Rheological control enables printing of ultra lightweight cement composite for warmer climates

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ABSTRACT

- 3D printing has advantages such as customized production, reduced waste, and reduced lead-time of rapid prototype.
- 3D printing of ultra-lightweight cement composite containing cenospheres, white cement, and silica fume aims at solving problems in the cement industry.
- Cement mixture contains superplasticizers providing fluidity, cenosphere reducing thermal conductivity and silica fume sustaining strength. Meanwhile, typical ingredients for concrete remain unchanged, specifically cement and water.
- Rheological and structural characterization to obtain printable ink has been carried out to demonstrate the performance of this mixture in comparison to other available alternatives.
- As a result, the poly(carboxylate ether) based superplasticizer enables 3D printing of ultra lightweight cement composite and it offers a faster and more accurate construction with a decrease in the cost.

OBJECTIVES

Problems in cement industry:

- CO_2 emission in production
- Thermal conductivity
- Strength & durability
- Problems in workability

3D Printing offers:

- Faster and more accurate construction with potentially less waste
- A decrease in the amount of labor and consequently cost of labor
- Customization in design

- 3D printing of cement requires a special ink composition with modified rheological properties. To sustain the stability and to obtain printable material, chemical additives are used such as superplasticizer, cenosphere and silica fume.
- This study aims at finding the most optimum percentages of ingredients (cenosphere, silica fume, SP, cement, water) for the cement mixture to obtain a printable cement ink.

PROJECT DETAILS

Materials

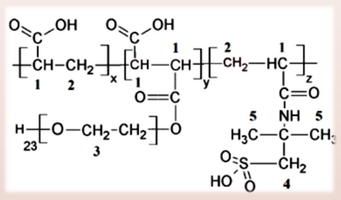
1) SUPERPLASTICIZERS :
Poly(carboxylate ether) derivatives

How do they disperse cement particles ?

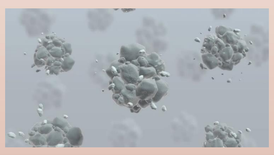
- **Electrostatic repulsion**
- **Steric hinderance**

As a result;

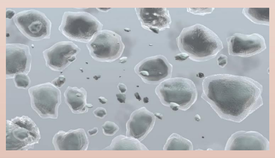
- ✓ *Increase in workability*
- ✓ *Increase in stability*



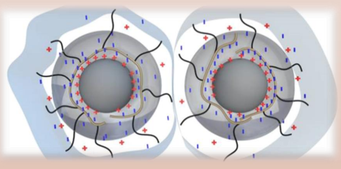
(Akhlaghi et al., 2017)



Aggregated cement particles, without superplasticizer.



Dispersed cement particles, with superplasticizer

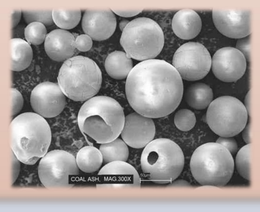


2) Ordinary Portland Cement

- Portland cement is the most common type of cement in general use around the world.
- White OPC was used to make the samples

3) Cenosphere

- Hollow spheres with strong shell
- Structural lightweight filler and workability enhancer
- Bulk filler
- Shrinkage reducer in cement grouts
- Decreased thermal conductivity



4) Silica Fume

- Spherical particles finer than 1 μm
- High compressive strength
- Increased toughness
- High electrical resistivity
- Low permeability and resistance to chemical attacks

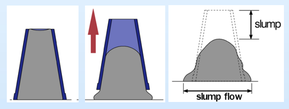
PROJECT DETAILS

The characterization of composite

	w/b	Water	OPC	Silica Fume	Cenospheres	SP
		g	g	g	g	g
LCC1	0.4	30.5	45	0.93 (1.25%)	30	0.75 (1%)
LCC2	0.4	30.5	45	0.93(1.25%)	30	0.9 (1.2%)
LCC3	0.4	30.5	45	0.93(1.25%)	30	1.125 (1.5%)
LCC4	0.4	30.5	45	1.5 (2%)	30	0.9 (1.2%)
LCC5	0.4	30.5	45	2.25(3%)	30	0.9 (1.2%)

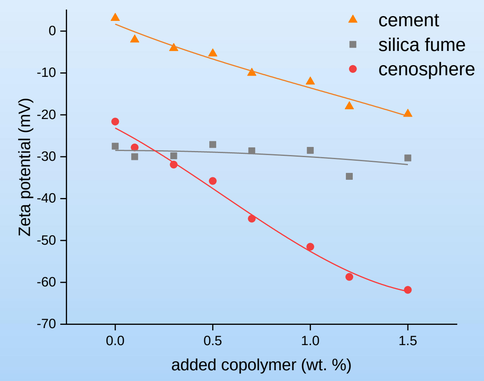
Mix proportions of lightweight cement composites (LCC)

Fluidity test

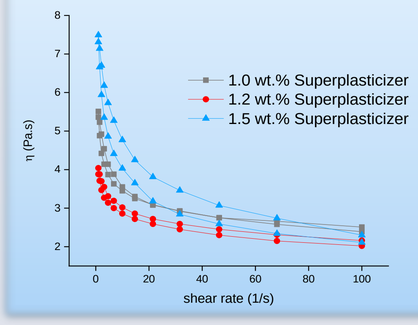


Added copolymer wt. %	Slump flow diameter (mm)
0	57.5
0.75	140
1	145
1.2	165
1.5	160

Electrokinetic characterization

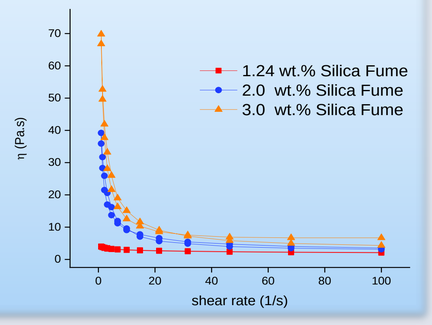


Rheological characterization

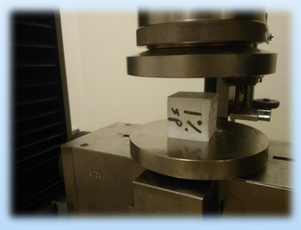


Non-Newtonian Fluid,
Shear thinning fluid

- ✓ *Yield Stress*
- ✓ *Plastic Viscosity*
- ✓ *Shear Stress*

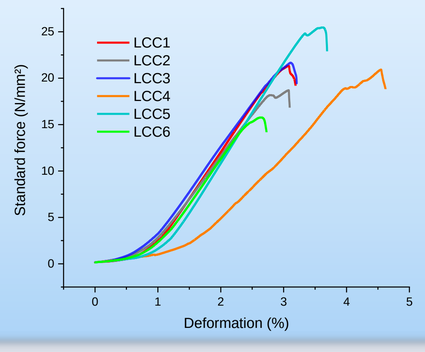


Compressive Strength Test



The lightweight cement composite cubes rested 7 days in the environment with constant temperature and humidity.

After 7 days, the cubes are tested with UTM for the compressive strength test.



CONCLUSION

- Structural characterization demonstrates that the addition of polymer increases slump flow diameter, confirming increase in fluidity and dispersion of molecules.
- Electro kinetic characterization indicates that the zeta potential of cement particles decreased to negative values from ~+1 mV confirming the adsorption of polymers
- Decrease in viscosity with increasing shear rate is revealed by rheological characterization. This type of behavior is called shear-thinning. Adding more silica fume increases viscosity.
- Increasing the load capacity is greatly related to silica fume. After addition of a certain amount, the composite turns into brittle structure
- An alternative superplasticizer added lightweight cement composite enables 3D printing of concrete which offers a faster and more accurate construction with a decrease in the cost while having greater load capability among 3D printing lightweight cement mixtures in the literature.

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