THE BIG 5 SAUDI

Co-located with: HVAC R EXPO SAUDI · FM EXPO SAUDI Facilities Management Solutions · STONE & SURFACE SAUDI ARABIA المملكة العربية السعودية

Introducing: WINDOWS DOORS & FACADES EVENT SAUDI · SAUDI GLASS

18 – 21 FEBRUARY 2023

RIYADH FRONT EXHIBITION AND CONFERENCE CENTER (RFECC)

Fillers’ Scientific applicability toward a Carbon-Neutral Concrete

Saad Bin Howimal (MEngSc, Ph.D)

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

مدينة الملك عبدالعزيز للعلوم والتقنية KACST

King Abdulaziz City for Science and Technology

www.thebig5saudi.com

Content

- Background and Motivation
- The Research Mechanism
- Multi-size fillers
- Technical and Non-Technical Concrete Performance
- Conclusions

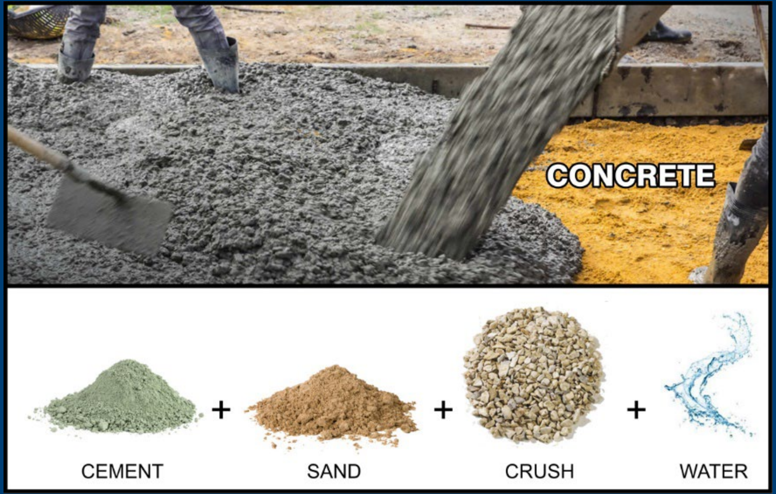
Concrete

- Concrete is the world's most used construction material

- According to GCCA, around 14 billion cubic meters of concrete are cast each year

- Cement clinker is produced at around 1400°C huge energy consumption

- Ordinary Portland Cement (OPC) production phases is the source of about 8% of annual global CO_2 emissions



Sustainability in Concrete

- Concrete is an intensive global greenhouse gas (GHG) emitter due to its inclusion of cement binder
- The concrete industry wants to be carbon neutral by 2050, 50% less emission by 2030
- For every tonne of cement produced there is a tonne equivalent of CO_2 released in the atmosphere
- To achieve the sustainable development goals of the United Nations we should:

Reduce raw material consumption

Recycle into environmentally friendly products

Reuse construction waste to free up landfill space

Pathways to net-zero emissions by 2050

- Using alternative or non-CO_2 emitting fuels for clinker production
- The use of pozzolanic and inert fillers to partially replace OPC in high-performance concrete (HPC)
- Designing concrete mixture by particle packing and Aggregate optimization

- Curing HPC by injecting a liquefied recycled carbon dioxide and storing it into concrete
- Type IL Cements Portland Limestone Cements (PLC)

High-Performance Concrete

- low water/cement ratio
- Superplasticiser admixture addition
- Well-graded aggregate; plenty of intermediate particles
- Use of microfine fillers and supplementary cementitious materials (SCM)

All to achieve,

High workability

Low-heat of hydration generation

High strength concrete

Low permeability

Low shrinkage

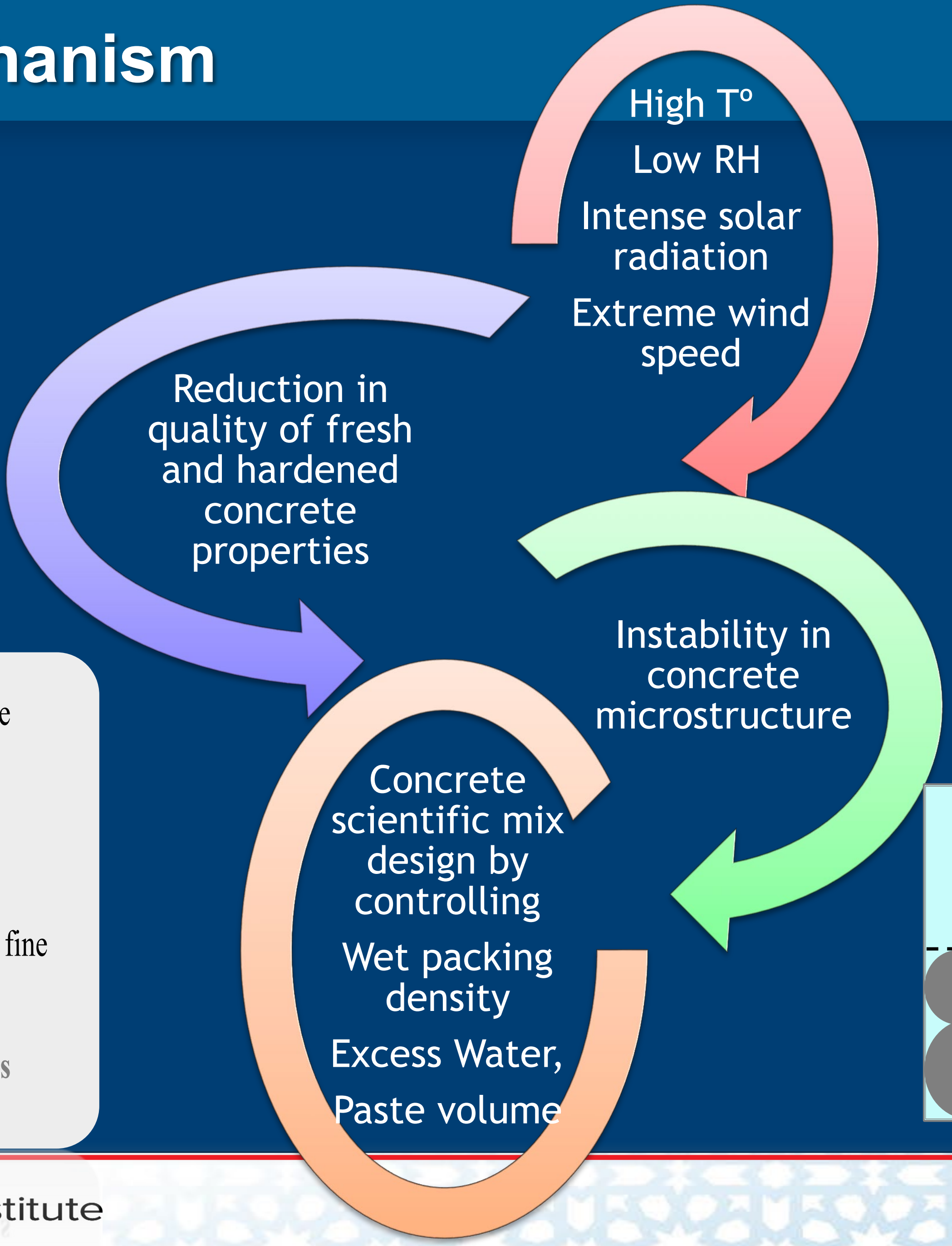
Motivation of the Research

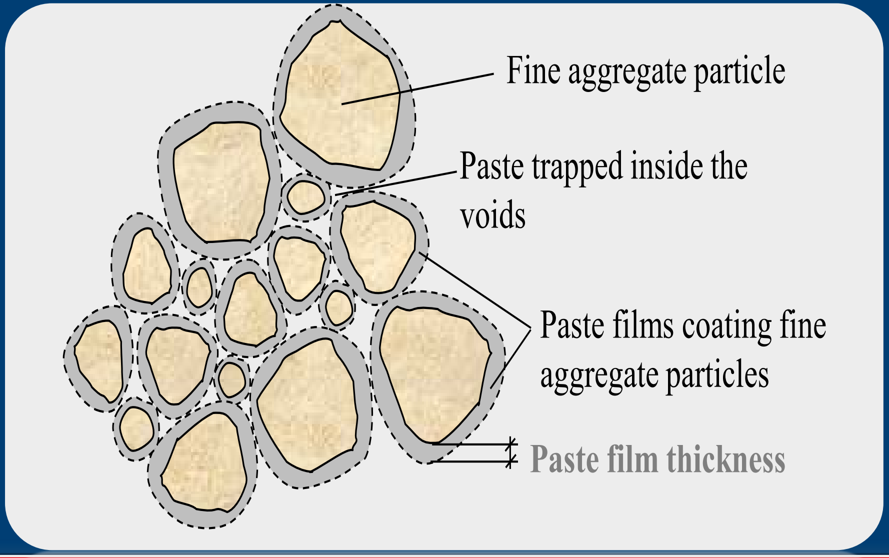
- To produce **low-carbon footprint and high-performance concrete**
- Replacing part of the cement with environmentally friendly filler materials in the composition of HPC
- In HPC, water is low → not all cement particles hydrated → un-hydrated cement act as a filler

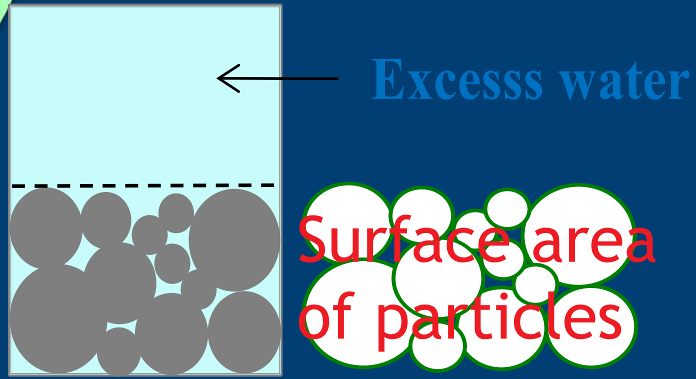
Cementitious and non-cementitious Fillers that can:

- Cut concrete mix design materials cost
- Reduces carbon dioxide emissions
- Save the energy to produce cement clinker
- Improve fresh and hardened concrete properties

The Research Mechanism







Type IL Cements
Portland Limestone Cements (PLC)

- 10% Reduction in CO_2 emissions from cement plants,
  10% Reduction in concrete's carbon footprint
  by switching from OPC to PLC without affecting performance or durability
- Governed by ASTM C595 Standard Specification for Blended Hydraulic Cement
- Match's the performance of ASTM C94 for ready mixed Concrete
- Effective with SCM, such as fly ash, slag and microsilica
- Permitted by ACI 318 Building Code for Structural Concrete
- Australian standard allow up to 20% to be added with blended cement

CHEMICAL AND ANALYTICAL DATA
Mean Values. These Do Not Represent A Specification

Mean Percent by Weight		(UAL 8.5)	
Total Calcium as	($CaCO_3$)		99.0
Total Magnesium as	($MgCO_3$)		0.6
Silica	(SiO_2)		0.2
Ferric Oxide	(Fe_2O_3)		<0.1
Alumina	(Al_2O_3)		<0.1
Specific Gravity		UAL 2.13(b)	2.71
Bulk Density (compacted)	(g/cm^3)	UAL 2.10(a)	1910
Bulk Density (loose)	(g/cm^3)	UAL 2.10(a)	1350

Why Limestone filler

- Limestone powder acts as an accelerator during early cement hydration (Nucleation) due to formation of additional carbo-aluminate hydration product

- Limestone particles size and specific surface area (SSA) is finer than cement (broaden PSD)

- Inactive filler to replace cement – reduces cementitious paste volume (CPV) (Low heat of hydration) (low cracks)

- Denser particle packing effects (space filling): voids ↓

  performance ↑

Applications of PLC

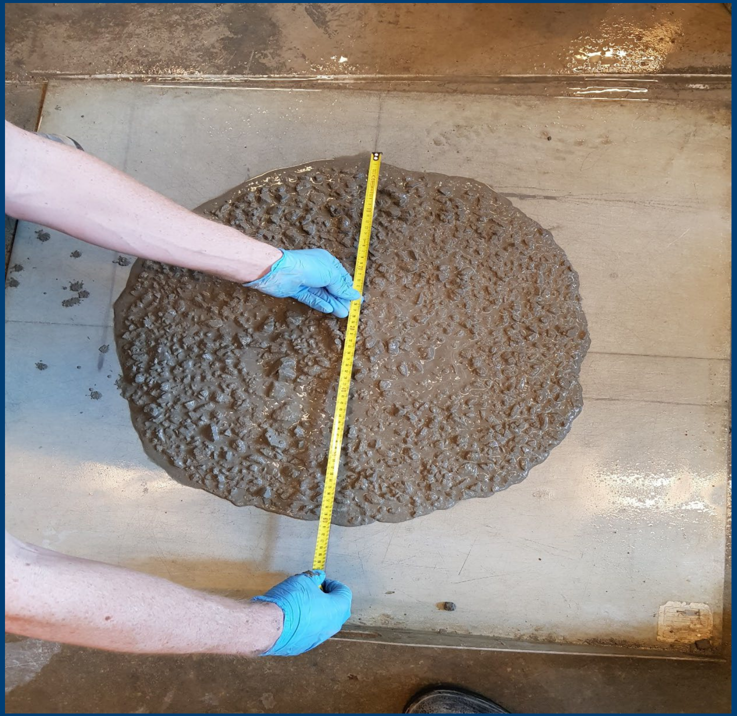
- PLC concrete pavements
- Transportation infrastructure
- Bridge deck
- Foundation
- Geotechnical work
- Structural members in any type or size of building
- Exterior finishes
- Hardscaping
- Parking lots.

Technical Concrete performance tests

STATE OF CONCRETE	PERFORMANCE PROPERTY	TESTS TYPE
Fresh properties (Rheological)	Workability and flowability	Slump flow test
	Passing ability	L-box test J-ring test
	Segregation stability	Sieve segregation
Hardened properties (Mechanical)	Strength	Compressive strength
	Drying Shrinkage (volume stability)	Length changes of concrete specimens

Concrete performance tests

L-box test

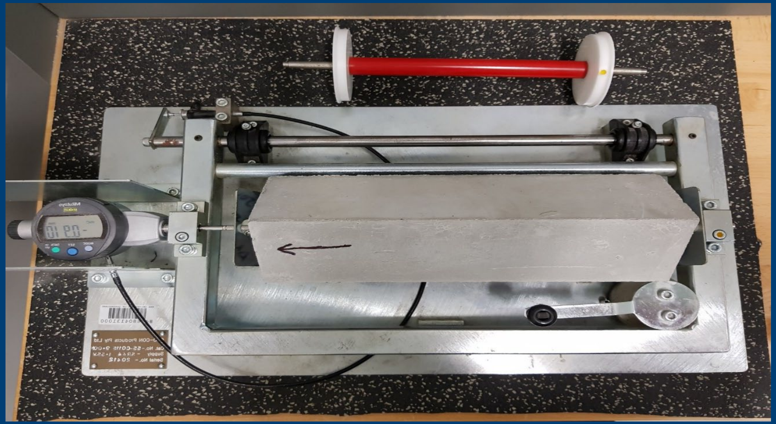


Slump flow test

Sieve segregation Test

Compressive Strength Test

Drying Shrinkage Test

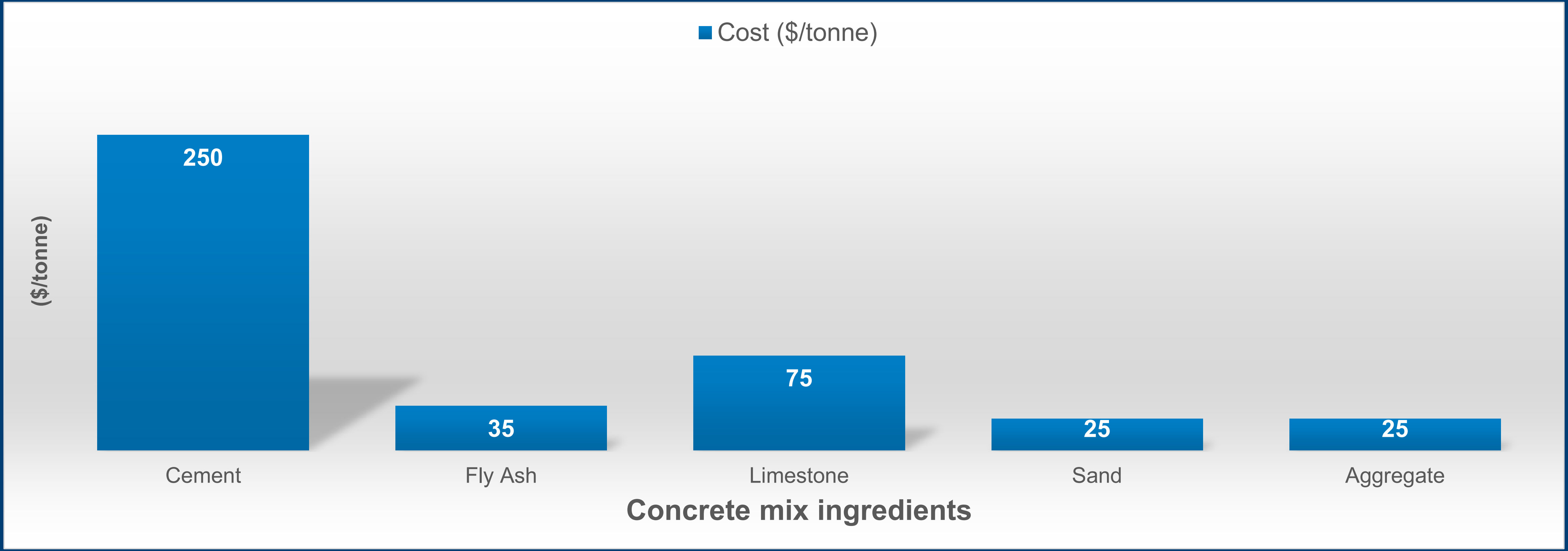


Test results- Strength development and Drying shrinkage

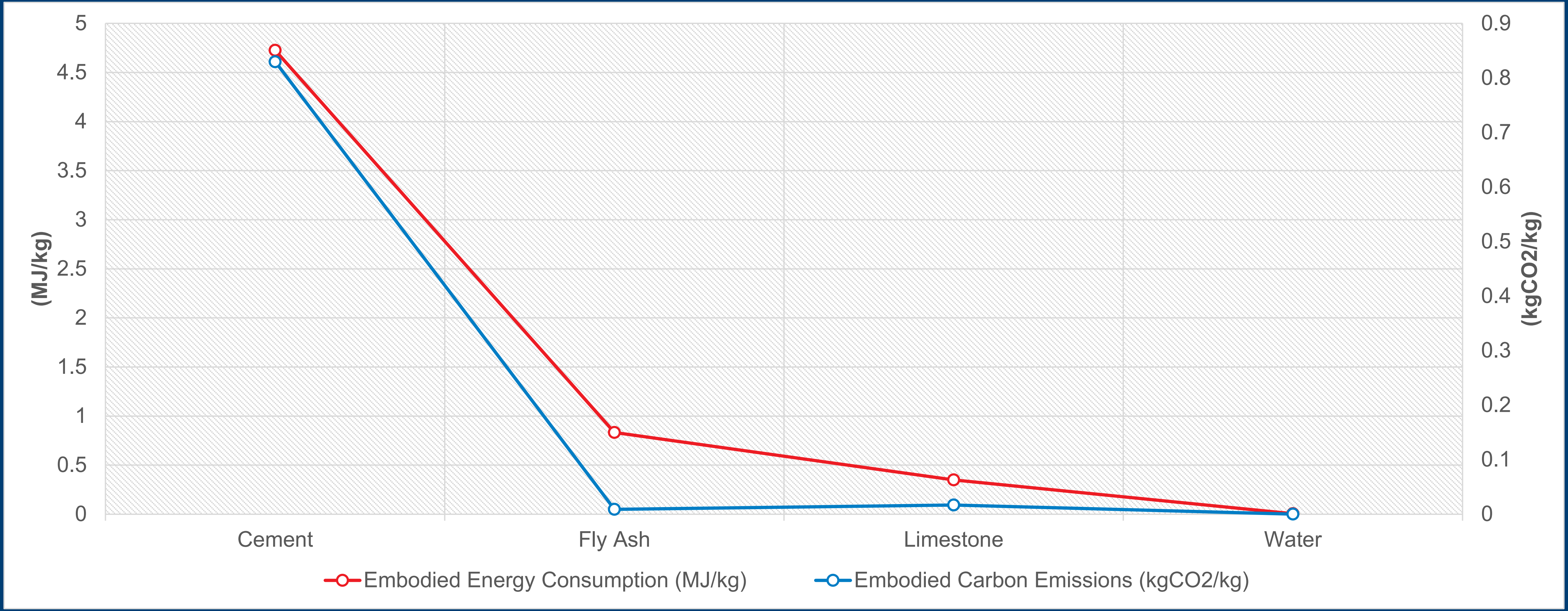
	Limestone filler Replacement			
	0%	15%	25%	35%
Water/cement ratio	0.4	0.4	0.4	0.4
SP (% of Powder Mass)	0.47	0.74	0.84	1.07
Slump flow Spread (mm)	460	540	550	690
28-day Compressive Strength (MPa)	55	58	59	66
56-day drying shrinkage (με)	610	600	530	440

Non-Technical Performance

1- Cost Analysis



2- Environmental Analysis



CONCLUSIONS

- Incorporation of cementitious and non-cementitious fine fillers
- Maximization of flowability and rheology (excess water)
- Improvement in strength, volume stability, and durability
- Denser wet particle packing density and better filling ability
- More excess paste coating around aggregates (film thickness)
- Production of sustainable, low-cost and high-performance concrete

In Brief …

Carbon neutral concrete is possible. Solutions are available today, and new ones are being developed for the future.

Less Clinker Into Cement, Less Cement Into Concrete

Challenges

- Technical (innovation in technology)
- Economical barriers
- Market acceptance

Thank you

For the most up-to-date information please visit the American Concrete Institute at:
www.concrete.org