# Effective Clinker Replacement Using SCMs in Low Clinker Cements

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# Introduction

- » Global cement demand is set to quadruple by the year 2050[1] due to rapid urbanization and associated infrastructure development.

- » Cement industry is the major source of global anthropogenic $CO_2$ emissions.

- » Low clinker cements might be a potential solution!!!

[1] WBCSD Roadmap for Cement Industry

# Supplementary Cementitious Materials

» Fly ash, Slag, Calcined clay, etc are the common SCM used.

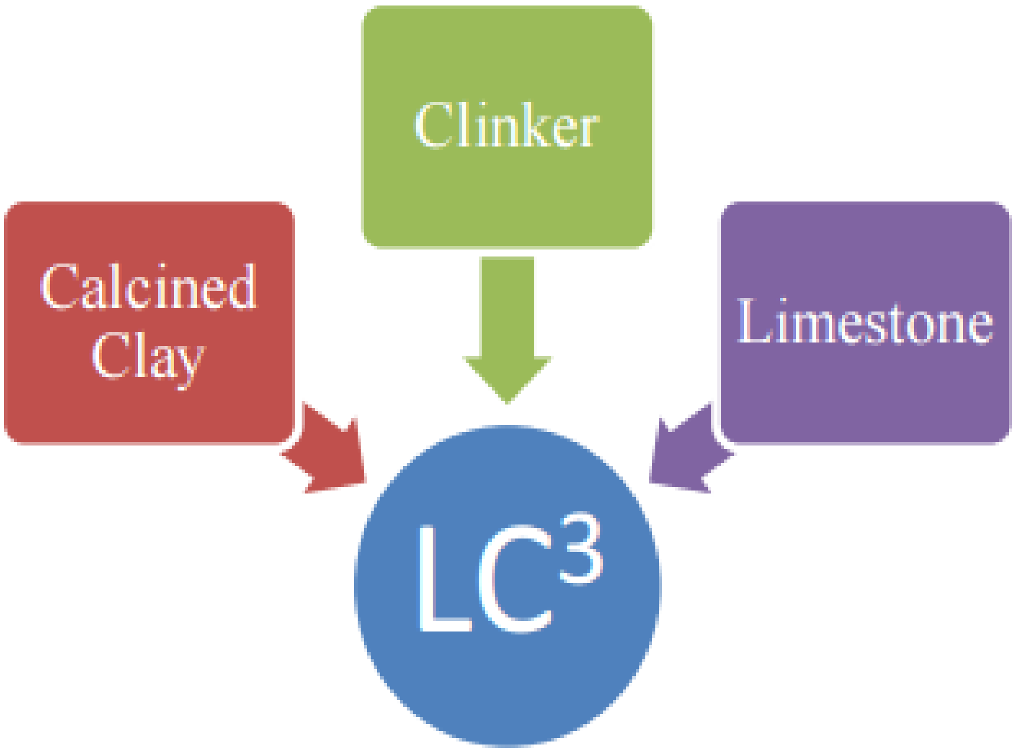
» The replacement levels possible by single SCM is limited

» Each SCM has its own advantages and disadvantages.

» A combination of SCM can be used exploit the synergetic effect

» Ternary cements can reduce the clinker factor up to 50%

# Limestone Calcined Clay Cement



# The Chemistry

» Limestone is known to react with the aluminate phase to form carboaluminates

» Carboaluminate phases are known to stabilize the ettringite phases thereby improving the volume efficiency.

» Metakaolin ensures greater early age strengths when compared to fly ash based PPC.

# Ternary Cement System

» Hydration products of ordinary Portland cement are well known

» Ternary cement systems are much more complex than OPC or PPC

» A detailed investigation is required in to the hydration chemistry of ternary cement blends

# Optimization of $LC^3$

- Thermodynamic modeling can help in the prediction of phases formed.
- However, it does not give information about rate of reaction or microstructure development.
- How to optimize such a complex system??

# Optimization of $LC^3$

» Volume efficiency could be a critical parameter in the design.

» Maximum volume efficiency of the reaction products

» Ensure that none of the raw materials will remain unreacted.

» Raw materials to be proportioned in such a way that reaction products with better space filling properties are formed.

# Optimization of $LC^3$ system

» Characterization of raw materials – using QXRD, TGA, XRF etc.

» Establishing the reaction stoichiometry of the hydration reaction – helps in the theoretical calculation of the volume of products and reactants.

» Verification and quantitative estimation of phases formed after hydration.

» Theoretical and experimental calculation of porosity.

# Optimization of LC$^3$ Blends

» Estimation of the total portlandite that can be produced from the system

$C_3S + 5.3\ H\ \text{->}\ CSH + 1.3\ CH$

$C_2S + 4.3\ H\ \text{->}\ CSH + 0.3\ CH$

» Metakaolin reacts with portlandite as shown below[2].

$AS_2 + 6CH + 9H \quad C_4AH_{13} + 2CSH$

$AS_2 + 5CH + 3H \quad C_3AH_6 + \quad 2CSH$

$AS_2 + 3CH + 6H \quad C_2ASH_8 + CSH$

[2] Murat, M., 1983

# Optimization of $LC^3$

- Formation of Carboaluminates

  $C_3A + C\hat{C} + 11H \rightarrow C_4A\hat{C}H_{11}$

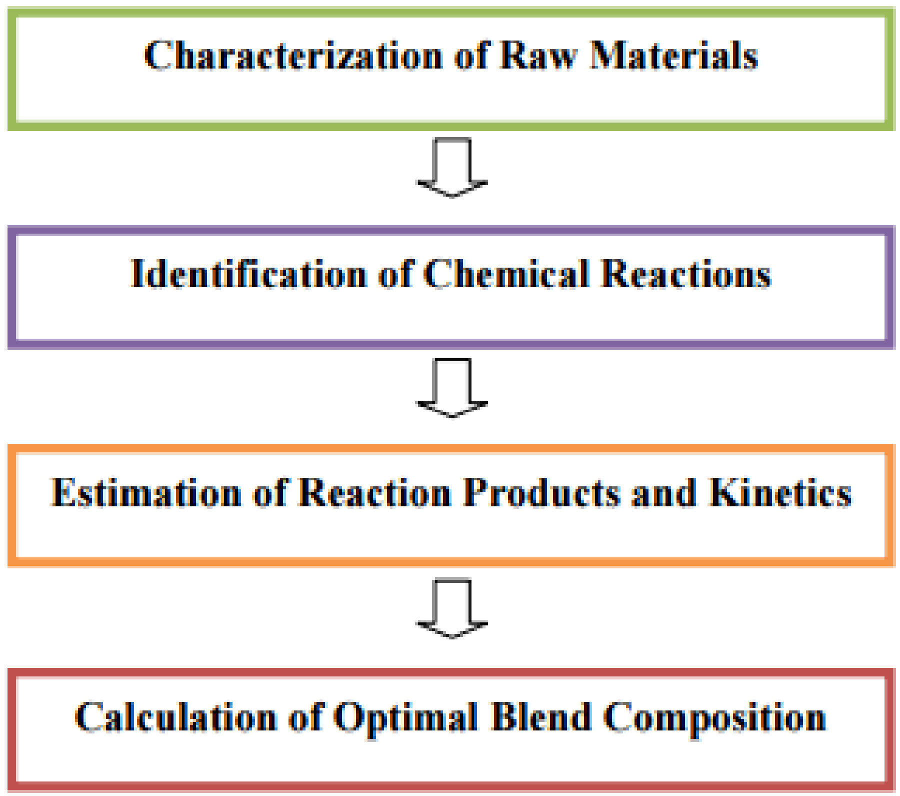
  $3C_4A\$H_{12} + 2C\hat{C} + 18H \rightarrow C_6A\$_3H_{32} + 2C_4A\hat{C}H_{11}$

  $C_3A + 0.5\ C\hat{C} + 11.5\ H + 0.5\ CH \rightarrow C_4A\hat{C}_{0.5}H_{12}$

- Estimation of degree of hydration will help in determination the phases formed at different time periods

- However distribution of microstructure cannot be determined.

# Framework for LC$^3$ Optimization



# Conclusion

- Cement chemistry of $LC^3$ is complex and not well understood.
- A detailed study in to the microstructure and hydration is required.
- Volume efficiency based approach could be a viable method for the optimal design of low clinker cements.
- Reduction of time from conception to implementation

# Thank You.

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