Exploring early age deformations in 3D printed concrete walls through Digital Image Correlation (DIC)



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Outline



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- Background information
 - Different measurement techniques
 - Restraint effect & free shrinkage
- Shrinkage behaviour in 3D printed concrete
 - Height-adjusted shrinkage analysis
 - Thickness-adjusted shrinkage analysis
- Conclusion

3D Printing at ASU





Problem Statement





- Higher binder content
- Absence of formwork
- Immediate exposure conditions



Due to use of higher binder content and immediate exposure conditions – Shrinkage is a challenge

(Roussel, N. et al. 2018; Qian & Kawashima, 2018; Markin et al. 2024)

Early-age shrinkage measurement techniques





Digital Image correlation (DIC), was used to evaluate the early-age shrinkage behaviour

(D.S Kurup et al. 2024; Moelich et al. 2020, J. Sun et al. 2013, B.Pan et al, 2009)

Experimental matrix



Mixture ID	Mass fraction of binder ingredients				Water-to- binder (w/b)	Superplasticizer dosage (% by	Superplasticizer dosage (% by
	OPC	Limestone	Fly ash	Type IP	ratio, by mass	mass of binder): Cast specimen	mass of binder): Print specimen
OPC	1.0	0	0	0	0.35	0.4	-
L ₃₀	0.7	0.3	0	0	0.35	0.4	0
$L_{15}F_{15}$	0.7	0.15	0.15	0	0.35	0.4	0
IP ₃₅	0	0	0	1	0.35	1.0	0.5

Measurement of early-age deformation in 3D printed concrete wall



Measurement of Shrinkage Behaviour in 3D Printed Concrete - Validation ??

• Cast specimens were produced using 3D printable mixtures, and shrinkage was measured using both conventional extensometers and Digital Image Correlation (DIC).



Shrinkage Behaviour in 3D Printed Concrete - Restraint effect & free shrinkage







Printed Wall Element

DIC Analysis

Shrinkage Behaviour in 3D Printed Concrete



> Single filament



Restraint Effect

L



Restraint against height



R₁ = Restraint coefficient against height



ε₁ = Height adjusted strain (Observed Strain with Height Restraint Effect Removed)

Shrinkage Behaviour in 3D Printed Concrete



Single filament



Restraint Effect



Restraint against thickness



 ε_{free} independent of R₁ (restraint against height) and R₂ (restraint against thickness)

Shrinkage Behaviour in 3D Printed Concrete



Double filament



Conclusion



- Displacement and strain fields showed significant geometric restraint effect along both height and the thickness of the wall.
- Normalization of the observed strain was performed using two restraint coefficients (R₁ for height and R₂ for thickness) to extract the free shrinkage component.
- The free shrinkage response was found to be dependent on concrete mix design and independent on the wall geometry.



Thank you for your attention