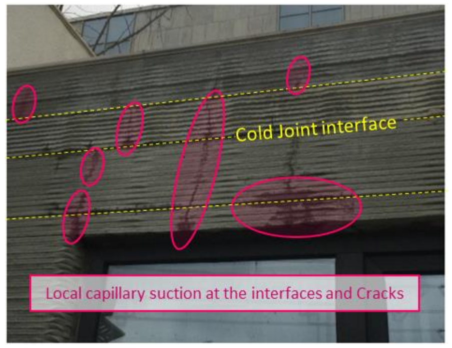
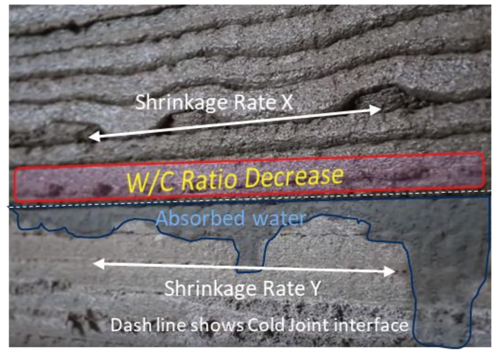
Structural Integrity and Shrinkage Behavior of 3D Printing Concrete

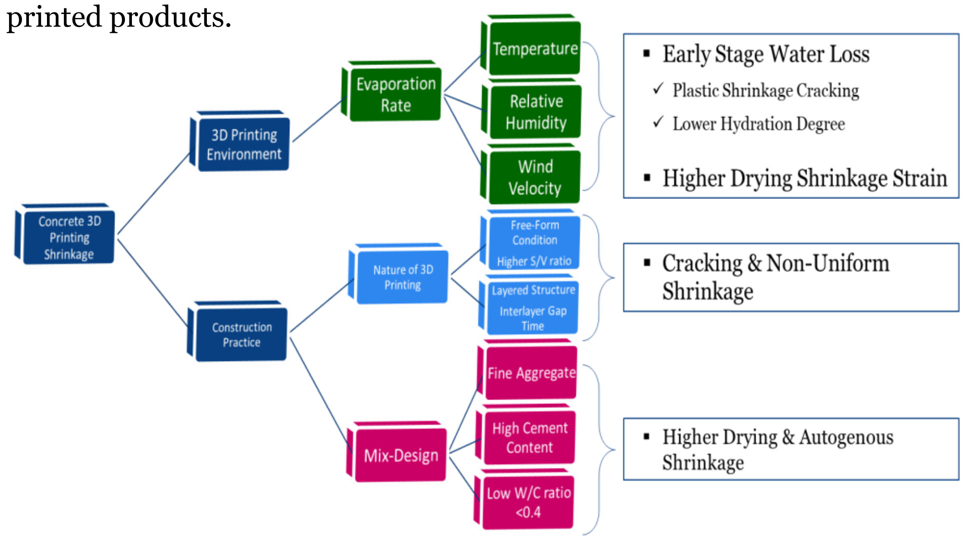
1. Introduction

Concrete 3D printing and conventional concrete casting processes are different in many aspects. In 3D printing, no formwork exists to cover the surface of freshly printed concrete, and water-to-binder ratio of printable





mixtures is lower than the conventional concrete mixtures. The higher surface exposure of freeform concrete can result in higher evaporation rate, leading to very low moisture content and a lower hydration degree of printed products.



Effective parameters in controlling the shrinkage behavior of printing concrete are divided into two main categories: 3D Printing Environment, and Construction Practice.

➢ Concrete 3D-Printing Vs. Conventional Concrete Casting

a. Construction Practice & Mix Design
- Using coarse aggregate limitation
- Higher amount of Cement
- Lower W/C ratio

b. Curing Condition:
- Higher surface exposure
- Almost impracticable post-processing
- Layered structure and final product's lower structural integrity
  - ✓ Local capillary water-intake at the interfaces and Cracks
  - ✓ Non-uniform Shrinkage

➢ Research Question

How the freeform nature of 3D printing and climatic parameters (T, RH, Wind) affect the structural integrity and shrinkage behavior of printable Geopolymer and Concrete compare to casting condition?

2. Methodology

Simulating the Printing Environment and Free-form condition by Changes in T and %RH and Removing Mould after Initial Setting Time respectively.

A thixotropic 3D printing concrete with a following composition was developed. The workability and printing quality have been studied by using a drop flow table and concrete rheology tests. Drying shrinkage experiments have been started according to different international standards with different S/V ratio. Samples have been cast in prismatic mould and kept in different curing condition of temperature and relative humidity for 28 days. To simulate freeform condition, all the samples have been de-moulded after their initial setting time of nearly 4 hours. Real 3D Printed samples also will be tested with the same condition and the mass loss and dimensional stability will be compared.

OPC Based 3D Printing concrete mix composition

S/C	W/C	Silica Fume*	High Range Water Reducer*	Thicker Agent*
0.8-1.2	0.35	2%	0.26%	0.01%

*in percentage of cement mass

Curing Condition

$H_L T_L$	45% - 15 C
$H_L T_H$	45% - 35 C
Standard	50% - 24 C
$H_H T_L$	85-90% - 15 C
$H_H T_H$	85-90% - 35 C

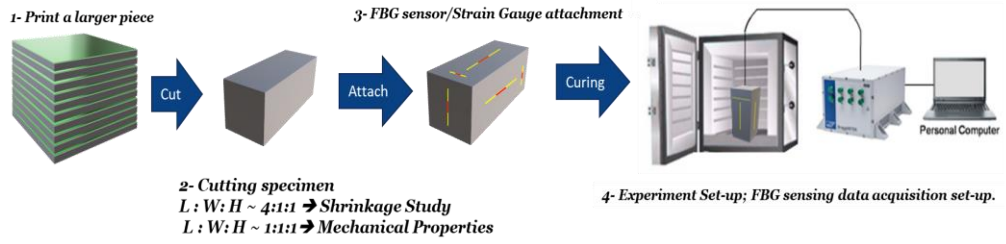
H=Humidity
T= Temperature

H: high
L: low

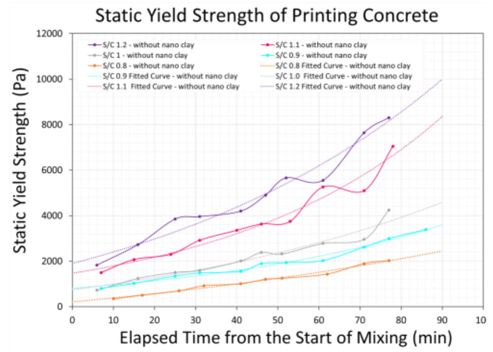
Standard Designation and Experiments Condition

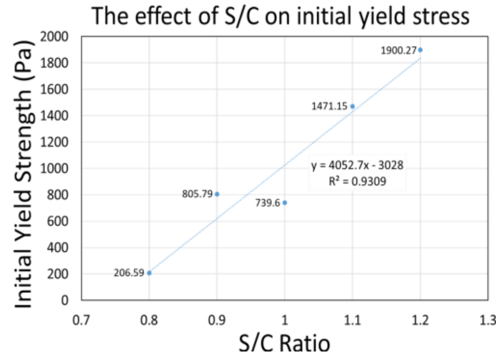
Standard Designation	Size	Initial Curing Condition	S/V
AS 1012.13-2015 AS 1012.8.4-2015	75 x 75 x 280 mm3	23 ± 2 ℃ 50 ± 5% RH	0.60
BS EN 12617-4: 2002 BS EN 196-1: 2005	40 x 40 x 160 mm3	21 ± 2 ℃ 60 ± 10% RH	1.125
ASTM C157 ASTM C511 ASTM C490	25 x 25 x 285 mm3	23 ± 2 ℃ 50 ± 4% RH	1.67

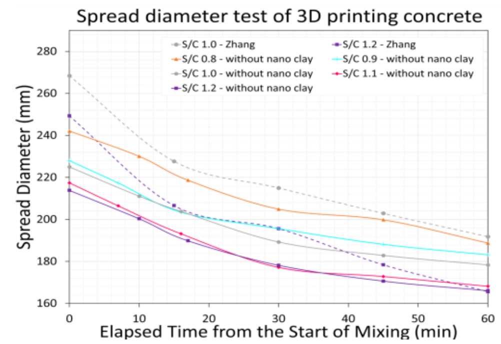
➢ Shrinkage Measurements of Printed Parts



3. Result & Discussion







In this study, a 3D printing concrete has been successfully developed based on initial yield strength and spread diameter within an optimum control range of 200-2000 Pa and 214-243 mm respectively. Drying shrinkage strain of these printable mixes is being measured in four different conditions obtained from the combination of High and Low humidity and temperature. The results of this study can be helpful to provide better curing condition considering the relationship between the printing environment condition and dimensional stability of printed products.

More Information

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