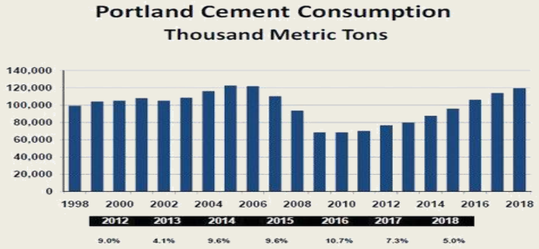
Low Cement Concrete (LCC) as a sustainable solution for Civil Industry

By : Othman Benamrane , Undergraduate Student
Supervisor : Dr. Leandro Sanchez
University of Ottawa, Department of Civil Engineering

Introduction

- The cement production is responsible for a large part of the global CO2 emissions (≅5%)
- Each year the use and the demand for cement products by the Civil Industry continues to grow
- In a standard mix design of concrete, the amount of Portland cement used is between 400 to 500kg/m^3
- For this, the construction industry in civil engineering is obliged to adopt sustainable strategies to reduce its dependence on cement.
- Using Packing model theories lead to reduction in the cement content by improving aggregates skeleton packing
- The purpose of this research is to investigate the effect of reducing the cement content with aggregate fillers on the properties of packing model designed concrete



(PCA Forecasts 2016)

Preliminary Research and Results

Theoretical Background

- Alfred continuous packing model was used to find the best aggregates distribution in the mix

$$CPFT = \left(\frac{d - d_0}{D - d_0}\right)^q * 100\%$$

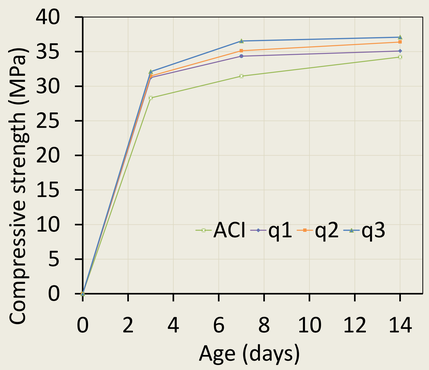
q : Factor represents the distribution coefficient
d_0: Minimum particle size
d : Average particle size being analyzed
D : Maximum particle size
CPFT : The cumulative volume percent finer

Methodology

- Packing models method has shown that is possible to design concrete in which the cement content is reduces by a significant amount
- Three q factors (0,26, 0,31 and 0,37) were selected based on the CPFT equation
- Different properties of the hardened state of the concrete were used to compare and choose the q factor with the best performance

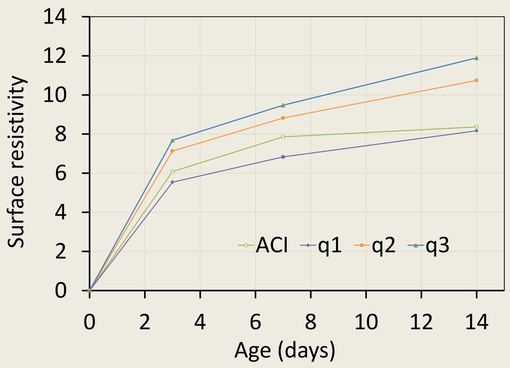
q-value	Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Course Aggregate (kg/m^3)	W/C	Bi Factor
Absolute volume method	380	797	1024	0,47	10,86
q1=0.26	401	814	1007	0,47	11,46
q1=0.31	341	808	1132	0,47	9,74
q3=0,37	277	789	1285	0,47	7,91

Results



Compressive Strength
- There is no significant difference in strength for the different q values
- q3 reached the wanted strength faster

External resistivity
- The q3 factor had a higher surface resistivity
- q3 can perform better as a cover



Best q Factor
- q3=0,37 has shown the best performance in term of all hardened state properties
- It was possible to reduce the cement content by 31% (270kg/m^3 for 400Kg/m^3)

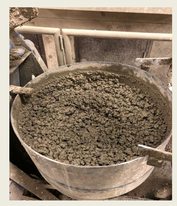
Research Improvement

- Aggregate fillers have been used to reduce the cement content and to improve the workability of regular concrete mixtures
- In this research 15% of cement was replaced by fillers in the concrete mix prepared using packing model with a factor of q3 = 0,37

Cement (kg/m^3)	Filler (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	W/C	Bi Factor
235	42	789	1285	0,47	6,7

Material and Preparation

- The fine/coarse aggregates were sieved to obtain the different sizes required
- The filler used (< 100 µm) was obtained by crushing Limestone coarse aggregates

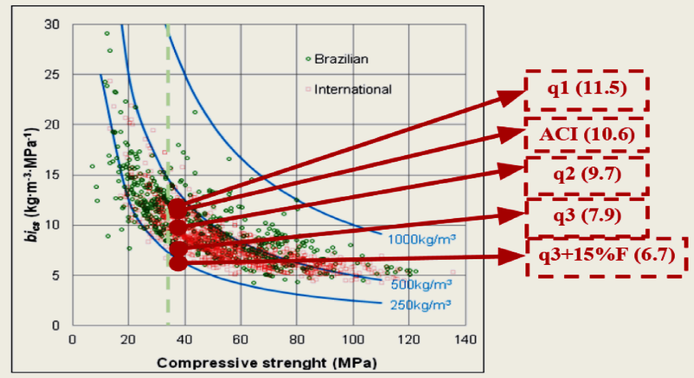


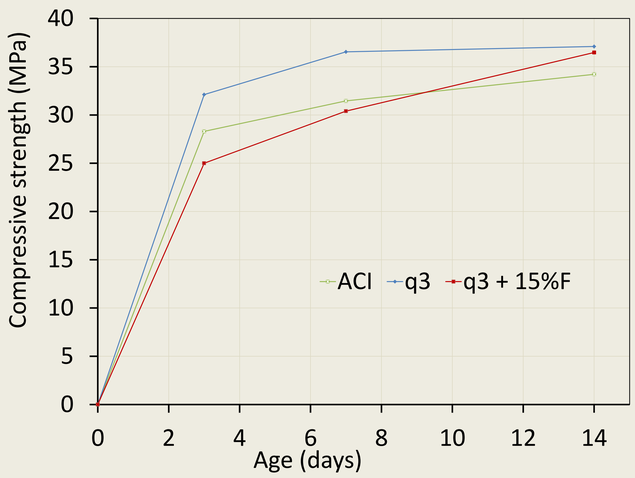
- 17 cylinders were casted to conduct the tests

Experimental Results and Discussion

Binder Efficiency

- The binder intensity allows measuring the amount of binder necessary to deliver a unit of Strength
- The use of the filler has permitted the reduction of cement content used by industry standard by an additional 15% (46% in total ; 235kg/m^3 for 400Kg/m^3)
- No SCM's, ad-mixtures, or other type of binder reducing agents were used



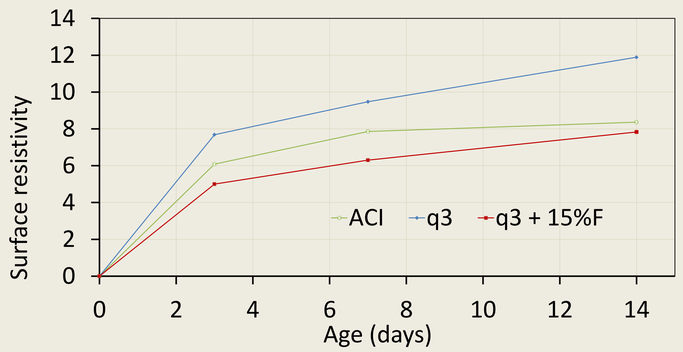


Compressive Strength

- At 3 days and at 7 days the q3 + filler showed lower strength values than q3
- Both mixes q3 and q3+filler reached the desired strength in the 14 days test.
- It is expected that the combination between the packing model and the filler results in an extra ±5MPa in the total strength (±40Mpa)

External Resistivity

- The use of the filler has decreased the surface resistivity of the q3 mix
- It is possible that the q3+filler mix will reach a higher external resistivity than ACI at 28 days



Conclusion and Further researches

- Packing models allowed the reduction of the cement content and the improvement of concrete performance.
- Replacing cement with fillers improved significantly the binder efficiency of concrete
- .The performance in term of compressive strength was good but the surface resistivity was higher without the adding of fillers
- The effect of fillers on the performance of packing model concrete can be improved by Investigating the rheological aspect, testing different fillers percentages and adding SCM's and chemicals

Acknowledgment

I would like to thank UROP for making this research possible. Special thanks for Dr. Leandro Sanchez for this opportunity. I would also like to acknowledge Sami Abu Shammeh and Derick Asirvatham for their well appreciated help and support.