

# Low Cement Content Concrete (LCCC) as a Sustainable Solution for Civil Industry



By: Sami Abu Shammeh , Undergraduate Student  
 Supervisor: Dr. Leandro Sanchez  
 Department of Civil Engineering, University of Ottawa



uOttawa

## INTRODUCTION

- Pressure is mounting in civil construction industry to adopt more environmentally sustainable methods to reduce CO<sub>2</sub> emissions as a result of cement production
- It is Important that the concrete industry considers its carbon footprint amongst increasing demand and tightening environmental restrictions
- A method to mediate this impact is low cement content concrete (LCCC)
- LCCC increases binder efficiency of cement
- Binder efficiency is strength developed per binder mass unit
- The binder efficiency could be improved by decreasing the amounts of Portland cement, since it typically amounts to (400-500kg/m<sup>3</sup>) in standard mix designs
- Packing model theory is based off the idea of enlarging the particle size distribution/grading of the aggregates in concrete
- Using packing model theories could lead to reduction in the cement content by improving aggregates skeleton packing
- Improving skeleton packing in concrete may affect other properties

## RESEARCH SIGNIFICANCE

- This project aims to analyze the behaviour of concrete mixtures designed with the use of Alfred continuous packing model.
- Three q factors selected and fresh properties (i.e. slump test) and hardened state (i.e. compressive strength, Ultrasonic pulse velocity, electrical bulk resistivity & surface resistivity) are analyzed.
- Comparisons are made between the different mixes and with conventional concretes used in the market.
- Discussions about the possibility of using low cement content concrete systems for structural applications is appraised.

q-value	Cement (Kg/m <sup>3</sup> )	Fine Aggregate (Kg/m <sup>3</sup> )	Course Aggregate (Kg/m <sup>3</sup> )	W/C	Bi Factor
q1 = 0.26	401	814	1007	0.47	11.46
q2 = 0.31	341	808	1132	0.47	9.74
q3 = 0.37	277	789	1285	0.47	7.91
Absolute Volume Method	380	797	1024	0.47	10.86

## EXPERIMENTAL INVESTIGATION

- Three 35MPa concrete batches representing different q factors; 0.26, 0.31 and 0.37 The q factors were selected based on the CPFT equation.
- Performance as cover against corrosion is studied
- The structural capabilities will also be studied after producing the highly packed low cement sustainable concrete.

## ALFRED MODEL

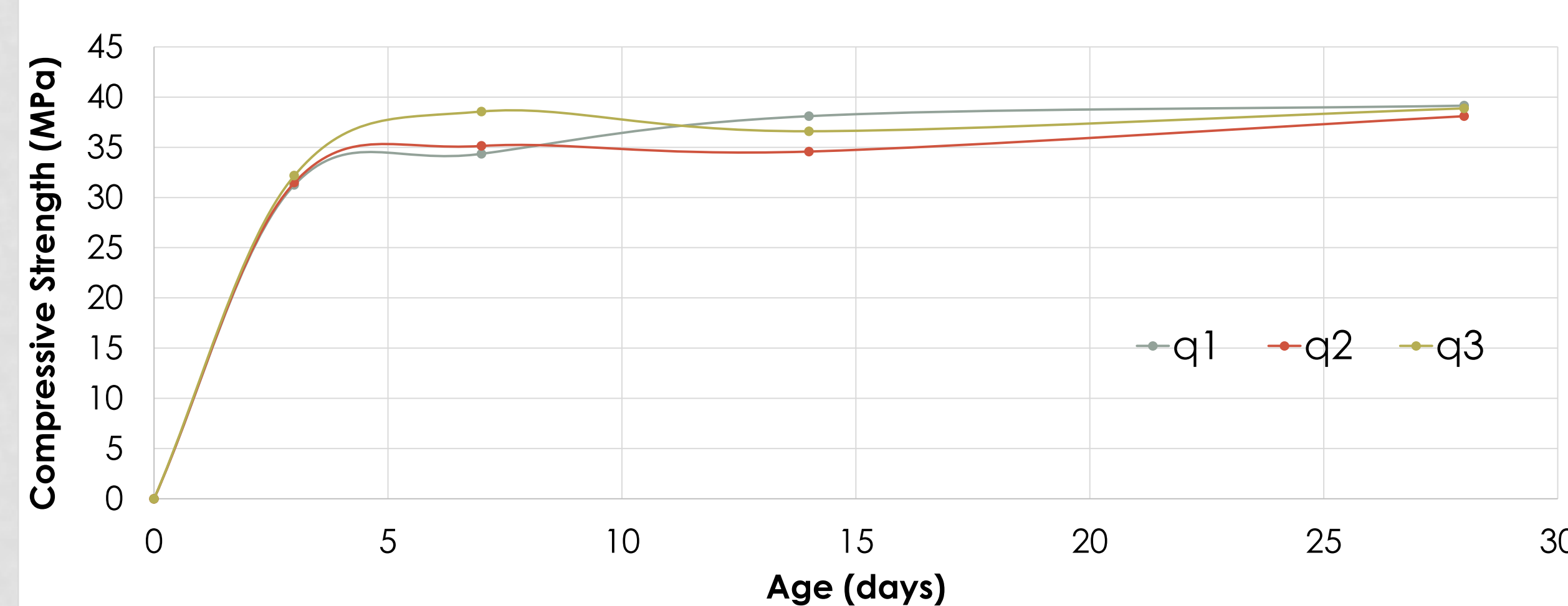
- Goal is to develop more sustainable concrete by decreasing the cement content while maintaining the mechanical properties.
- As the q factor increases, amount of fine particles decreases

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

- q factor represents the distribution coefficient
- d<sub>0</sub> is the minimum particle size
- d is the average particle size being analyzed
- D is the maximum particle size
- CPFT is the cumulative volume percent finer

## EXPERIMENTAL RESULTS & DISCUSSION

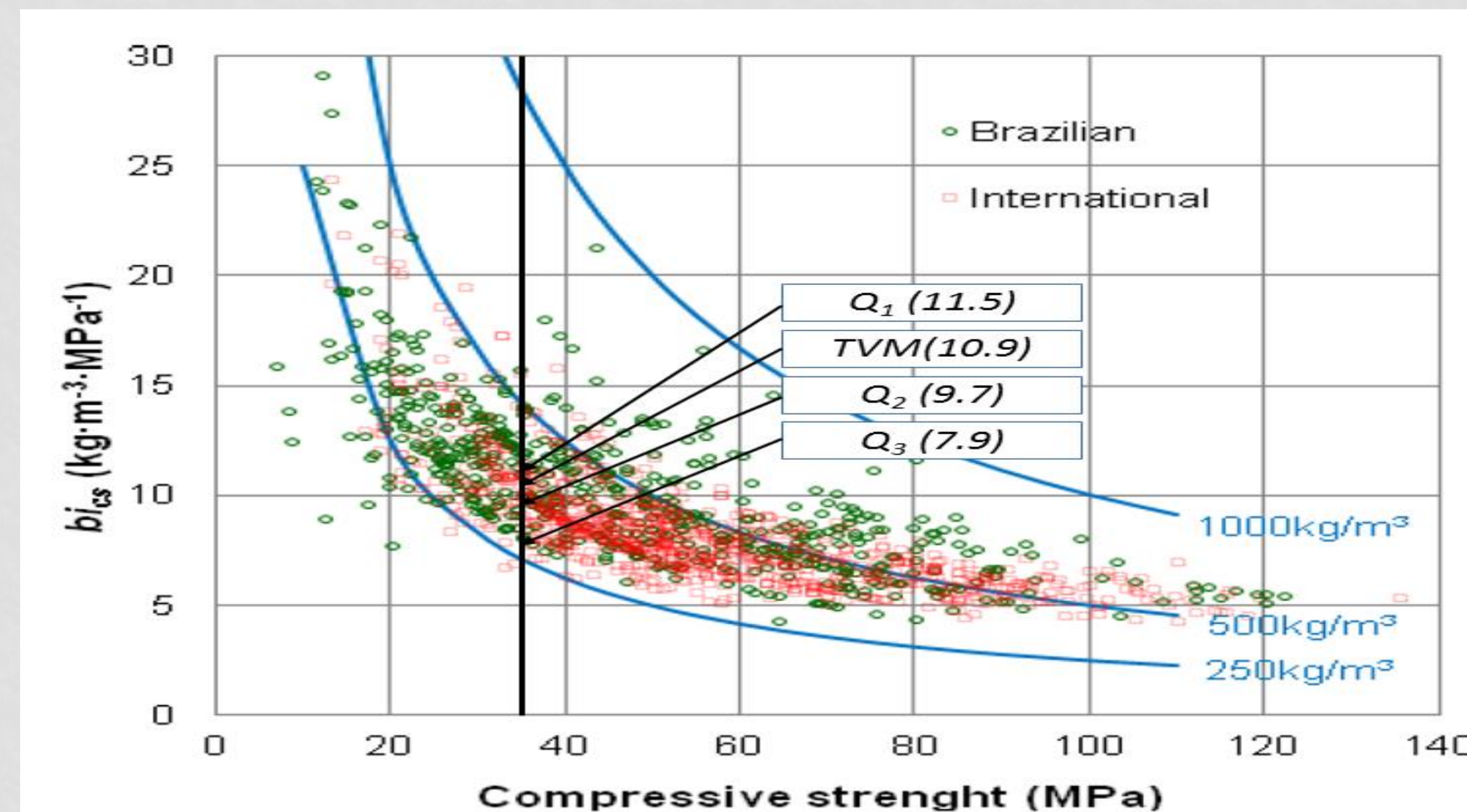
### COMPRESSIVE STRENGTH



- No significant change in strength from different q values
- q3 reached strength faster
- All values of q performed equally well
- Less cement was used for q3



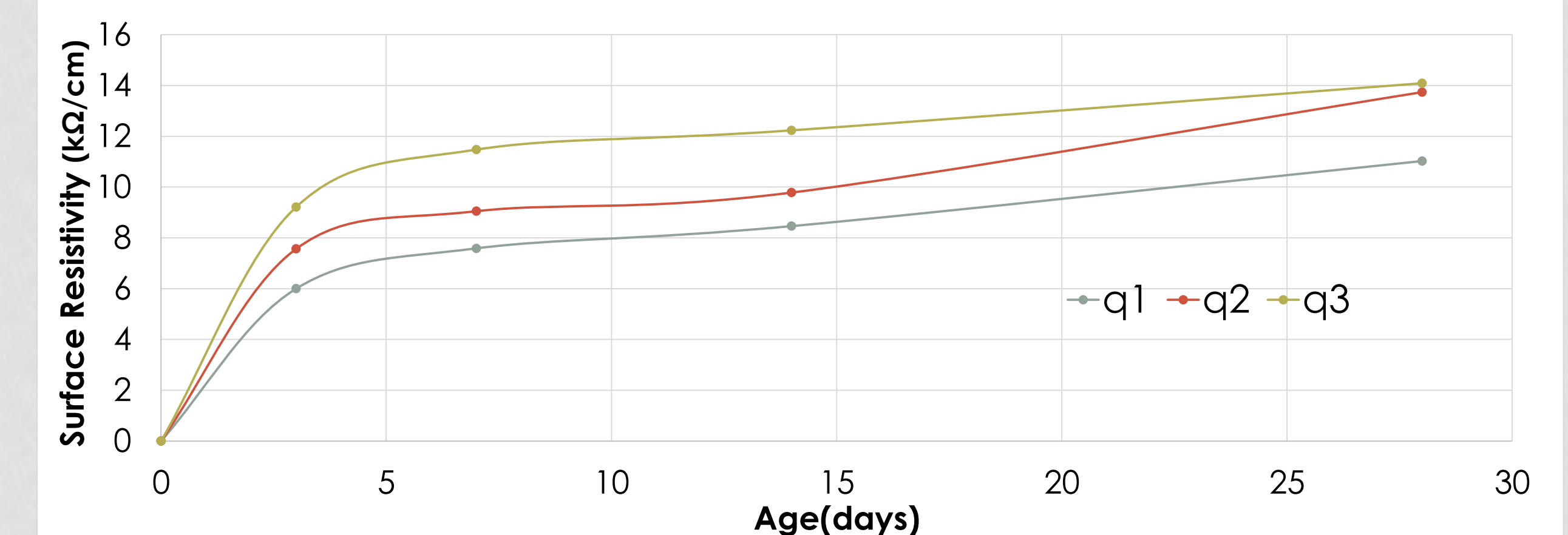
### BINDER EFFICIENCY



- Graph based on the International and Brazilian binder efficiency vs compressive strength
- The q3 factor of 0.37 is well below industry standards
- No SCM's or ad-mixtures were used
- The results were obtained without the use of any other type of binder reducing agents.



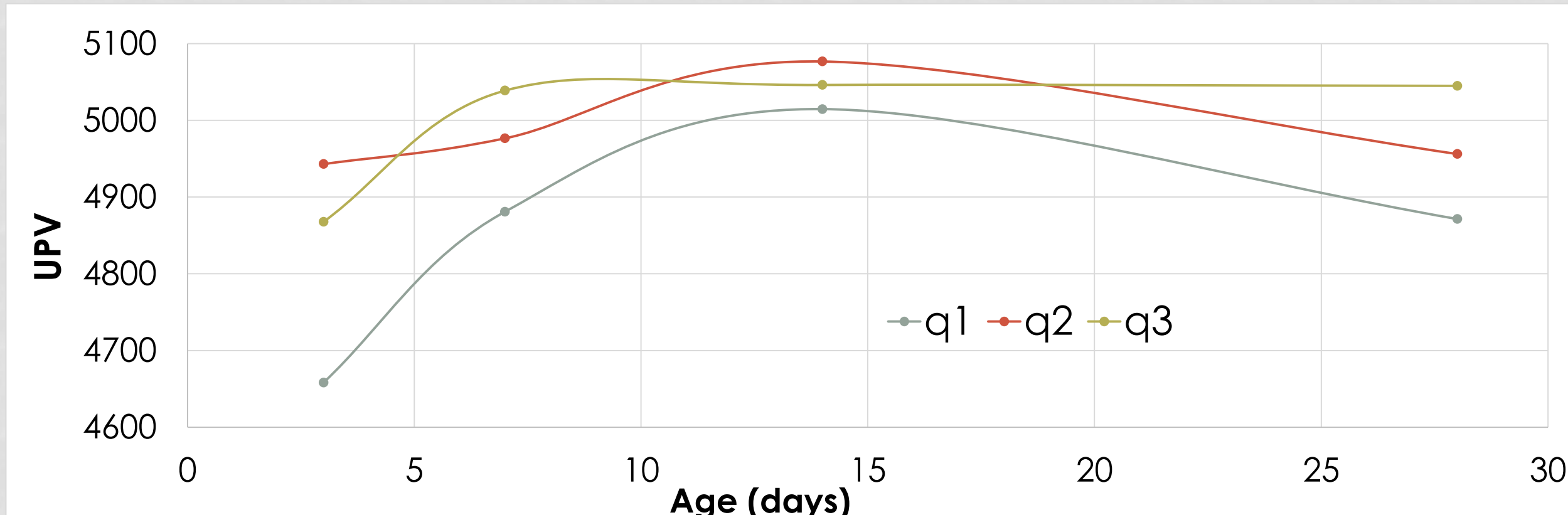
### EXTERNAL RESISTIVITY



- The q3 value had a higher surface resistivity
- q3 could perform better as cover
- lowest porosity based on Alfred Model
- More porous concrete tends to allow corrosion in the reinforced steel rebar faster than less porous concrete



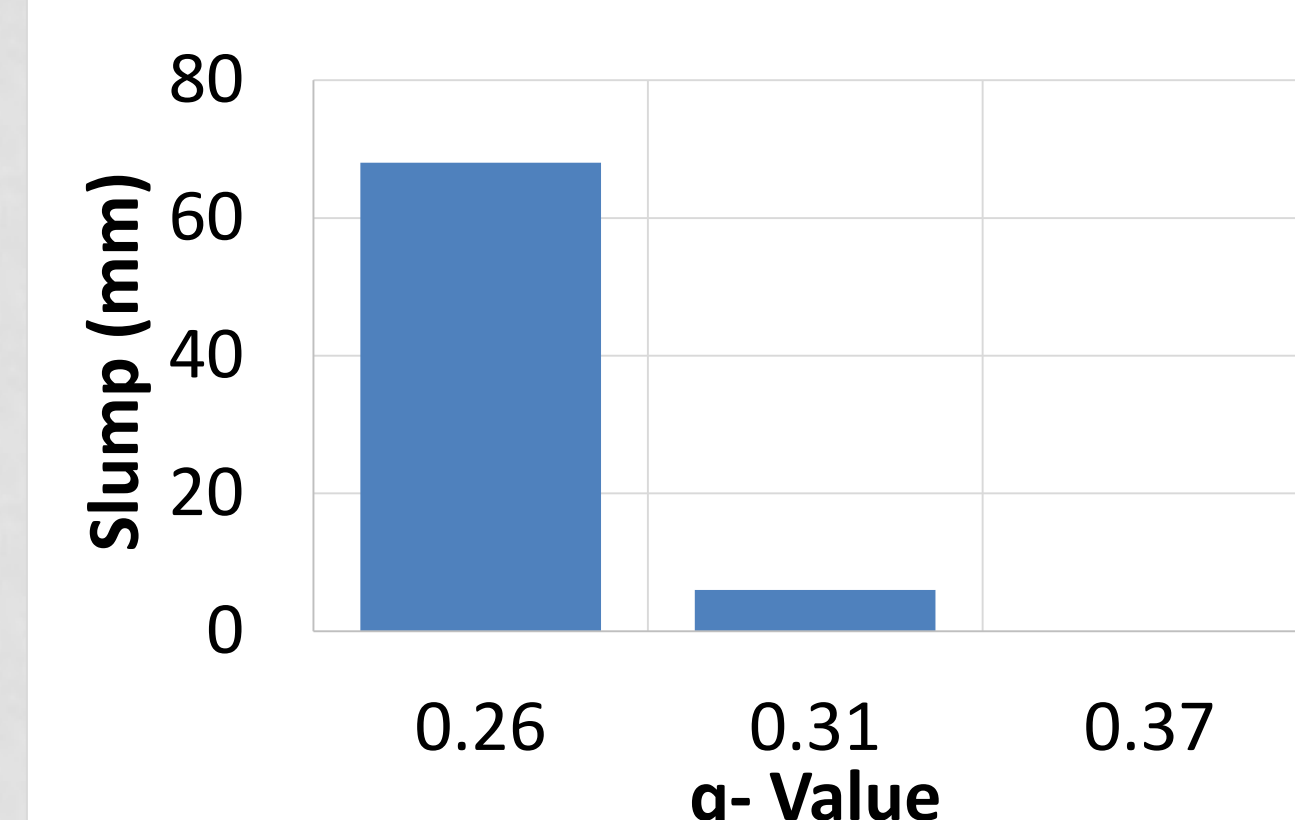
### ULTRASONIC PULSE VELOCITY



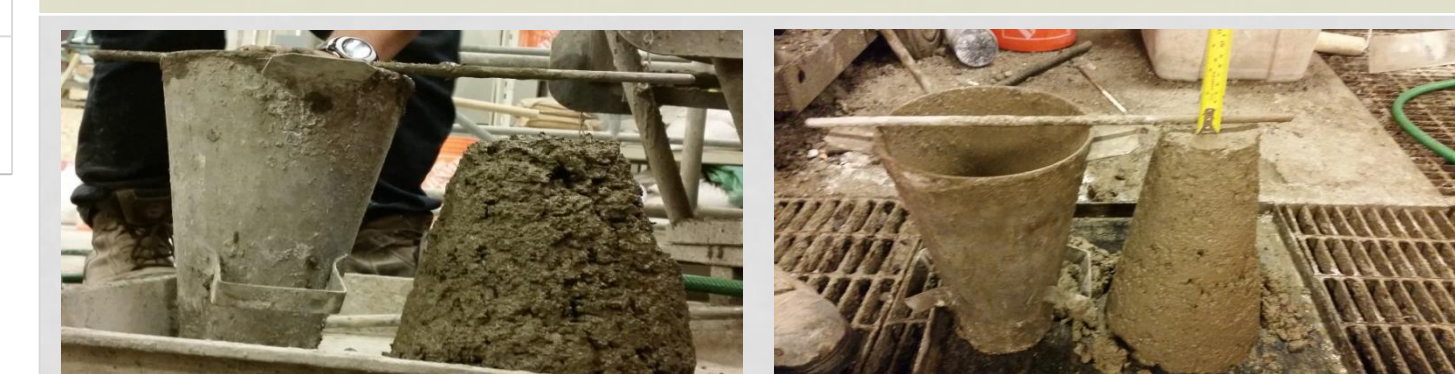
- Except for 14 day mark, q3 higher UPV throughout
- All q factors had excellent quality concrete
- Less voids, tighter packing
- Can relate UPV to voids since there is no cracking



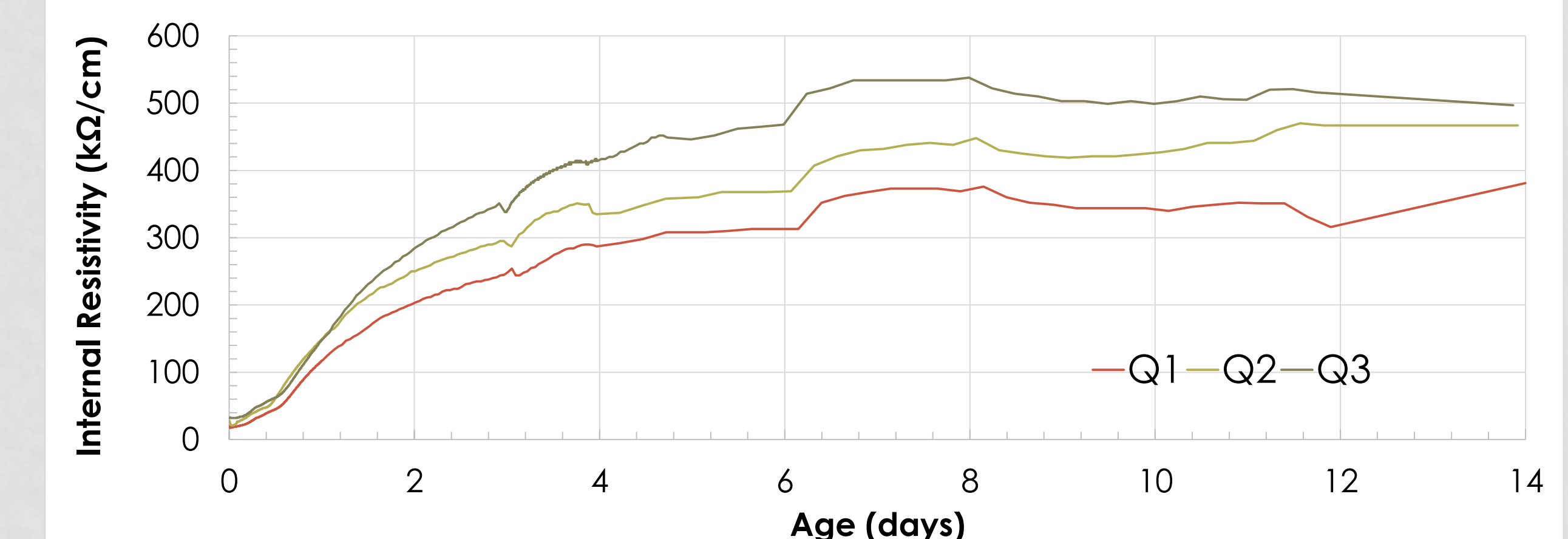
### SLUMP & WORKABILITY



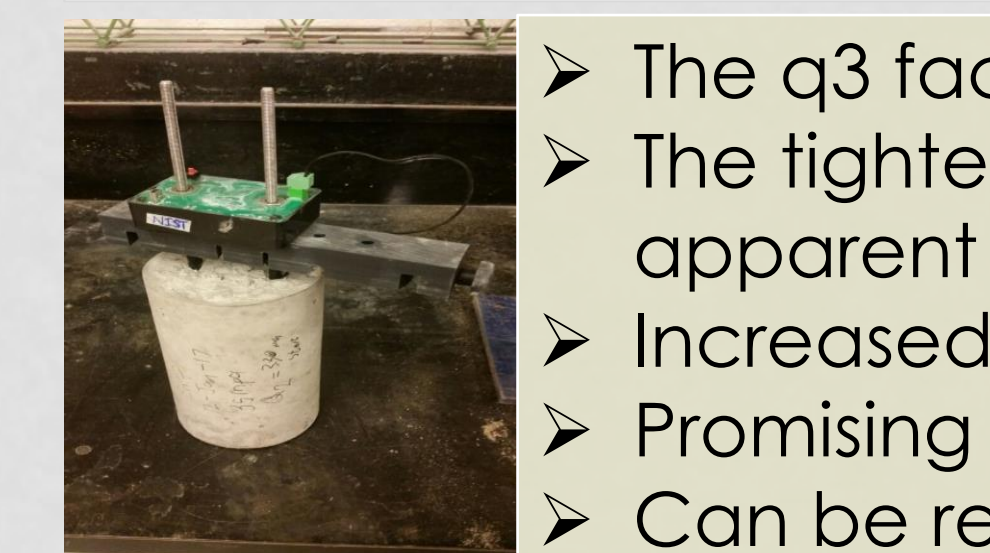
- q3 had limited workability
- q1 had 69mm of slump and adequate workability
- Special attention should be taken to the fresh state of the q3 material.



### INTERNAL RESISTIVITY



- The q3 factor had a higher resistivity throughout
- The tighter the skeleton packing, the less the apparent the voids
- Increased resistivity from tighter packing
- Promising results for use as concrete cover
- Can be related to decrease of voids in final product



## CONCLUSION & FURTHER RESEARCH

Based on the results of this experimental investigation, the following conclusions are drawn:

- The use of packing models seems to enable the development of low cement content systems with interesting performance and low bi factors.
- The use of continuous packing models and different distribution moduli seem to improve both mechanical and durability related properties, but Special attention should be taken in well packed mixtures in the fresh state.

Based on the data obtained from these preliminary results, fillers, chemicals and SCM's will be used in order to enhance the properties of the mixtures studied in this project, especially in the fresh state, as well as further reduce cement content. Rheological measurements will also be performed in order to fully characterize the fresh state behaviour of concrete design. Moreover, durability-related studies will be carried out to understand the long term performance of LCCC systems.

## ACKNOWLEDGEMENTS

This research was made possible with funding provided by the UROP Scholarship. Special thanks to Dr. Leandro Sanchez for supervising this project. I would like to thank Derick Asirvatham and Saif Youssef for their collaborative efforts. I would also like to acknowledge the immense help by Giatec Scientific for the testing devices, and Lafarge Canada for the complimentary aggregates.