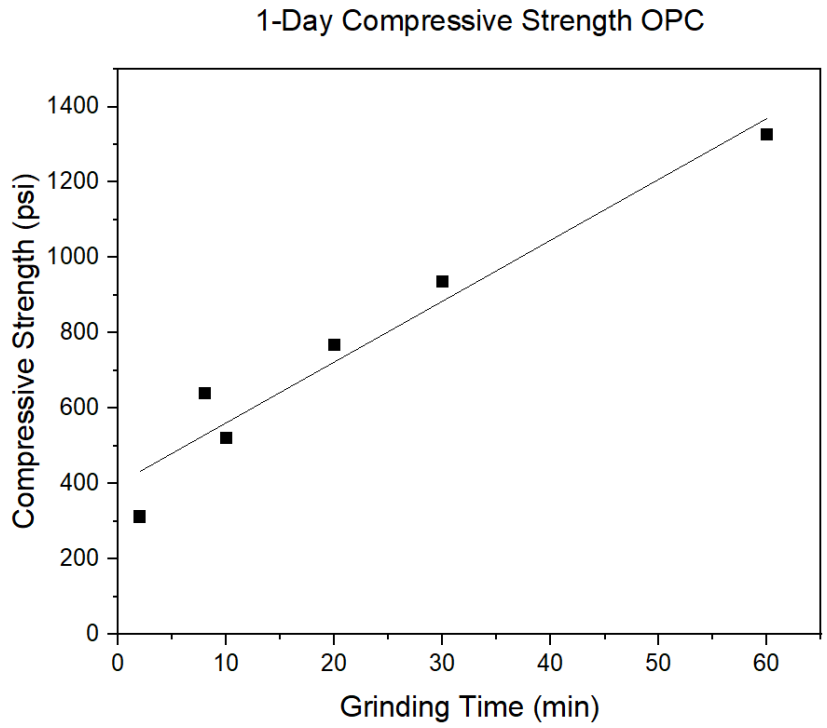
Holton et al. (2018).

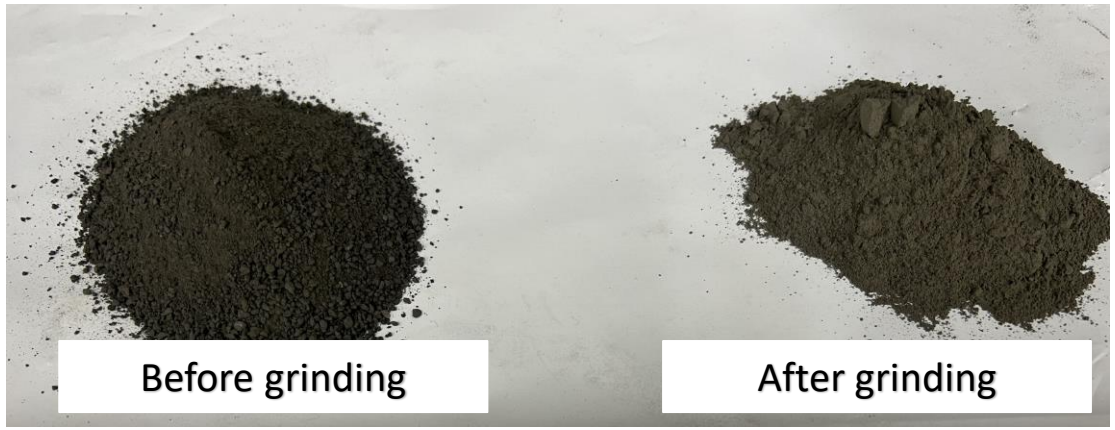
Limestone & Oyster Shells

- Limestone
  - $CaCO_3$
  - Supplementary Cementitious Material in LC3 blend
- Oyster Shell
  - Composed mostly of $CaCO_3$ and impurities
  - 10 million tons of mollusk waste per year (*Popović, et. al. Appl. Sci. 2023*)
  - 474.5 million Oysters produced in Louisiana alone (*Louisiana Department of Health*)
  - Waste deposits can become harmful to Marine Environments
  - Compared to limestone less carbon emitted since the limestone does not need to be quarried

Clinker Grinding Times

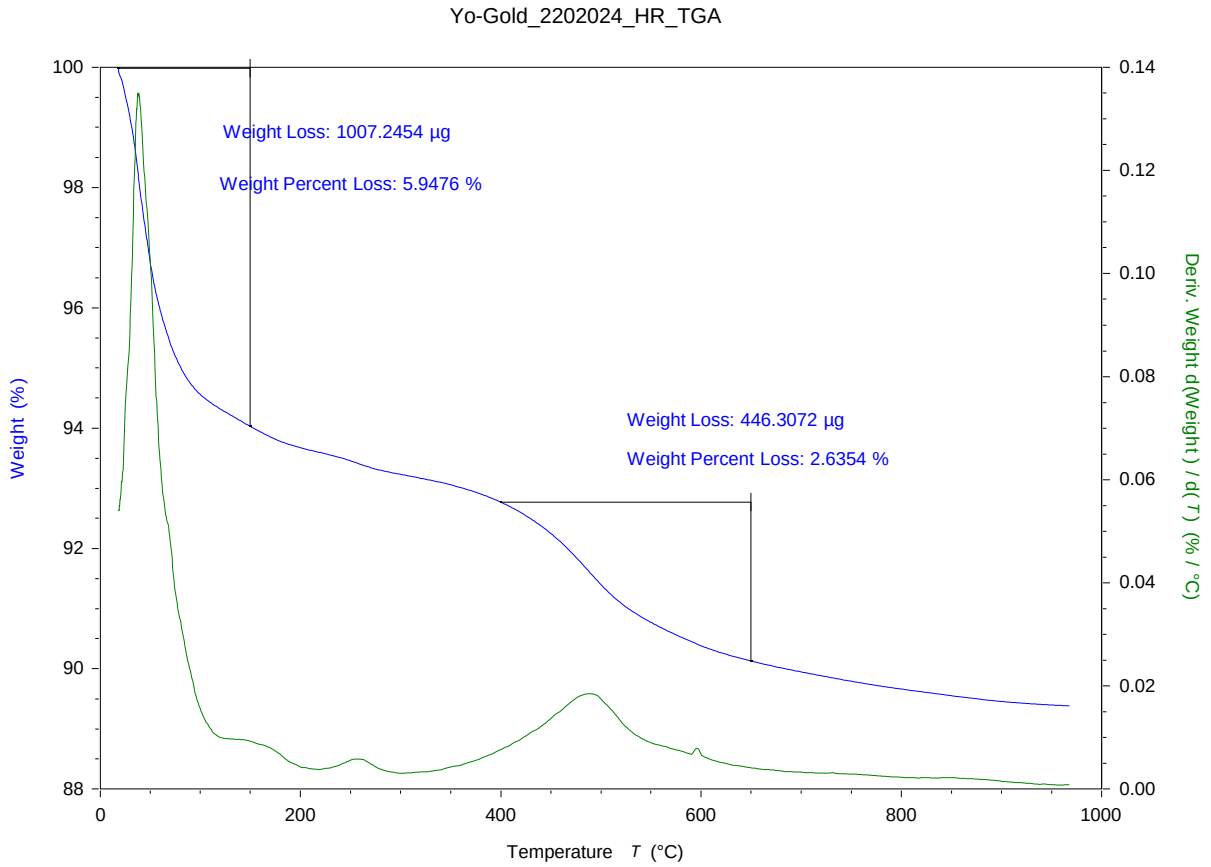
- Clinker
  - Clinker was delivered grinded but not fine
  - Multiple grinding times tested to determine optimal grind time
  - 30 minute was found to have acceptable strength and efficient timing





Thermogravimetric Analysis

- Conducted TGA for 6 different clay to determine kaolinitic content
- Analyze weight percent loss from 400-650°C
- Range: 4%-20% kaolinite weight
- Average: 13%
- Selected clay is ~20%

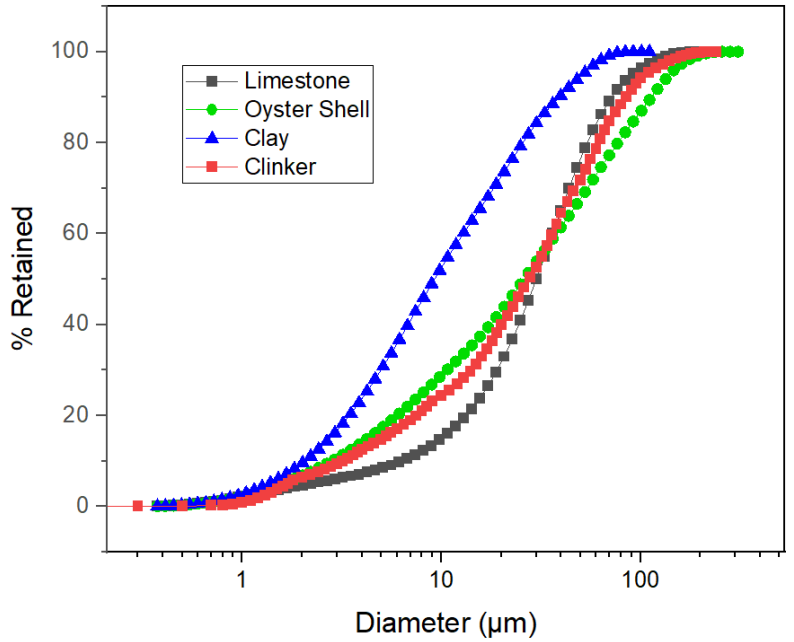


$$wt\%_{kaolinite} = wt\%_{kaol-OH} \frac{M_{kaolinite}}{2M_{water}}$$

(Scrienver et al., Cement and concrete research, 2018)

Material Characterization

- Particle Size Distribution
  - Limestone and Oyster Shell have similar PSD
  - Clay is the finest material (optimizes packing)
  - Clay was grinded for only 1 minute after drying
  - Clinker was grinded for 30 minutes



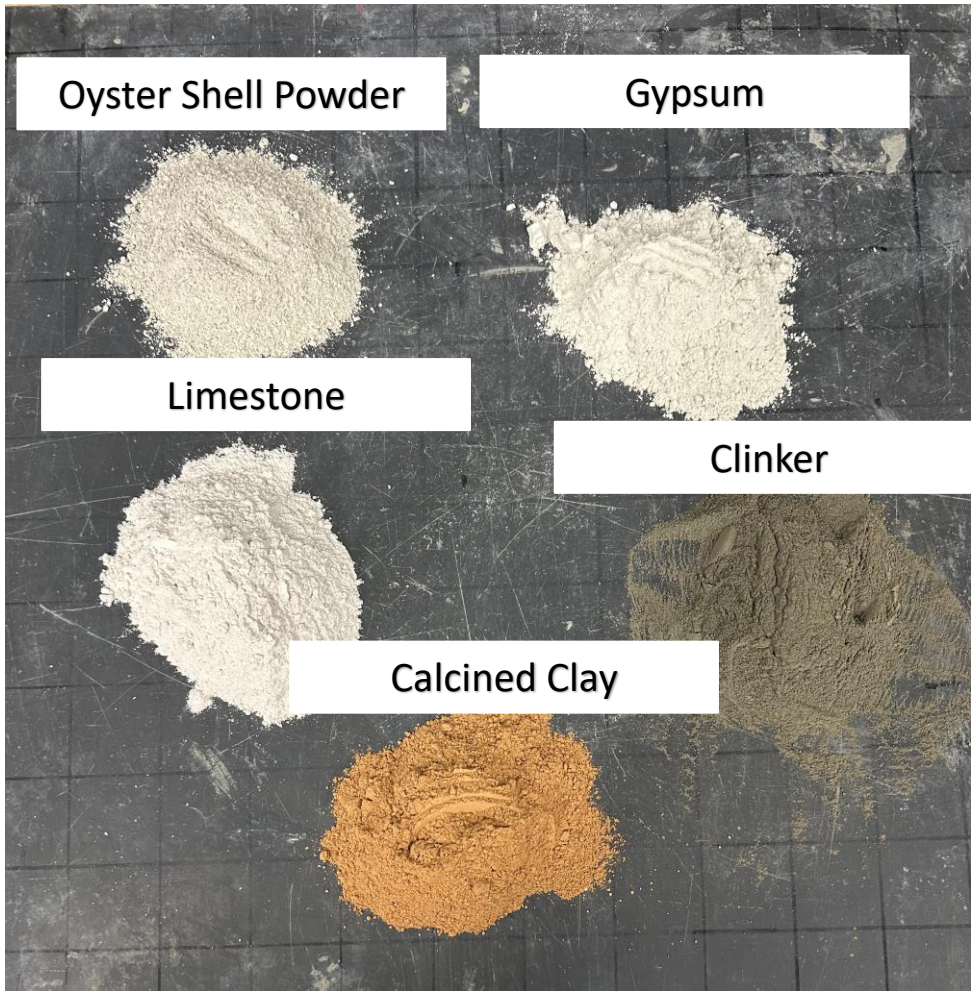
- XRF
  - Determined oxides present in Ingredients
  - Oyster shell and limestone oxides are very similar
  - Clinker has lower lime than typical

Chemical Components of Ingredients

Oxides	Calcined Clay	Clinker	Oyster Shell	Limestone
CaO	0.337	54.014	86.392	93.365
MgO	2.83	8.252	2.251	3.534
SiO_2	69.306	25.594	4.421	1.613
Al_2O_3	21.8	5.934	1.764	0.739
K_2O	1.252	0.926	0.317	0.268
Fe_2O_3	2.891	2.148	0.477	0.122
Ti	0.269	0.148	0.034	0.002
Na_2O	0.774	-	1.27	-
P_2O_5	0.34	-	-	-
S_2O_3	-	2.614	1.955	-
Total	**99.8**	**99.63**	**98.881**	**99.643**

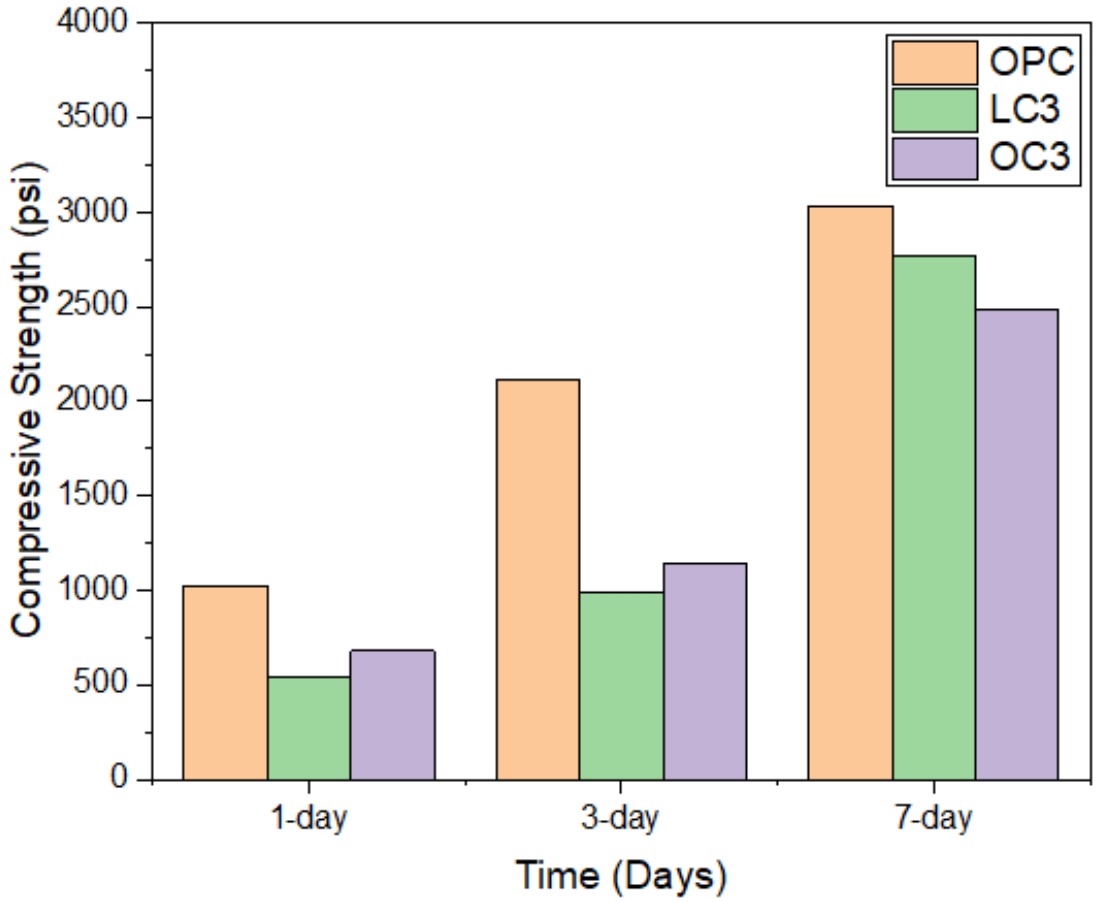
Mix Design

- OPC
  - Binder = 95% Clinker & 5% Gypsum
- LC3
  - Binder = 50% Clinker, 30% Calcined Clay, 15% Limestone, & 5% Gypsum
- OC3
  - Binder = 50% Clinker, 30% Calcined Clay, 15% Oyster Shell, & 5% Gypsum
- Mortar Mixes
  - Binder:1
  - Sand: 1.5
  - W/B: 0.40



Compressive Strength

- OPC is the strongest at each day
- 1 Day results show OPC hydrated the quickest
- LC3 & OC3 gained strength slower
- At 14 & 28 days expect OC3 & LC3 to be stronger than OPC



Conclusion

- Summary
  - Selected Clays
  - Performed TGA, PSA, XRF, & CST
  - Found large differences in 1-day strength between OPC and clay blends
  - Samples had similar strength as 7 days due to clinker particles being too large

- Further Work
  - Source more Clays
  - Conduct Activation Testing on Limestone and Oyster Shell
  - Monitor strength development at 14, 28, and 90 days
  - Conduct the durability testing
  - Research effectiveness of partially substituting Limestone with Oyster Shell

Funding Agencies:

LSU

Convention:

Louisiana State University

Thank you for your attention!

Andrew Callender, acall19@lsu.edu

Appendix

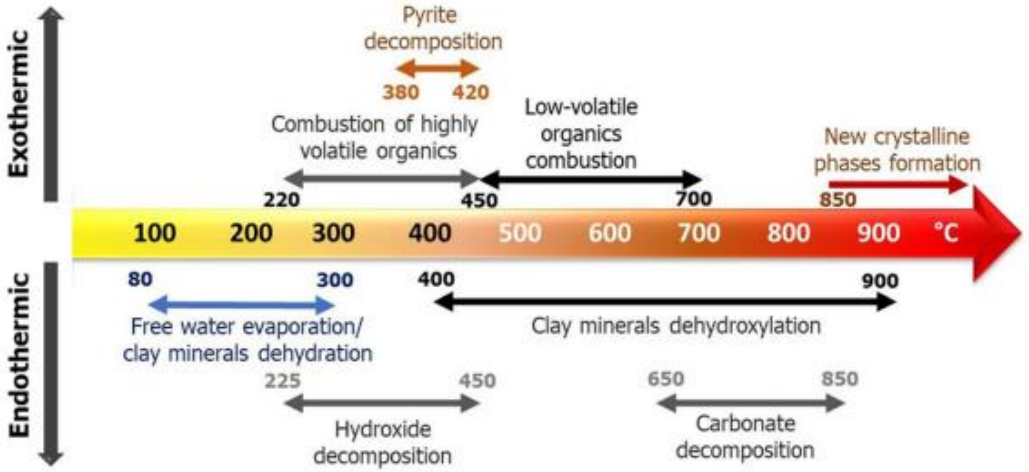


Fig. 1 Hanein, T., Thienel, KC., Zunino, F. *et al.* "Clay calcination technology: state-of-the-art" *Mater Struct* **55**, 3 (2022).

PSD (microns)

Sample	Clinker	Oyster Shell	Limestone	Clay
D_{10}	2.36732161	3.11982	5.72212	2.20399
D_{50}	25.17572288	27.9	29.3	9.6
D_{90}	85.0075504	116.2	71.1	38.9
Mean	37.1	44.2	35.1992	15.7