

Development of green cement and green concrete, based on partial replacement of cement with limestone powders and blast - furnace slag

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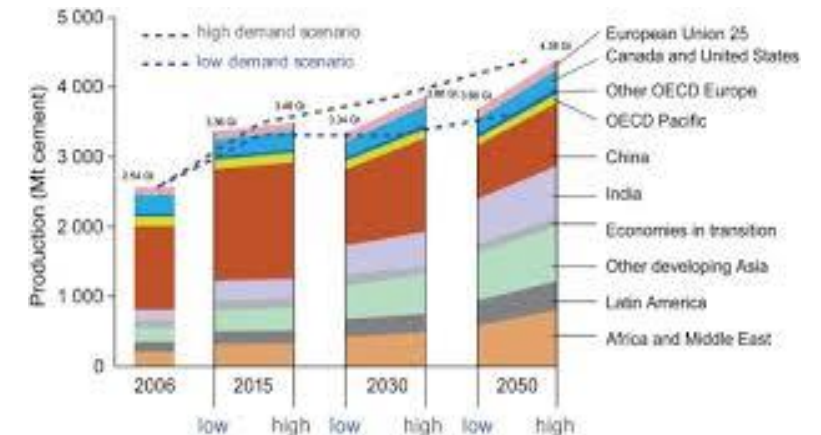


Introduction

Over the past few years there has been a growing interest in the development of Portland Cement by partial replacement of the clinker (active component) or the reduction of cement in the concrete mixture, with various chemical additives.

1. Active materials - Fly ash, Metakaolin, Slag, Silica fume.

2. Inert materials – Limestone, Silica



Motivation

The motivations to reduce the clinker and the cement content are threefold:

1. Environmental –

➤ lower CO₂ emission to the atmosphere.

❖ 1 ton clinker ⇒ 0.8 – 1.0 ton CO₂ emission

2. Economical - cost reduction.

3. Scientific\Technology – improvement of performances.



Limestone

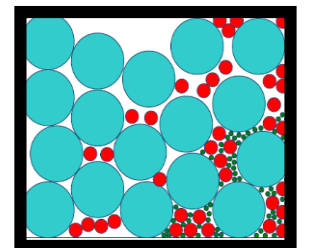
Limestone is one of the most attractive as it is considered:

- Natural
- Available
- Economical



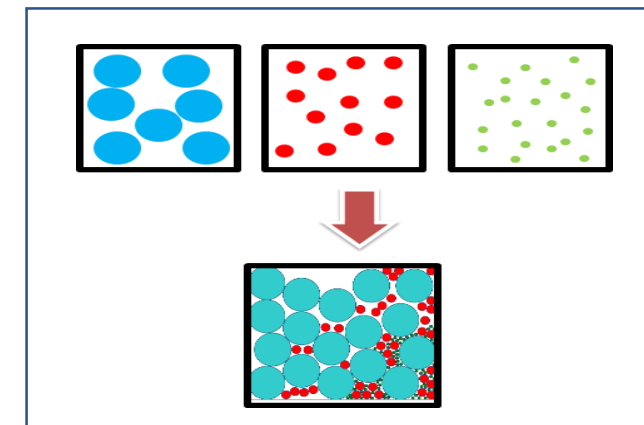
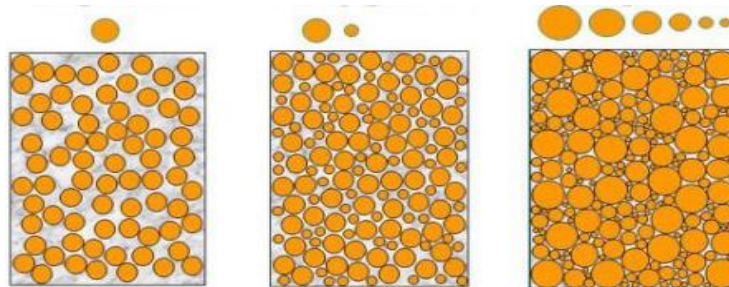
Research Goal

Development of blended cement & concrete mixture, by partial replacement of the clinker or cement mostly with limestone powders and other chemical additives, having several particle size distributions, in order to improve the cement & concrete performances.



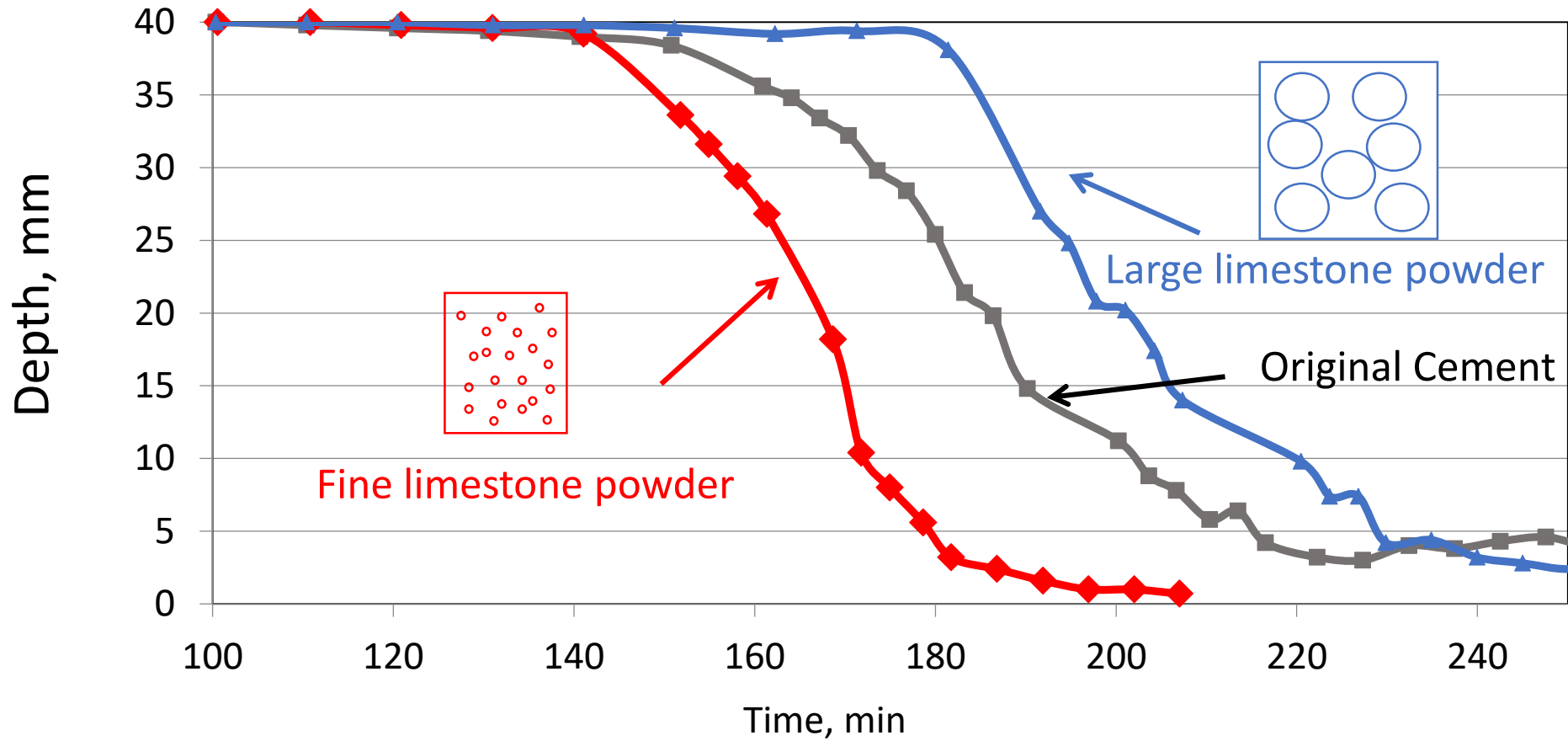
Hypothesis

- The ability to replace an "active" material with an inert additive, while achieving improved properties, can be obtained by increasing the Packaging Density of the blended cement & concrete mixture.
- Increased Packing Density, can be achieved by a combination of several different particle size distributions.



Setting Times

Penetration depths vs. time



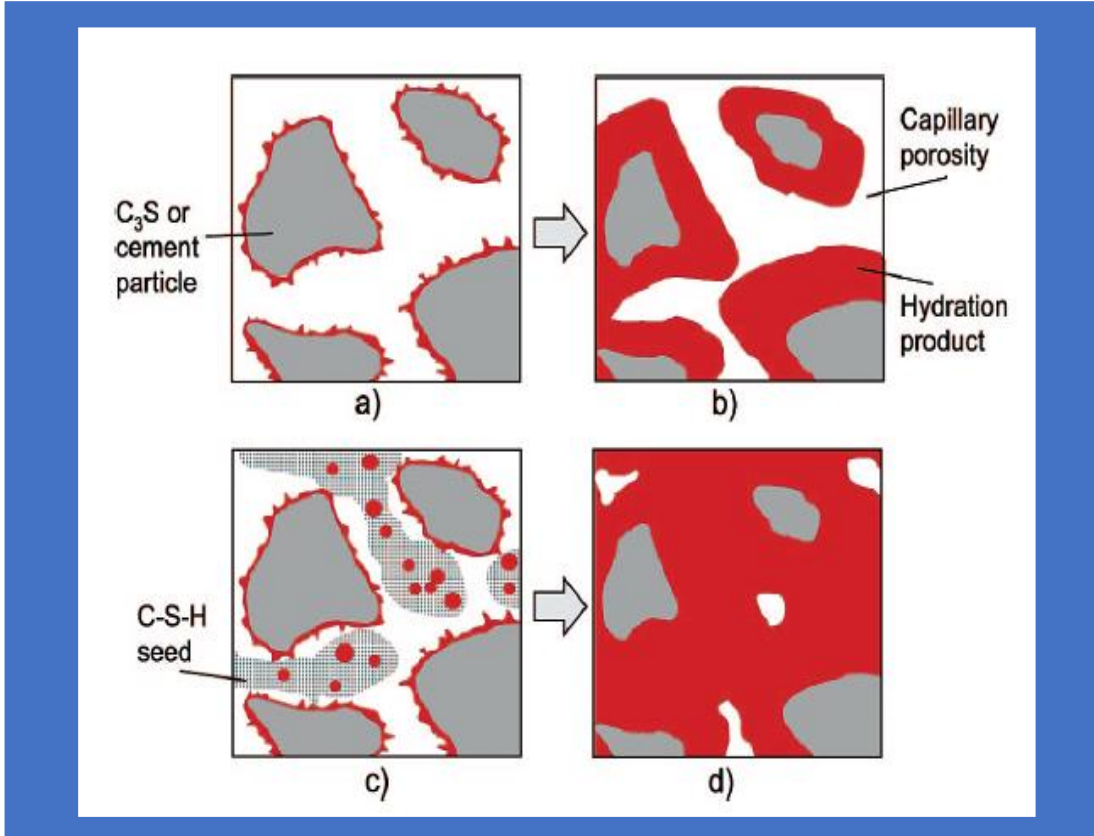
5 % wt.

Single-Particle-Size

Nucleation Centers

No limestone

Fine limestone



Jeffrey, 2009

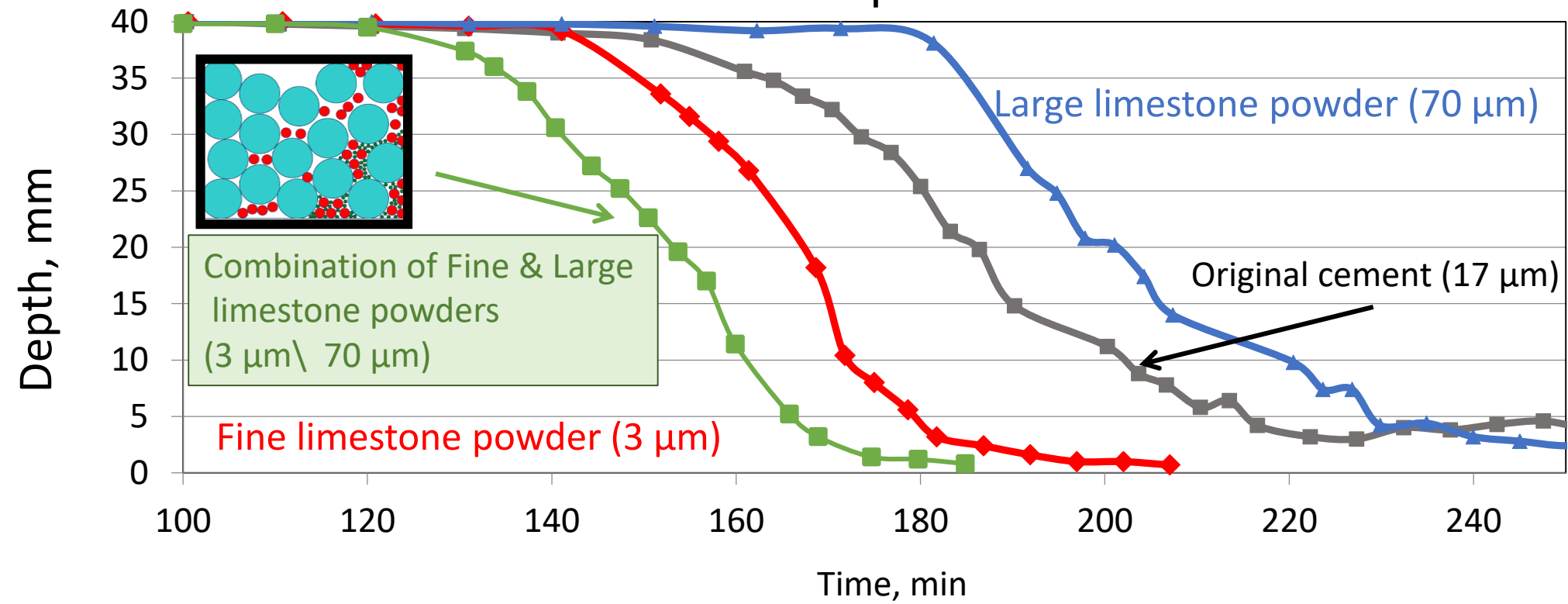
Increased number of nucleation centers



Faster hydration rate
more hydration products
at early age

Setting Times

Penetration depths vs. time



5 % wt.

Single-Particle-Size compared to combined sizes

Packing Density Measurement

$$\text{Packing Density} = \frac{V_{\text{Solid}}}{V_{\text{Solid+water}}} = \frac{1}{1 + \rho_P \frac{W}{p}}$$

Lecomte et al, 2009

where:

W = water required to mix cement paste to obtain normal consistency

p = the powder weight

ρ_p = the specific density of the dry

Larger amount
of water



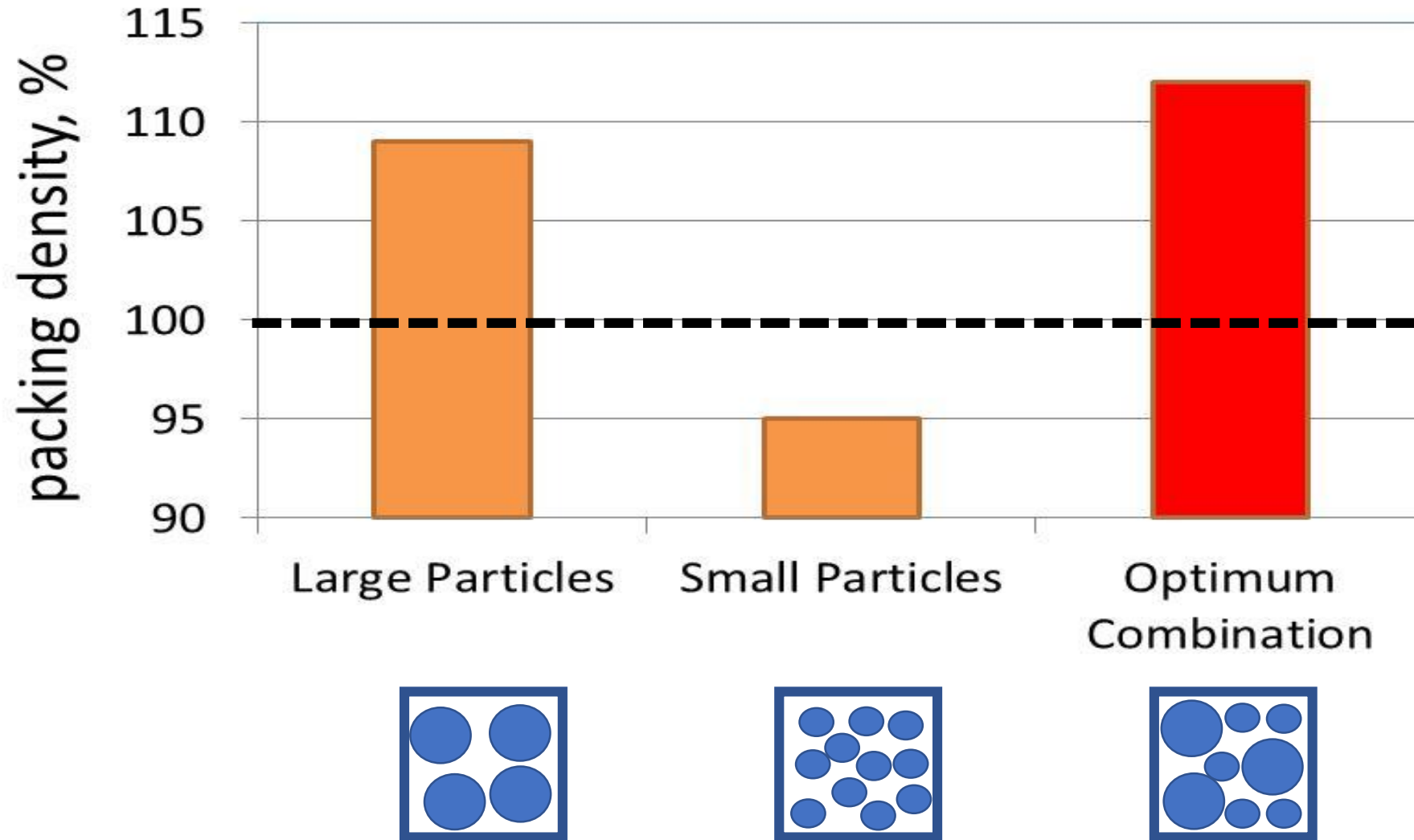
Greater voids
volume



Lower packing
density



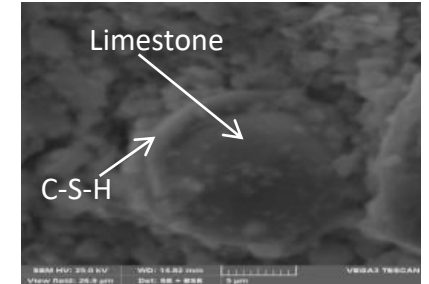
Packing Density



Influence of mechanisms involved

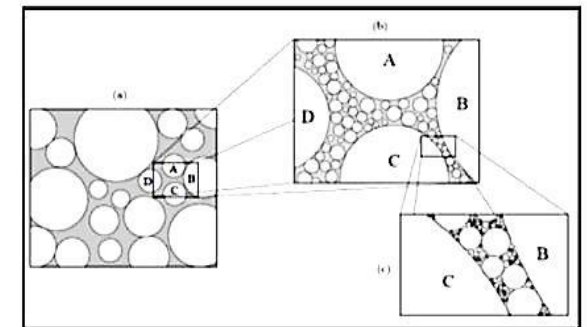
□ Nucleation Centers → Surface Area

Greater surface area, faster setting rate



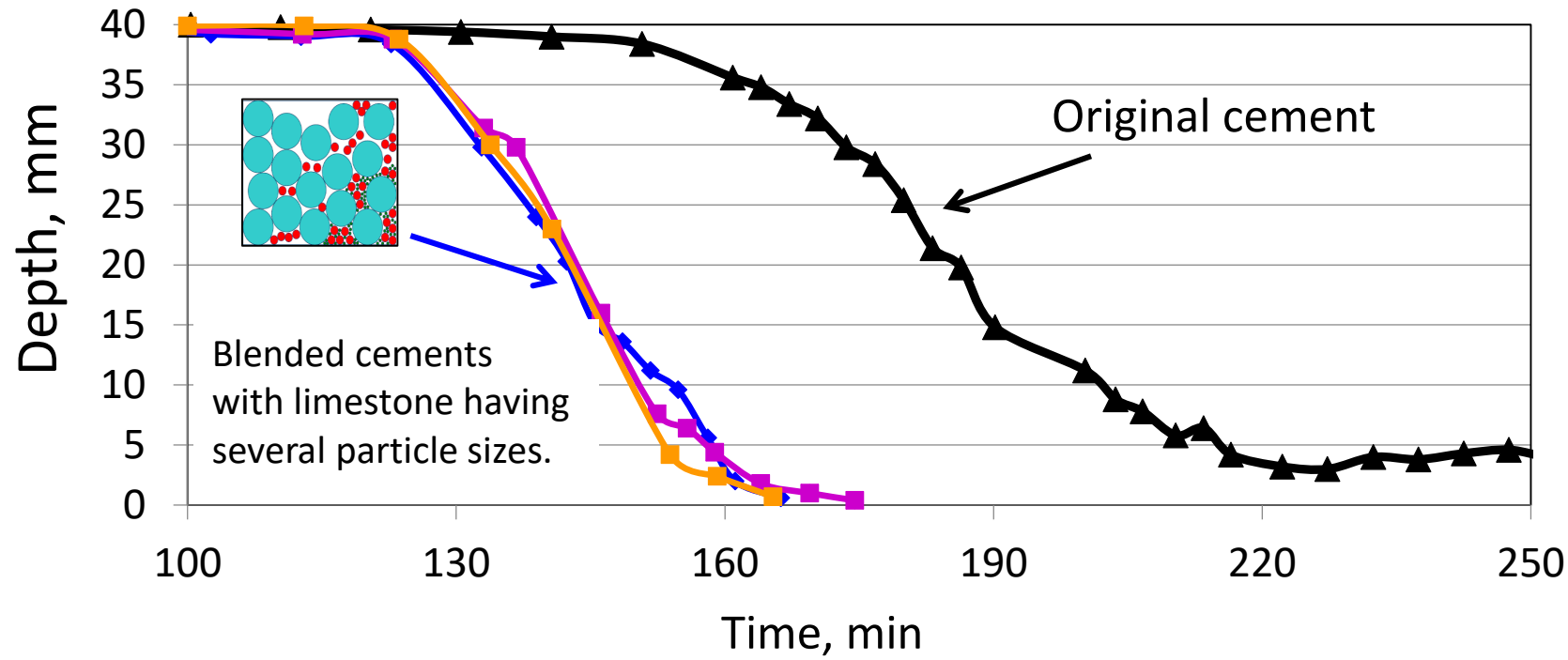
□ Packing Density → Solid Content

Greater solid content, lesser voids to be filled by hydration products



Setting Times

Penetration depths vs. time

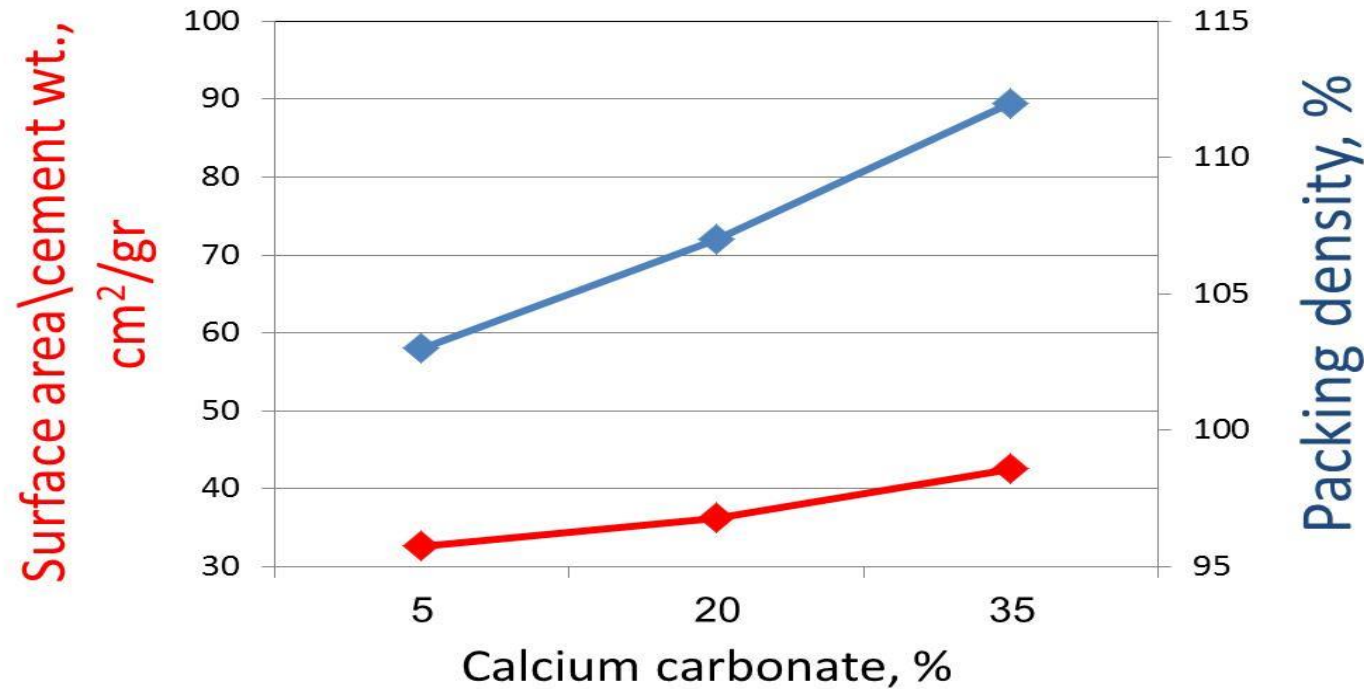


▲ Pure Cement
◆ 5% Replacement
■ 20% Replacement
■ 35% Replacement

Limestone having combined sizes

Replacement content	Small %	Similar %	Big %
5%			
20%			
35%			

Surface Area & Packing Density Combined Particle Sizes




Combined limestone particle sizes:

- Greater Surface Area
- Greater Packing Density

Limestone having combined sizes

Replacement content	Small %	Similar %	Big %
5%			
20%			
35%			



Development of both blended cement and concrete mixtures having reduced clinker

Nucleation Centers & Packing Density



Cement Production



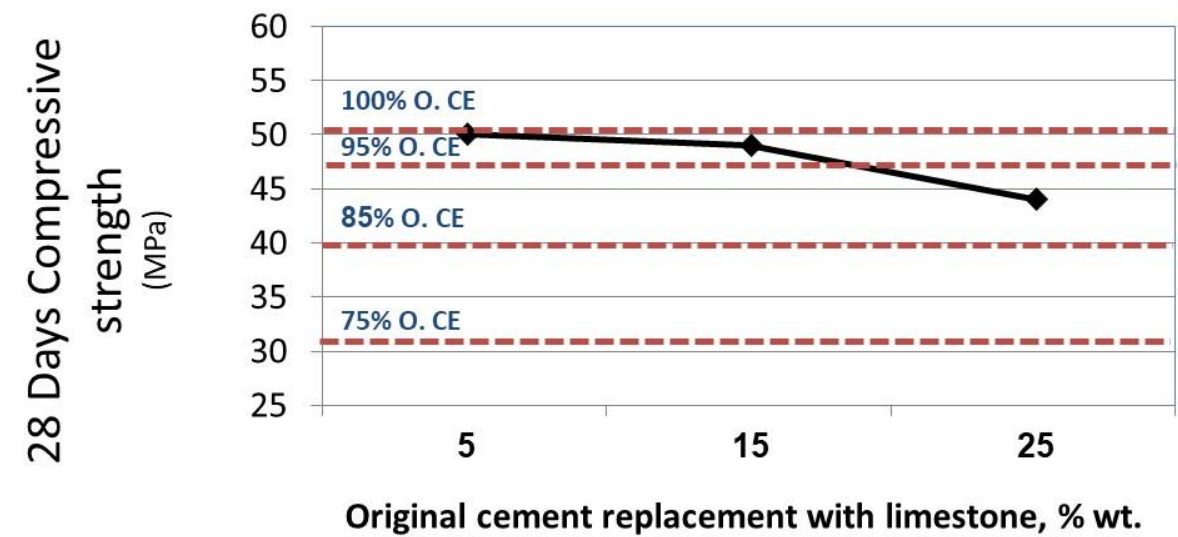
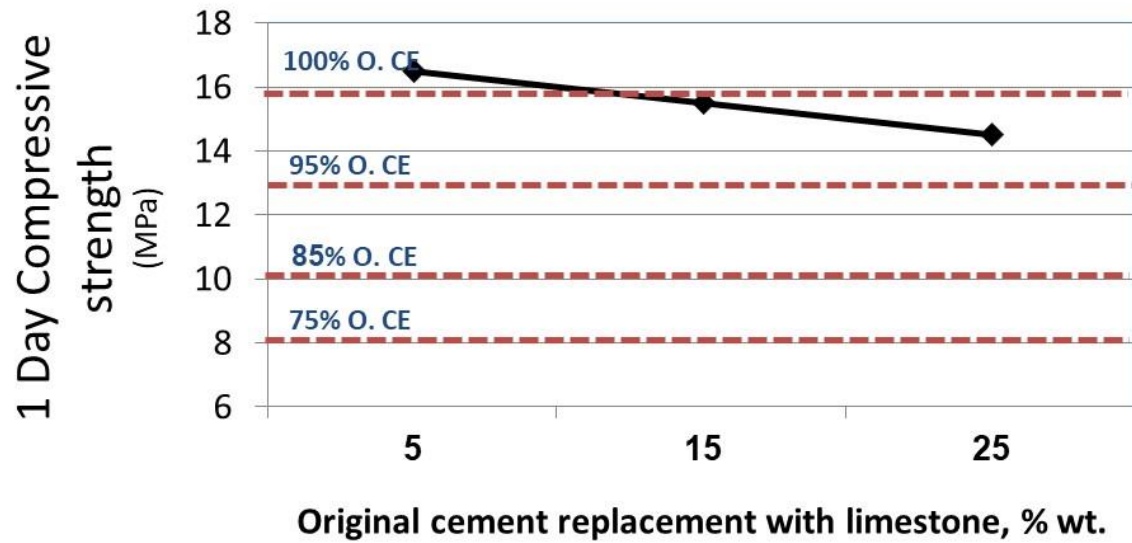
Blended Cement & Concrete mixture
Having reduced clinker amount



Concrete Production



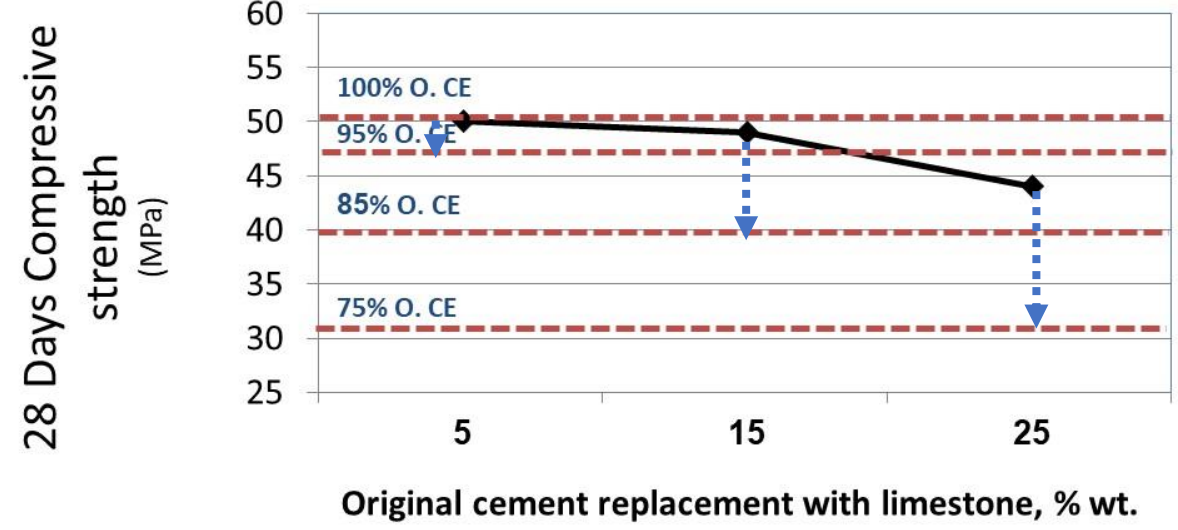
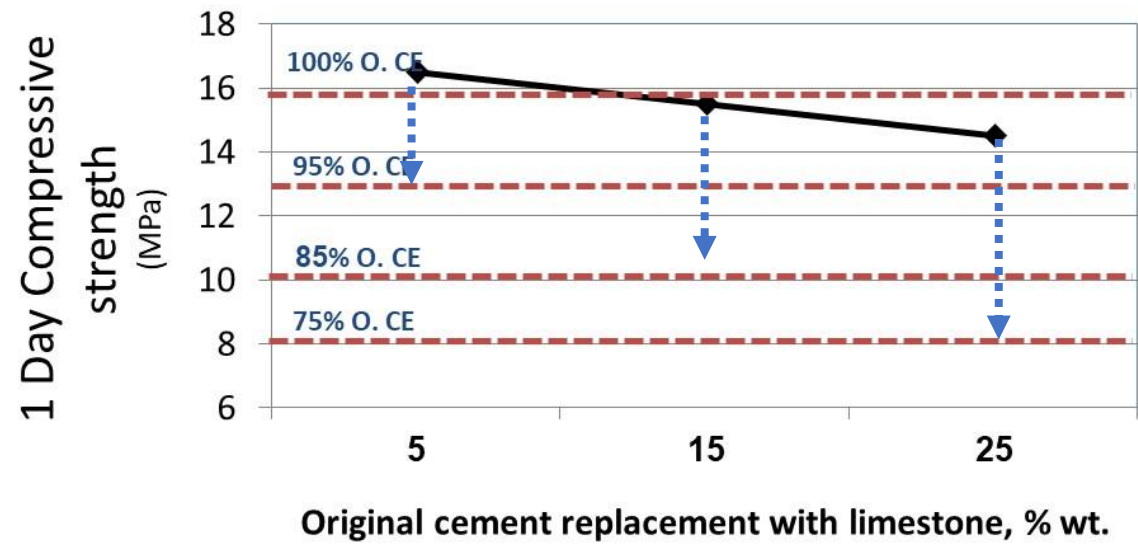
Partial Replacement of the Original Cement with limestone powders having various sizes



Combined limestone particle sizes:

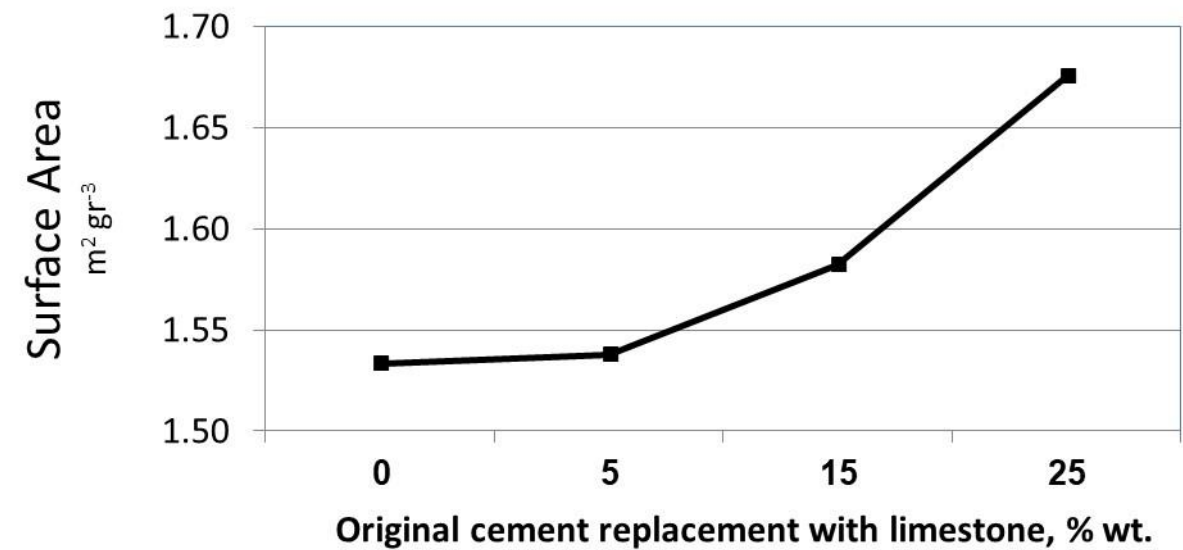
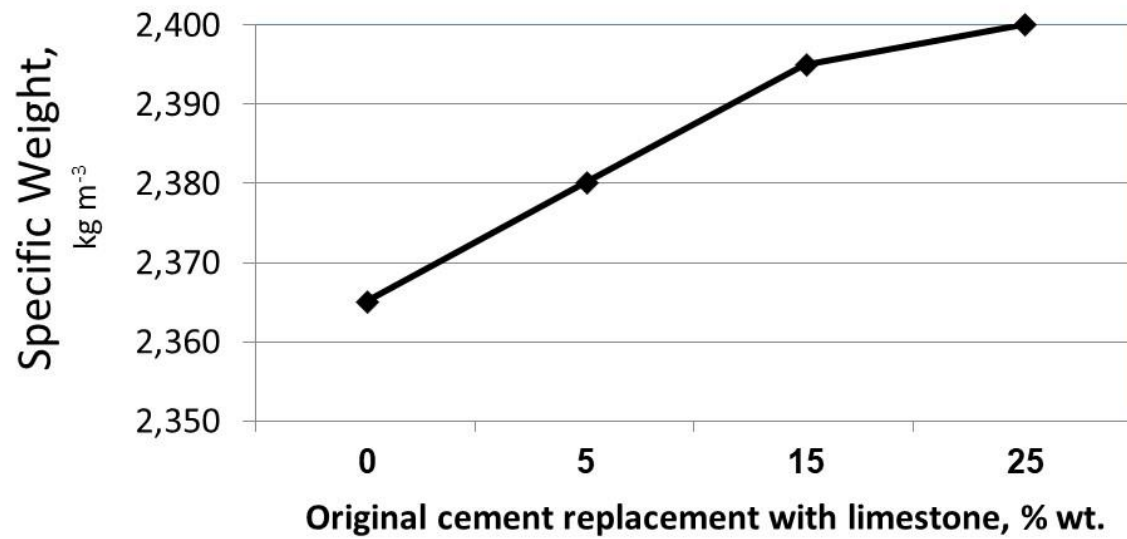
- Greater Initial Strength
- Greater Final Strength

Partial Replacement of the Original Cement with limestone powders having various sizes



Replacement amount, % wt.	Increased Initial strength, %	Increased Final strength, %
5	18	3
15	32	23
25	45	30

Partial replacement of the Original Cement with limestone powder having various sizes

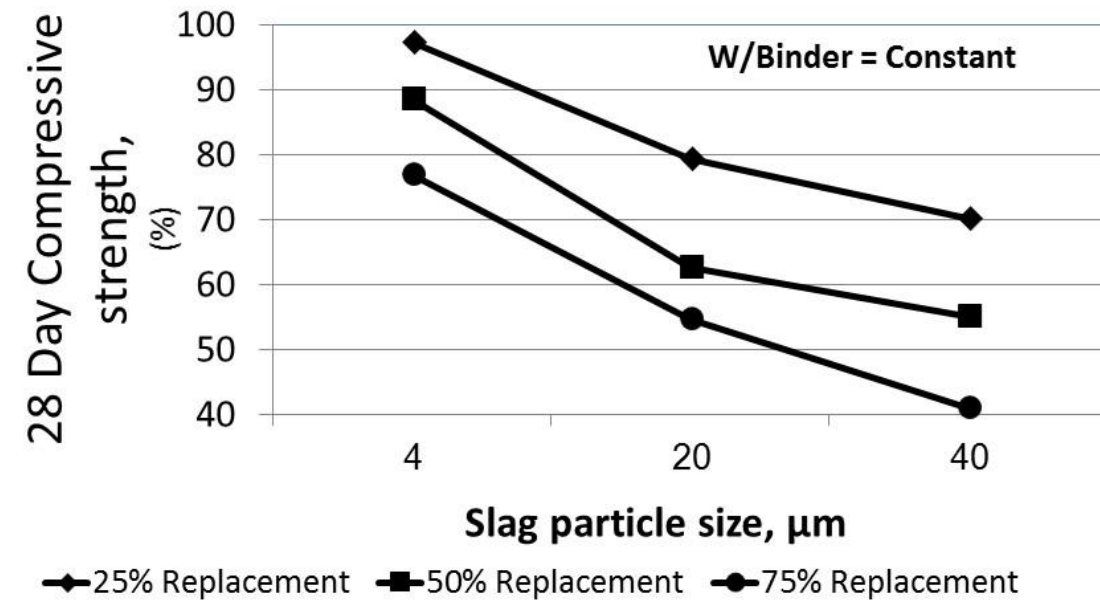
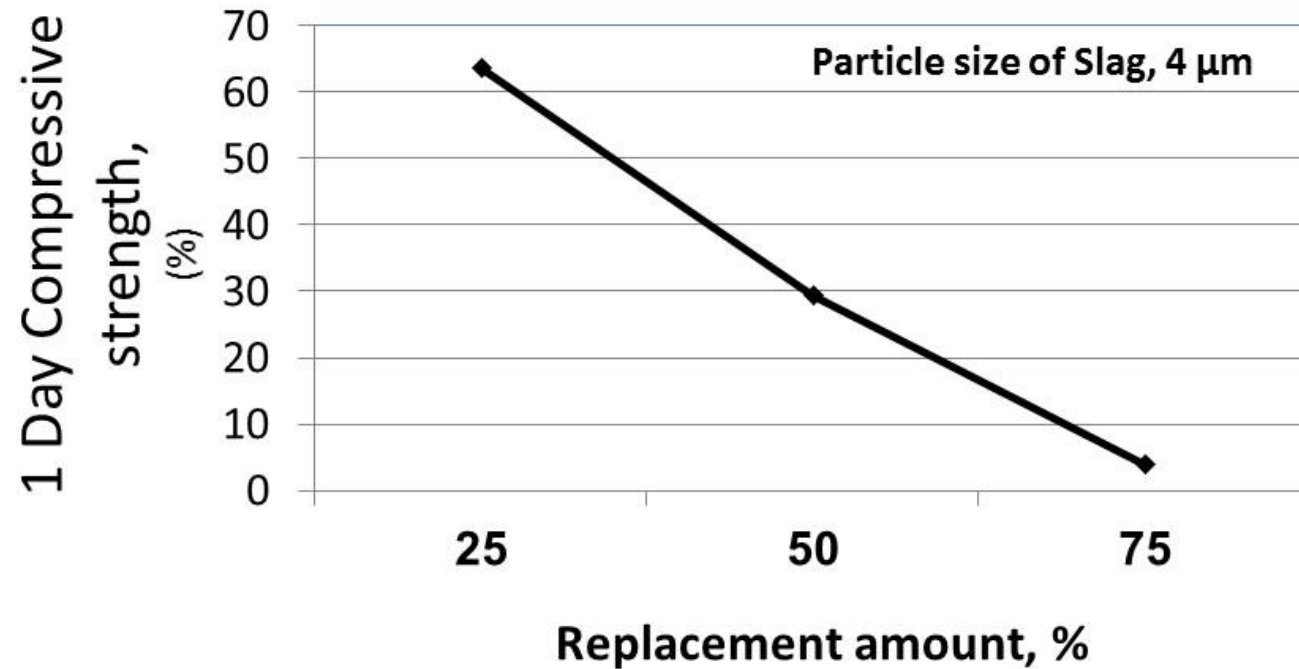


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Combined limestone particle sizes:

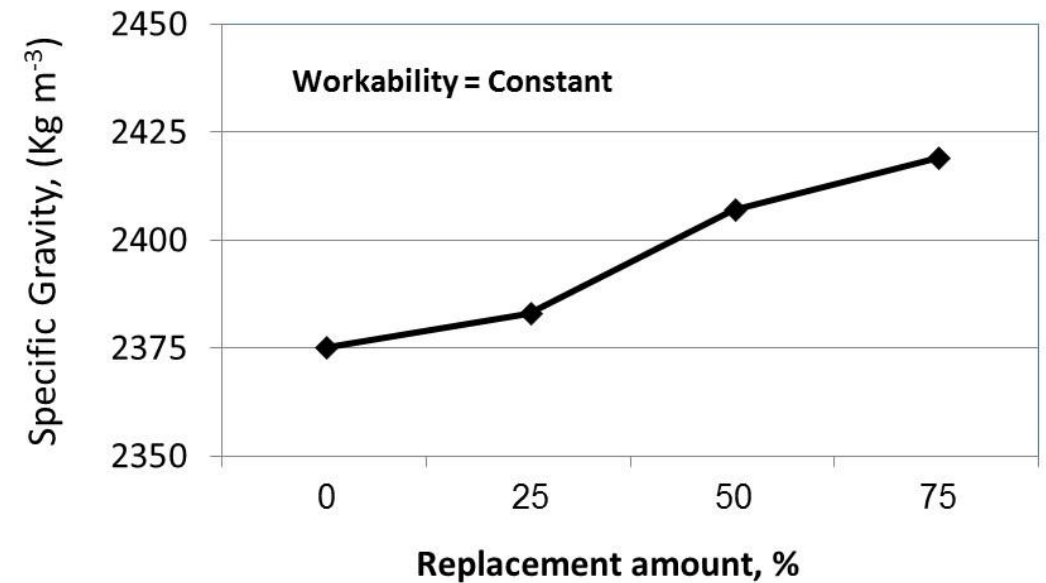
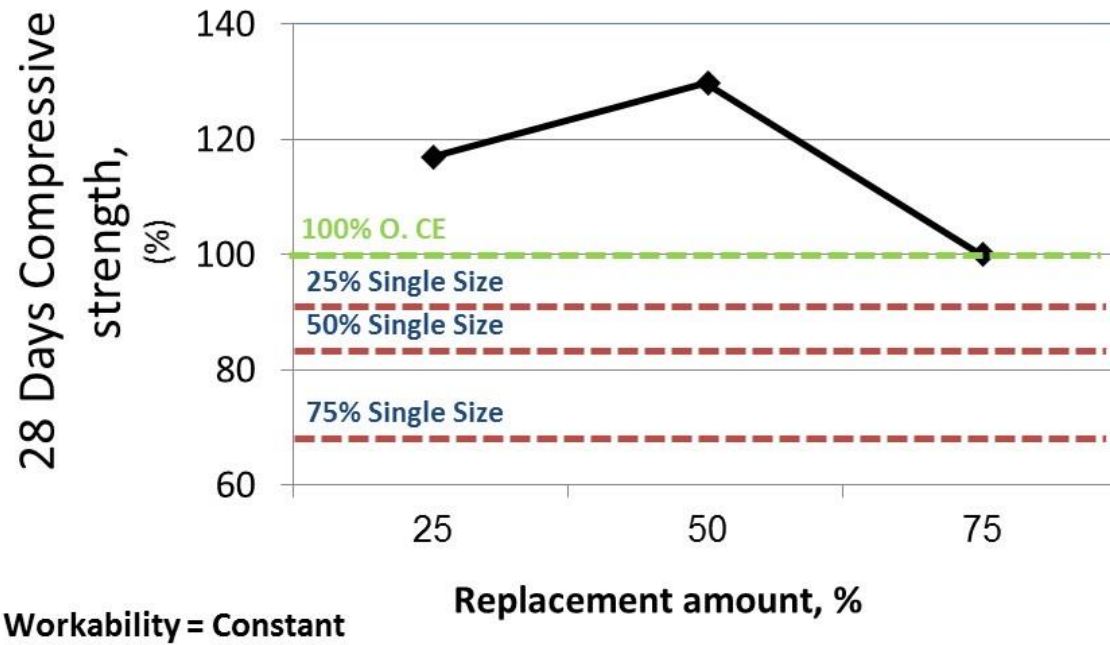
- Greater Specific Weight
- Greater Surface Area

Partial replacement of the Original Cement with Blast - Furnace Slag having a single size

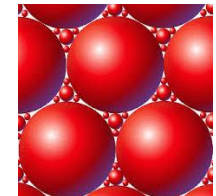


BFS having a Single-Particle-Size

Partial replacement of the Original Cement with Blast - Furnace Slag having various sizes

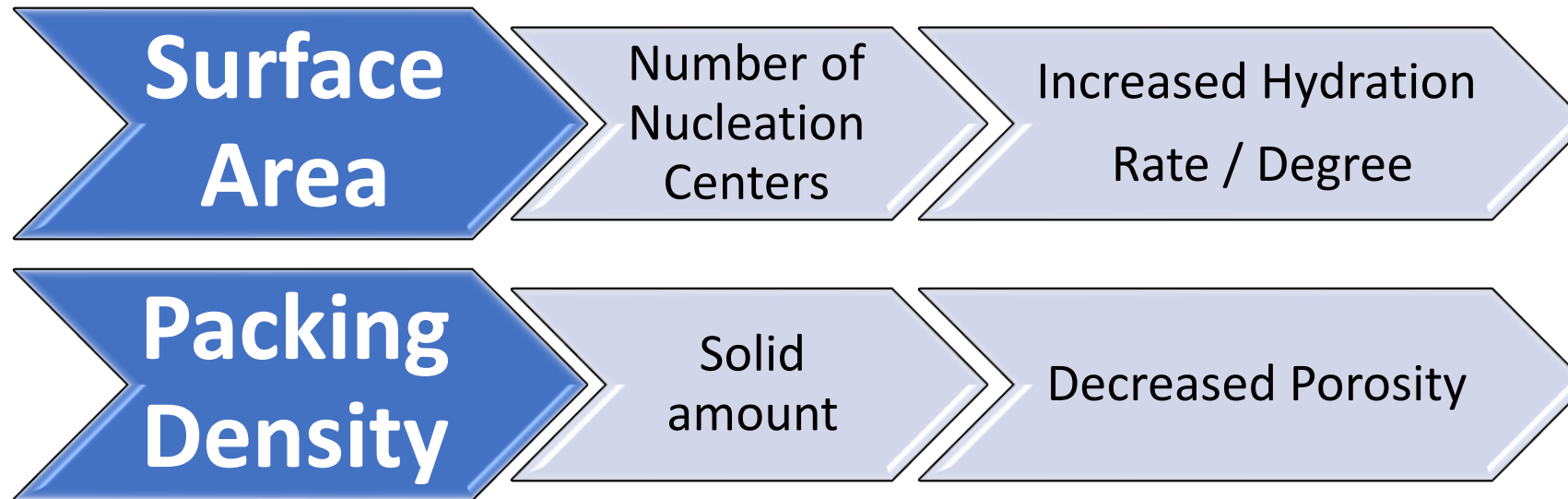


BFS having combined sizes



Conclusions

Two main mechanisms were found to effect the performances of cement and concrete mixtures ; Surface Area & Packing Density.



Conclusions

- Partial replacement of cement with chemical additives having fine particles



- Partial replacement of cement with chemical additives having large particles



Conclusions

- Blended of various chemical additives having various sizes ;

Packing Density

Surface Area

**Reduction of the
original cement
with various types
of additives**

**Development of Green Cement & Green
Concrete having reduced clinker amount
and improved performances**