Michigan Technological University

Performance evaluation of using waste glass powder and fly ash in alkali-activated slag binder and mortar samples as partial precursors

Dr. Qingli (Barbara) Dai, Sunday Eniola and Peifeng Su

Department of Civil, Environmental, and Geospatial Engineering
Michigan Technological University

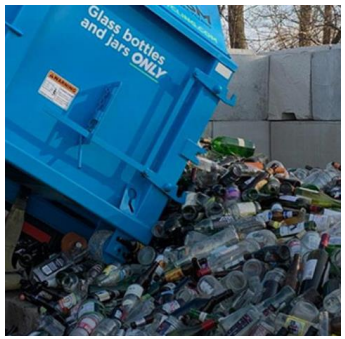
ACI Fall Convention 2023

Outline

- Motivation and Objectives
- Effects of added precursors on AAS binder performance
- Effects of added precursors on AAS mortar performance
- Glass powder–modified AAS mortar performance with added glass sands and recycled steel fibers
- Class F fly ash –modified AAS mortar performance with added glass sands and recycled steel fibers
- Conclusions
- Acknowledgements

Motivation

1. Landfilling is becoming unacceptable and costly due to limited available sites for waste disposal
2. The production of cement results in the consumption of energy and the emission of carbon dioxide
3. Alkali-activated materials exhibit significant potential as a viable alternative to traditional cement concrete
4. Waste glass can act as a precursor in alkali-activated slag to reduce the setting time, potential alkali leaching, etc.



Objectives

Evaluation of properties of Glass powder (GP) and class F fly ash modified alkali-activated slag (AAS) binder and mortar

1. Evaluate strengthen, shrinkage and efflorescence characteristics of GP-modified and class F fly ash-modified AAS binder
2. Investigate the mechanical properties of GP-modified and class F fly ash- modified AAS Mortar
3. Investigate the mechanical properties of modified AAS mortar with recycled glass sands and recycled tire steel fibers

Mixture design of AAS binder samples

Sample Types	Precursor Compositions			Activator		Water/ Precursor
	Slag-cement	Class F Fly Ash	Glass Powder	Na2O%	Si:Na Molar ratio	
C-AAS	100	0	0	4	1.0	0.45
AAS-F15	85	15	0			
AAS-F20	80	20	0			
AAS-GP15	85	0	15			
AAS-GP20	80	0	20			

Michigan Technological University

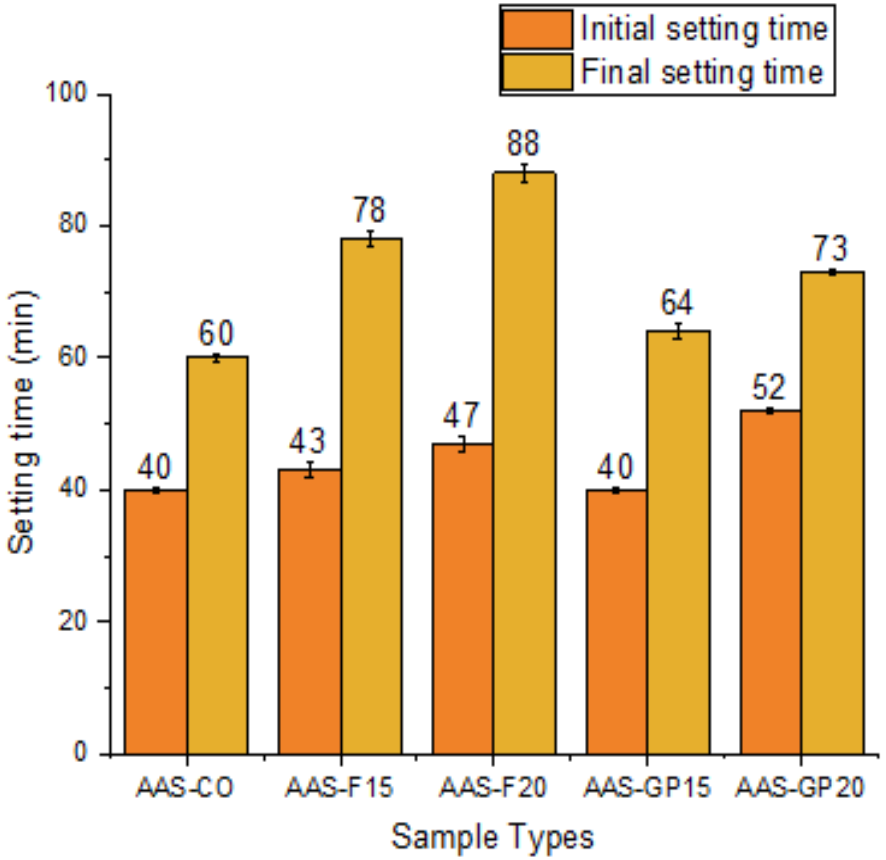
Mixture design of AAS mortar samples

Mortar mixture ID	Binder mixture ID	Aggregates Gradation percentages						RSF %Content
		#8-#4	#16-#8	#30-#16	#50-#30	<#50	Glass sands(#30-#16)	
C-AAS	C-AAS	10	25	25	25	10	0	0
C-AAS-S		10	25	25	25	10	0	1
C-AAS-G25		10	25	0	25	10	25	0
C-AAS-G25-S		10	25	0	25	10	25	1
AAS-F20	AAS-F20	10	25	25	25	10	0	0
AAS-F20-S		10	25	25	25	10	0	1
AAS-F20-G25		10	25	0	25	10	25	0
AAS-F20-G25-S		10	25	0	25	10	25	1
AAS-GP20	AAS-GP20	10	25	25	25	10	0	0
AAS-GP20-S		10	25	25	25	10	0	1
AAS-GP20-G25		25	0	0	10	75	25	0
AAS-GP20-G25-S		25	0	0	10	75	25	1

Outline

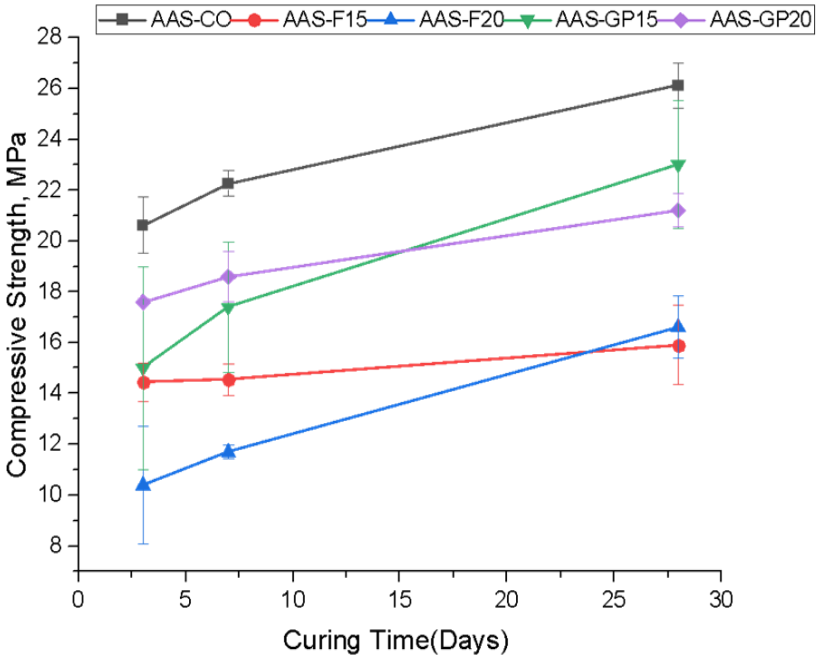
- Motivation and Objectives
- Effects of added precursors on AAS binder performance
- Effects of added precursors on AAS mortar performance
- Glass powder–modified AAS mortar performance with added glass sands and recycled steel fibers
- Class F fly ash –modified AAS mortar performance with added glass sands and recycled steel fibers
- Conclusions
- Acknowledgements

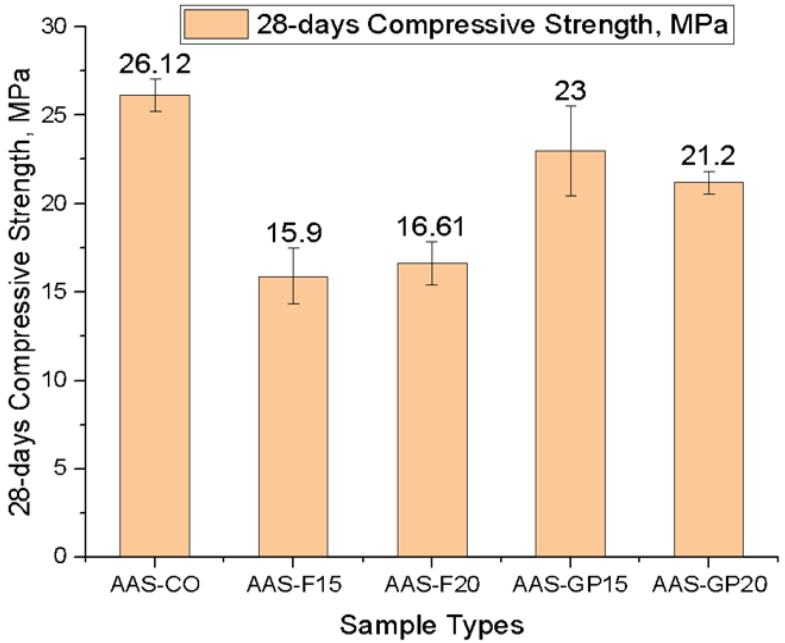
Setting Time



- The added class F fly ash increases the initial and final setting time (largely) comparing with control sample
- The added glass powder slightly increases the initial and final setting time.
- Both setting times increase with the added precursor content

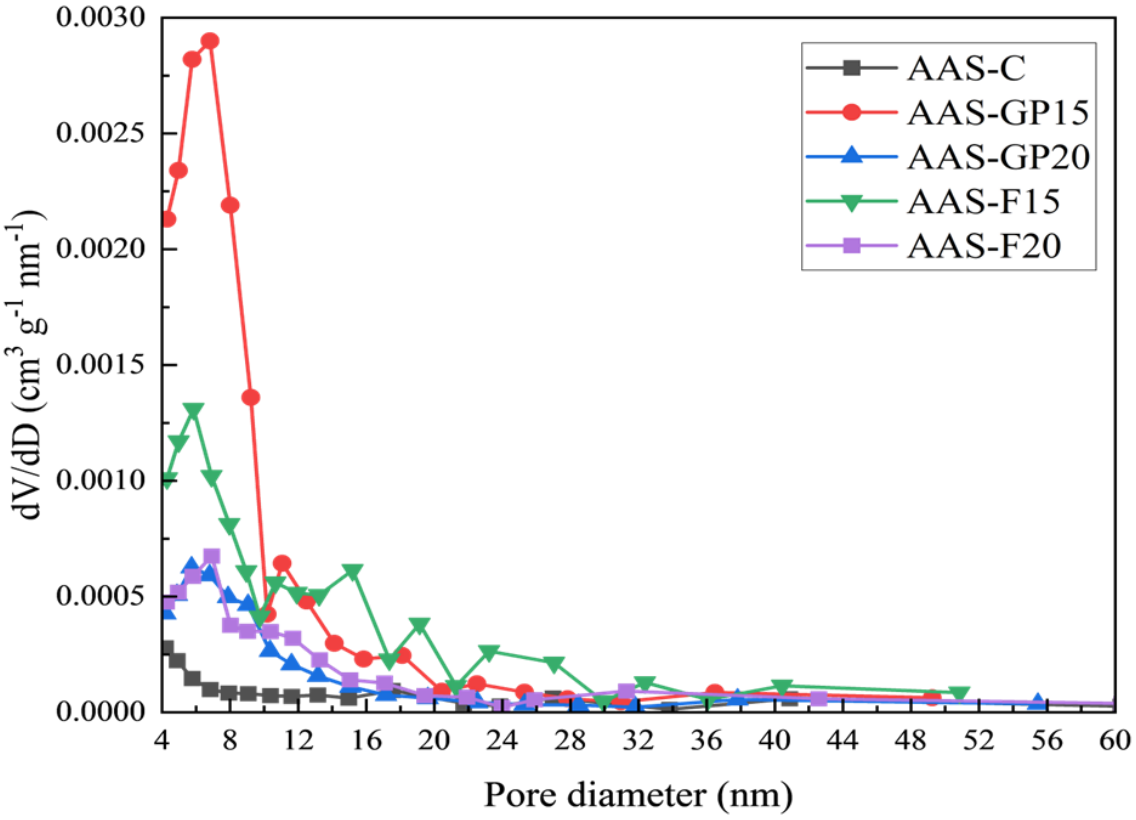
Compressive strength





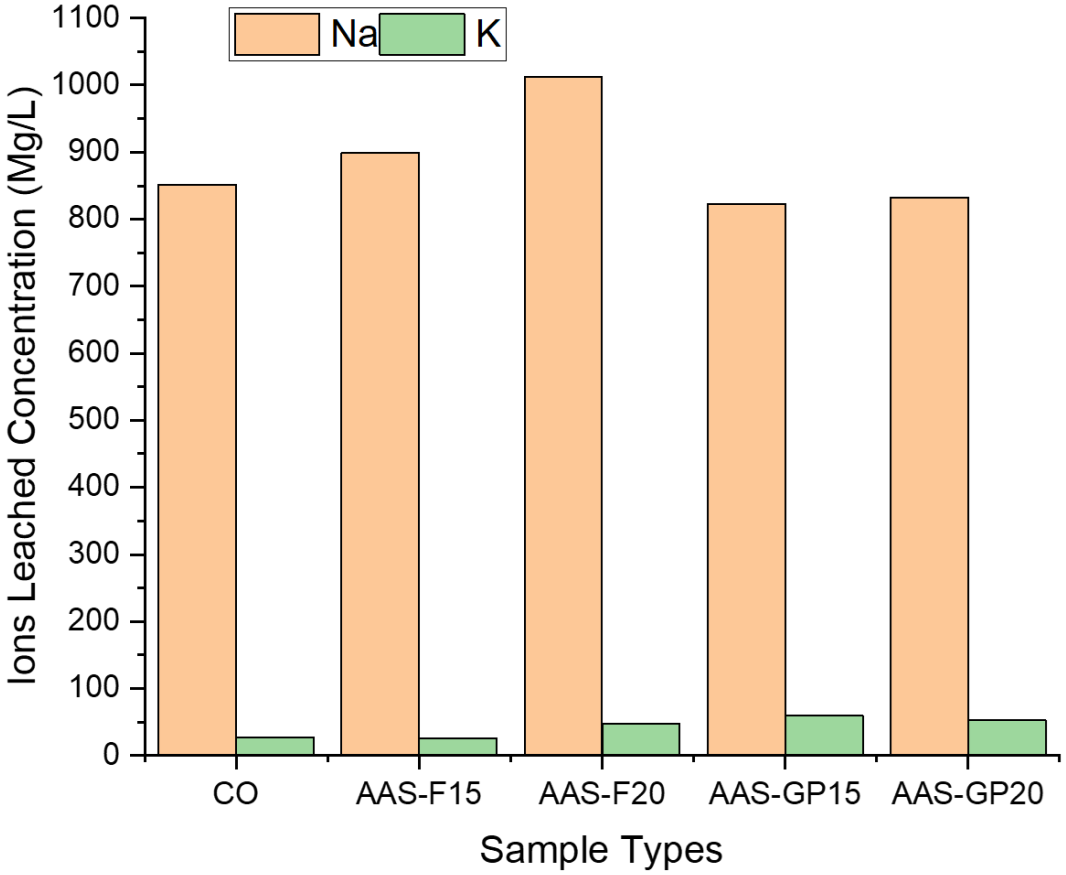
- Samples with 15% glass powder has the comparable compressive strength as control
- Sample with alternative precursor (especially fly ash class F) reduces compressive strength of AAS binder

Pore size distributions



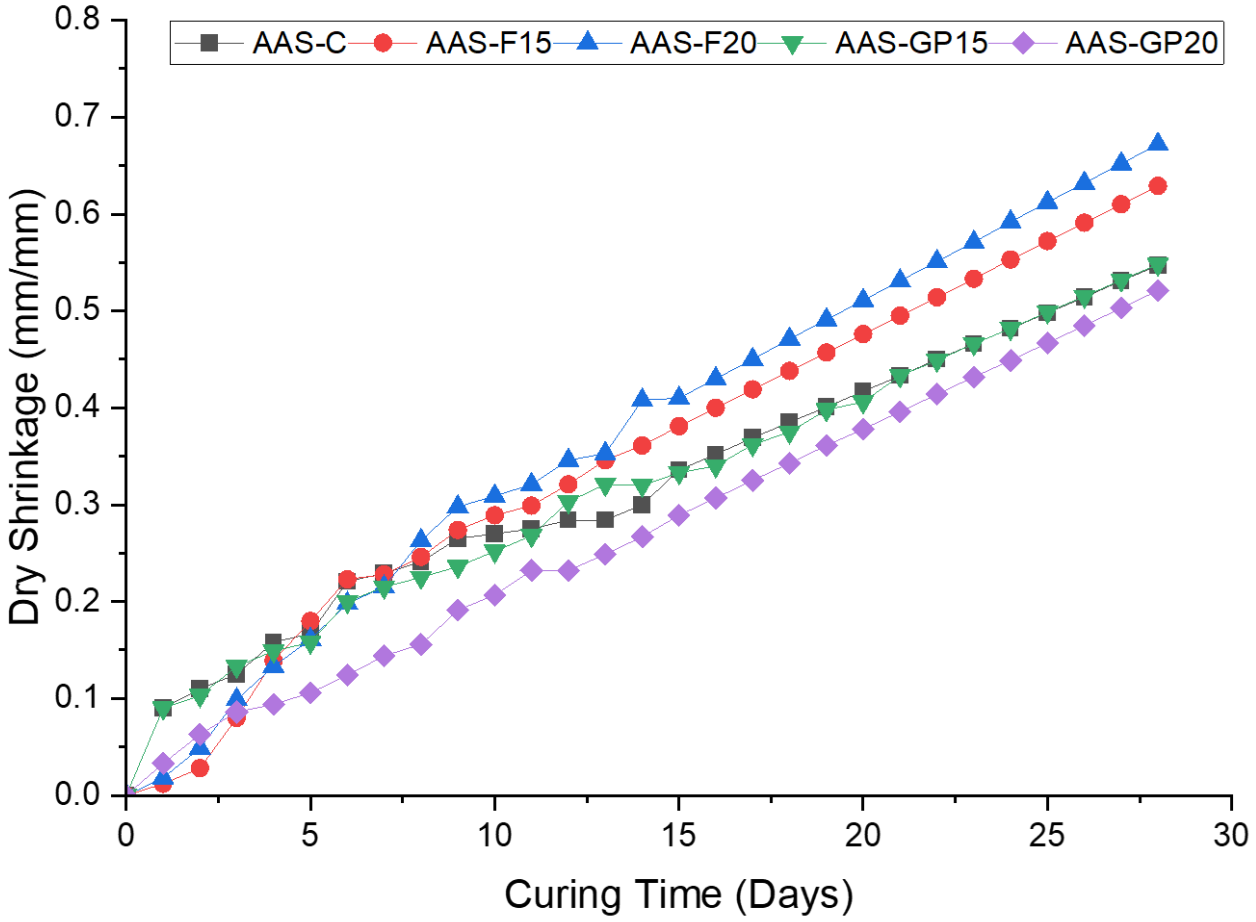
- The nanopore (less than 5-10 nm) showed largely increased geopolymer phases formed for 15% replaced precursor
- With 20% replaced precursor, geopolymer phases showed slightly increase due to filling effects and less reacted phases

Efflorescence test results



- The replaced glass powder precursor can reduce the sodium leaching (alkali leaching) since contains more silicate.
- The replaced fly ash class F increased the sodium or alkali leaching with added aluminum content.

Drying Shrinkage

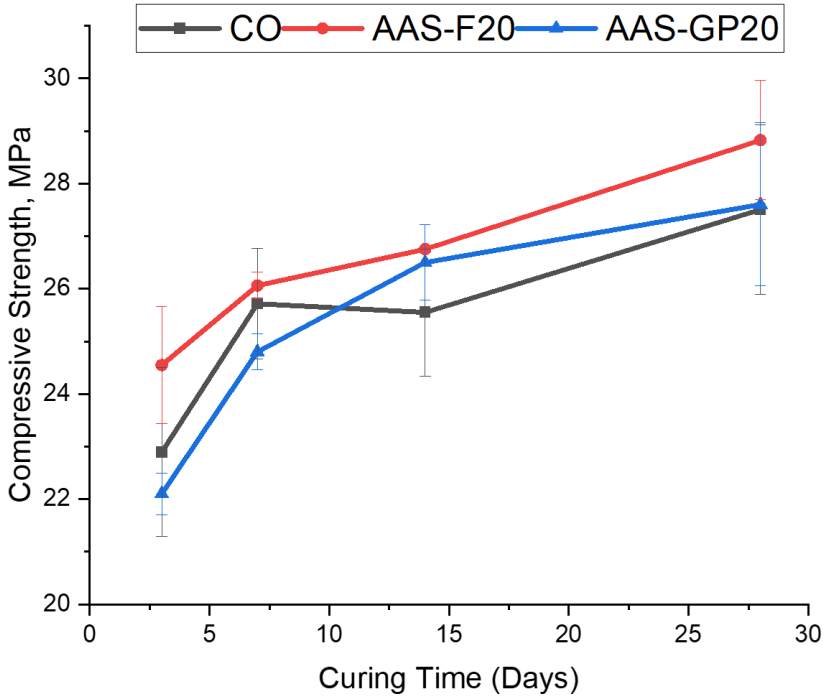


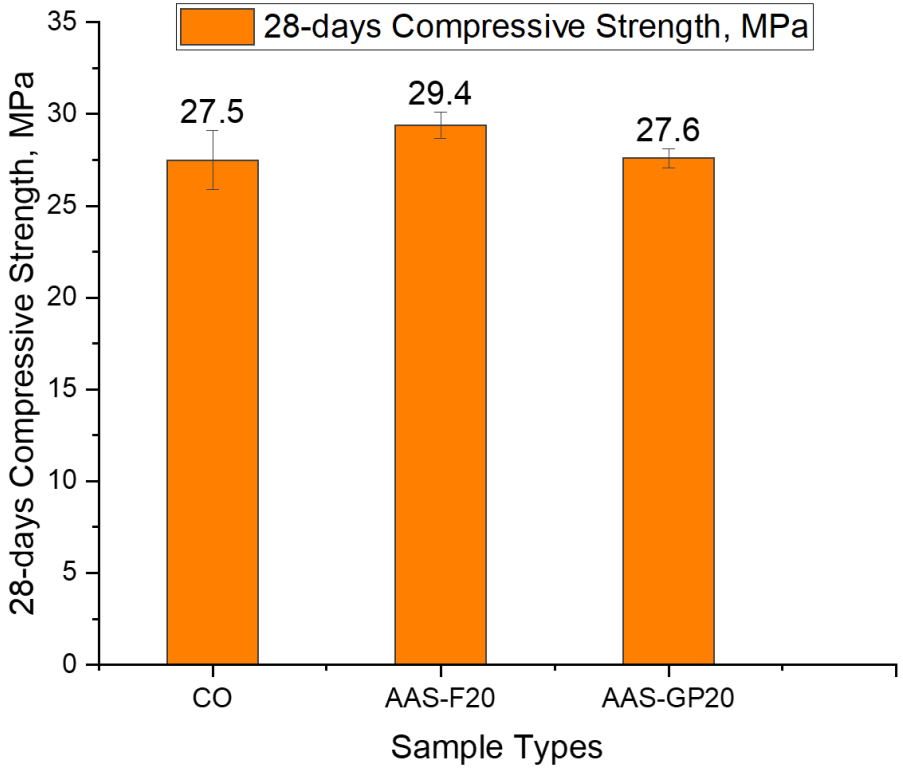
- The replaced glass powder can slightly reduce the drying shrinkage by comparing with control sample
- The replaced fly ash class F can slightly increase the drying shrinkage by comparing with control sample

Outline

- Motivation and Objectives
- Effects of added precursors on AAS binder performance
- Effects of added precursors on AAS mortar performance
- Glass powder–modified AAS mortar performance with added glass sands and recycled steel fibers
- Class F fly ash –modified AAS mortar performance with added glass sands and recycled steel fibers
- Conclusions
- Acknowledgements

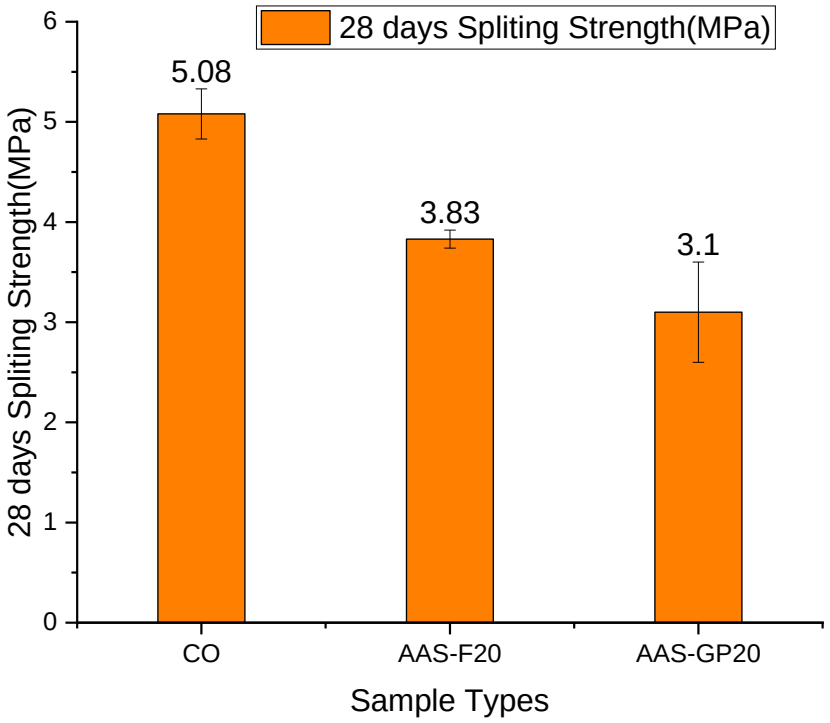
Compressive Strength

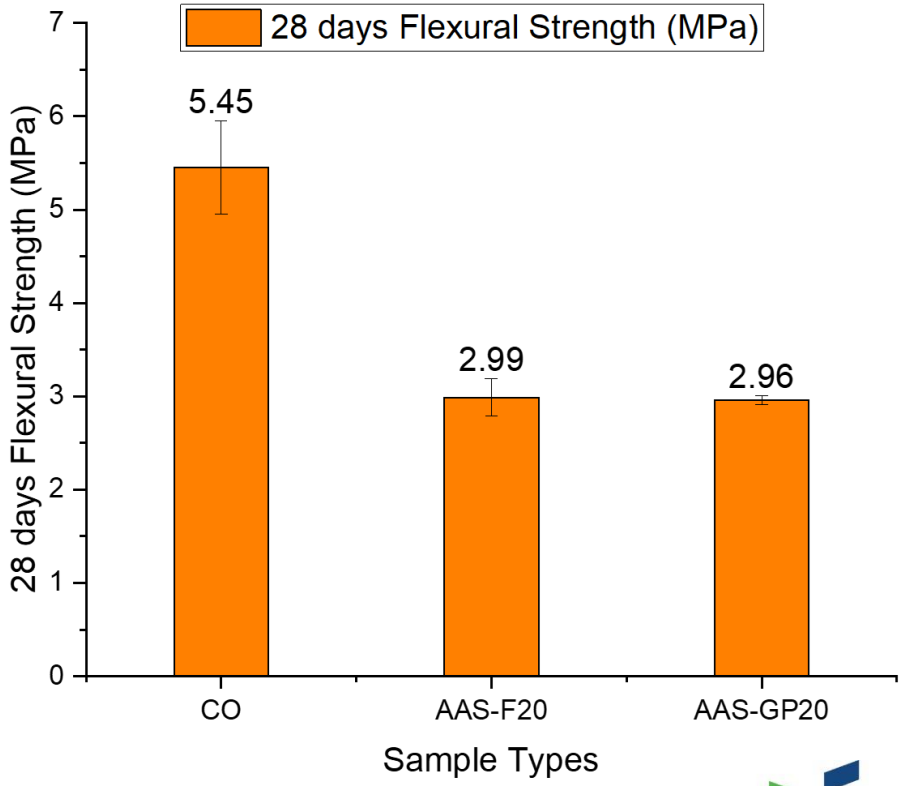




- The compressive strength is slightly increased with replaced Fly ash precursors
- The strength is slightly increased with replaced GP precursors

Split Tensile and Flexural Strength



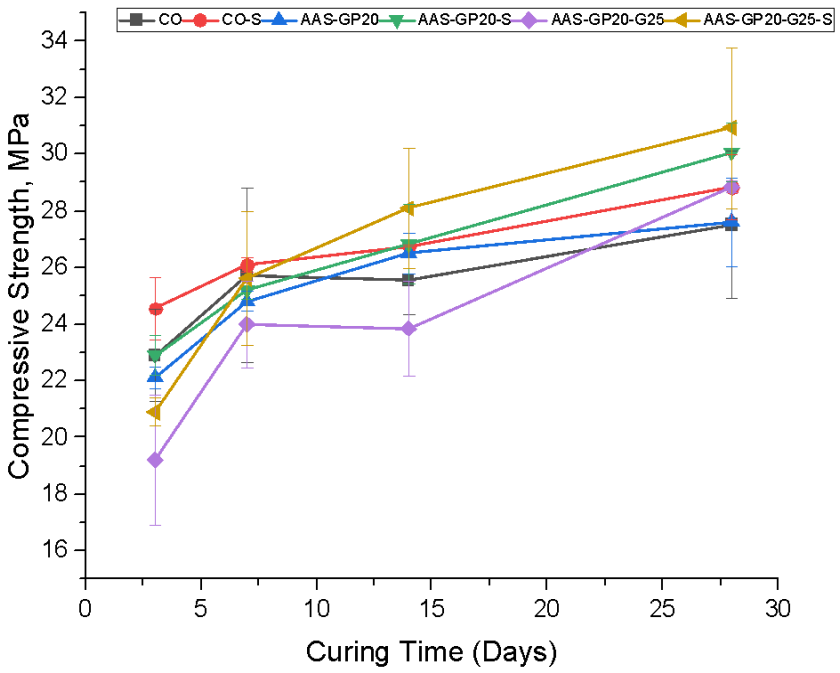


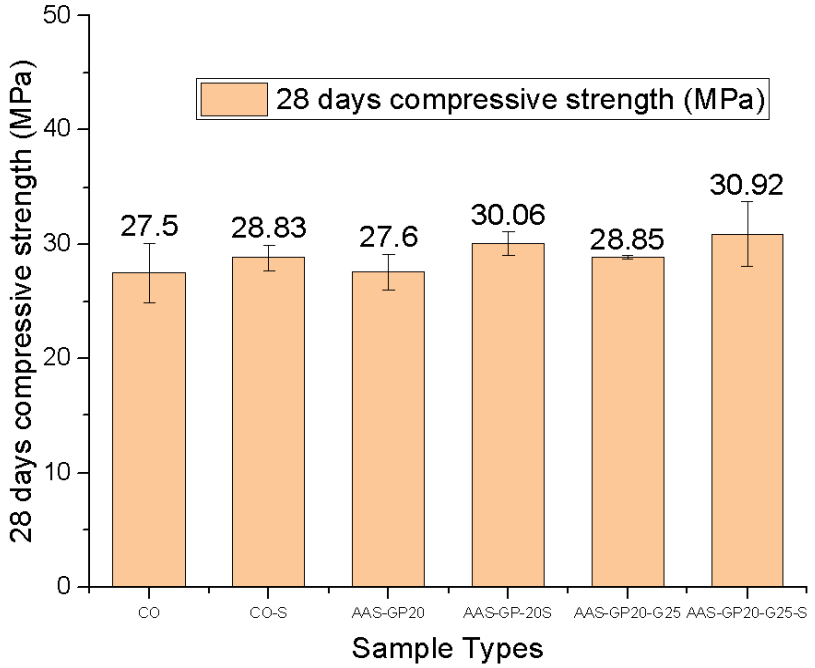
- Both strengths are reduced with 20% precursor replacement
- The large reduction indicate the filling effects of precursors can not contribute to the tensile and flexural strength.

Outline

- Motivation and Objectives
- Effects of added precursors on AAS binder performance
- Effects of added precursors on AAS mortar performance
- Glass powder–modified AAS mortar performance with added glass sands and recycled steel fibers
- Class F fly ash –modified AAS mortar performance with added glass sands and recycled steel fibers
- Conclusions
- Acknowledgements

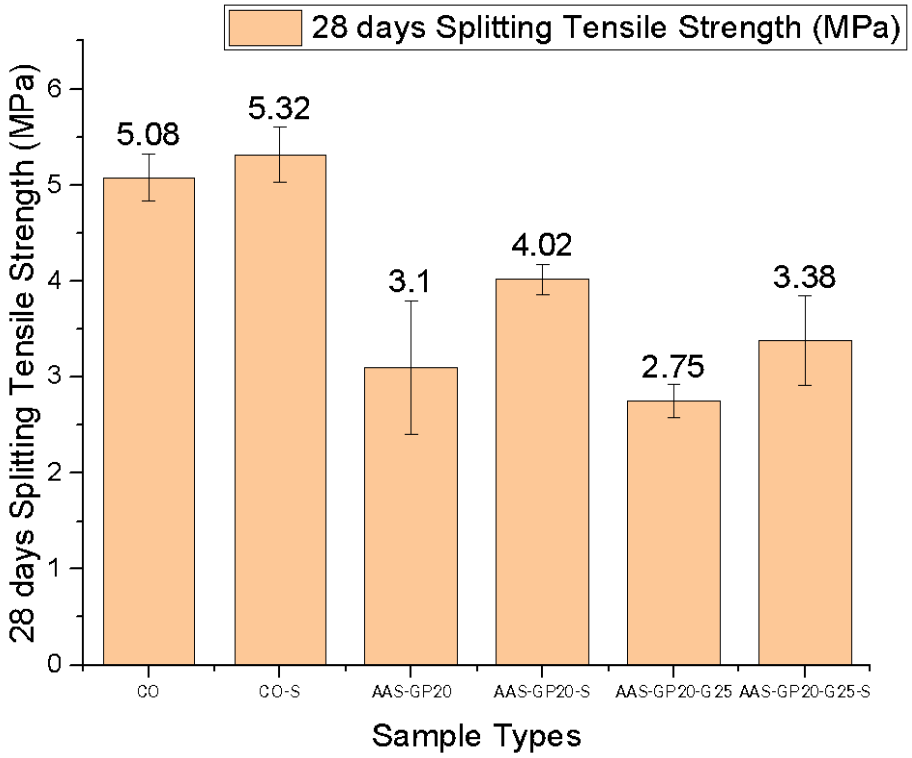
Compressive Strength

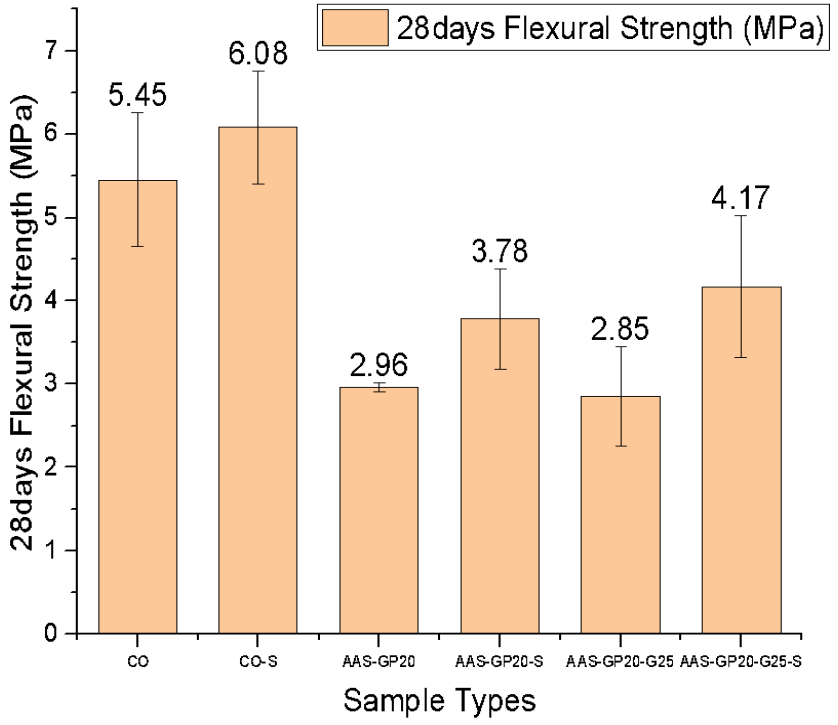




- The compressive strength improves with reinforcement of recycled tire steel fibers
- The strength slightly increases with replaced glass sands

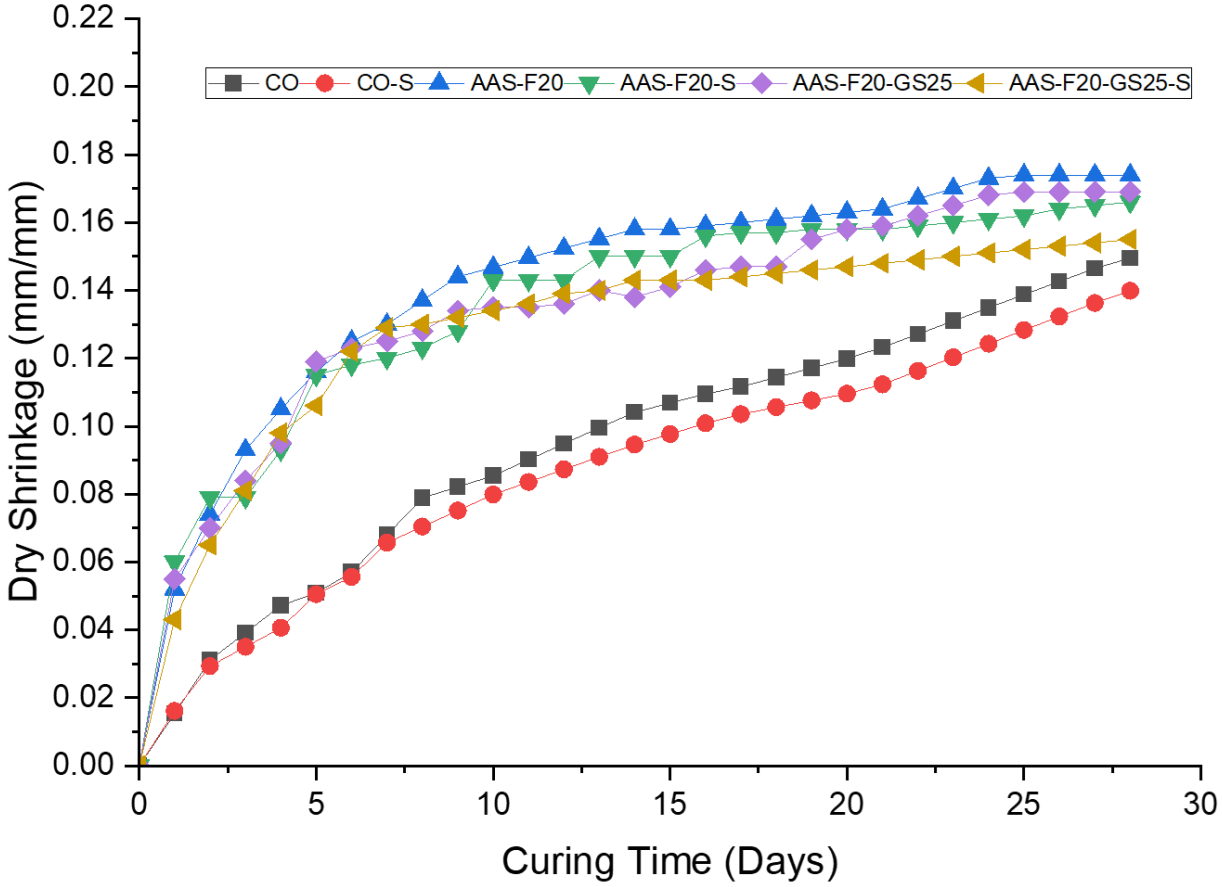
Splitting Tensile and Flexural Strength





- Both strengths are improved with recycled steel fiber reinforcement
- The use of glass sands slightly affect the tensile and flexural strength

Drying Shrinkage

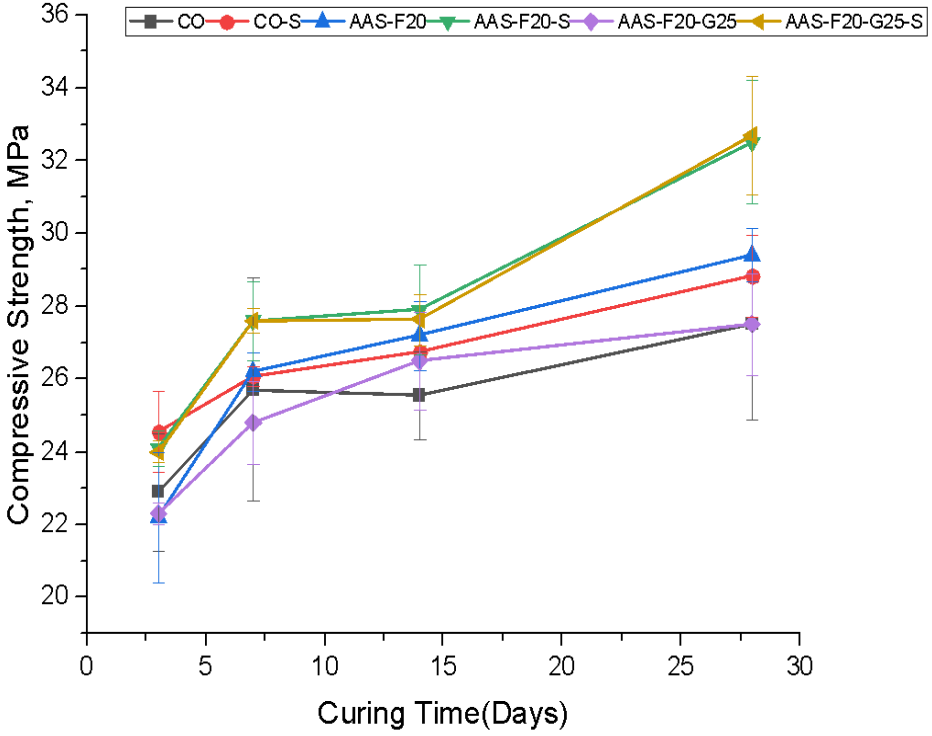


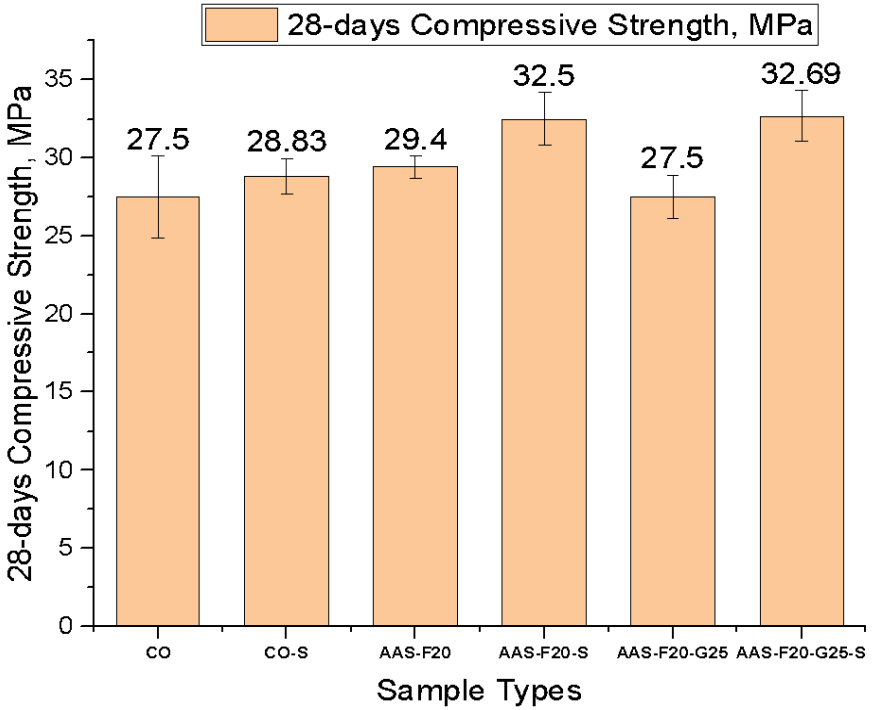
- The added steel fibers can reduce the drying shrinkage deformation of AAS mortar
- The use of glass sands can also reduce the shrinkage deformation of AAS mortar

Outline

- Motivation and Objectives
- Effects of added precursors on AAS binder performance
- Effects of added precursors on AAS mortar performance
- Glass powder–modified AAS mortar performance with added glass sands and recycled steel fibers
- Class F fly ash –modified AAS mortar performance with added glass sands and recycled steel fibers
- Conclusions
- Acknowledgements

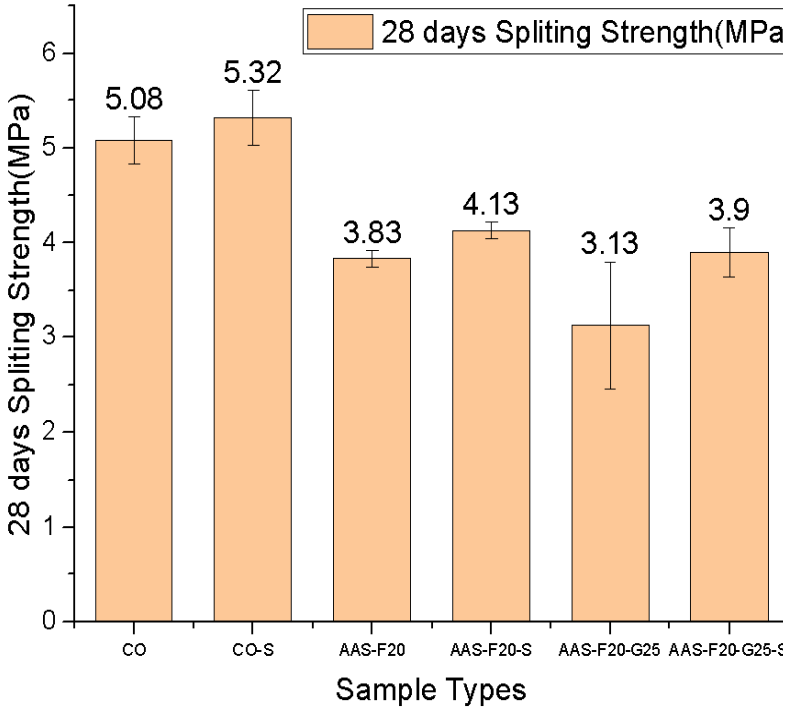
Compressive Strength

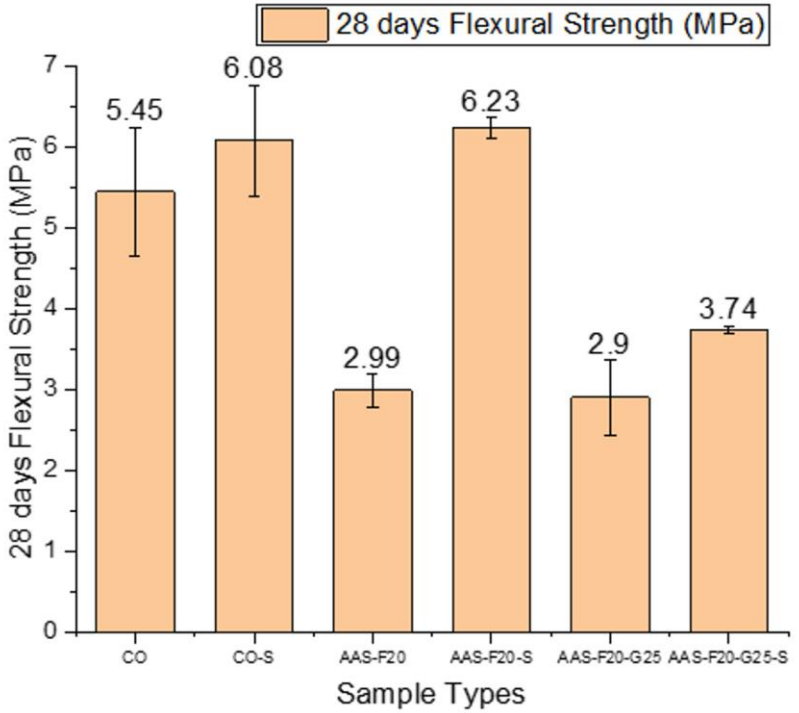




- The compressive strength improves with reinforcement of recycled tire steel fibers
- The strength slightly decreases with replaced glass sands

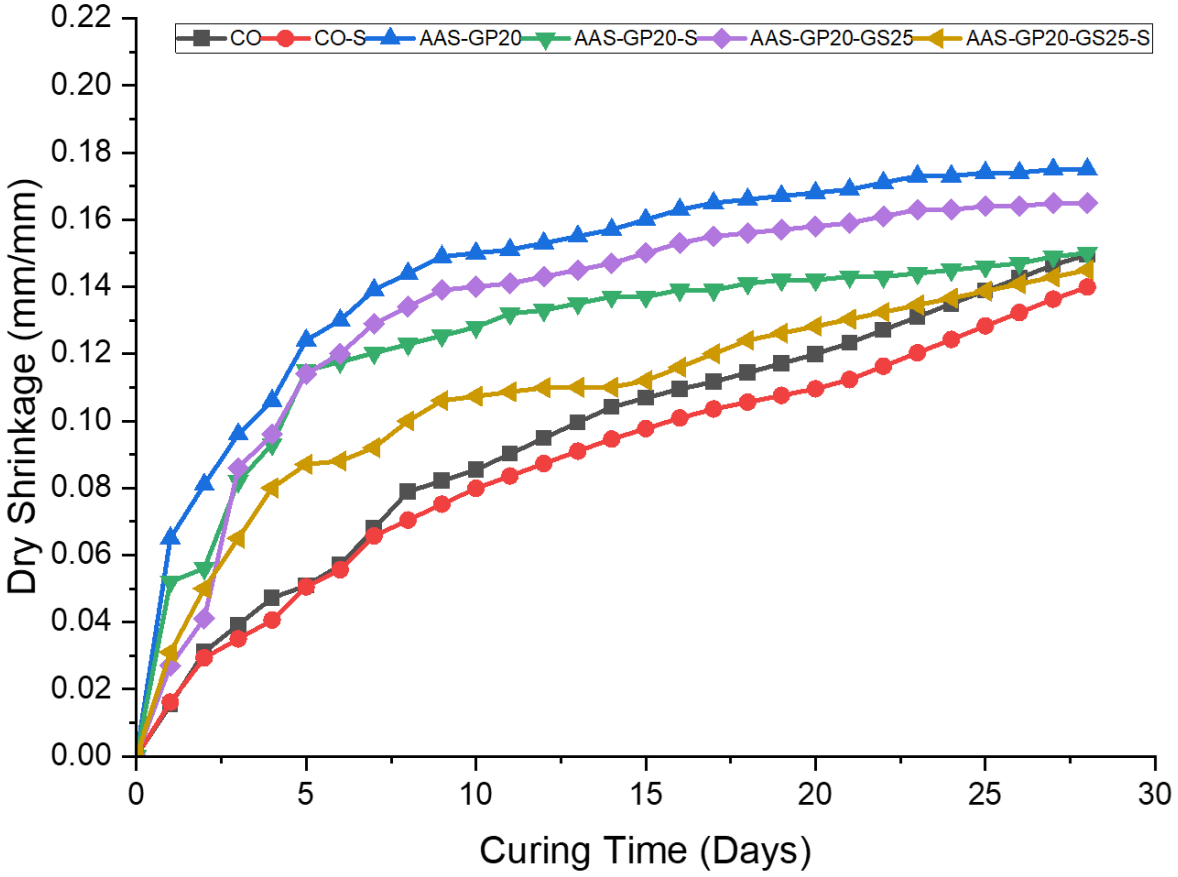
Splitting Tensile and Flexural Strength





- Both strengths are improved with recycled steel fiber reinforcement
- The use of glass sands decrease the tensile and flexural strength

Drying Shrinkage



- The added steel fibers can reduce the drying shrinkage deformation of AAS mortar
- The use of glass sands can also reduce the shrinkage deformation of AAS mortar

Conclusions

1. The replaced GP as precursors do not affect much on compressive strength but can increase the setting time and reduce the total alkali leaching by comparing with control and class F Fly ash AAS binder samples.
2. Comparing with 20% precursor replacement, the 15% replaced GP or class F Fly ash can increase the reacted geopolymer phases as shown in gel pore increases and strength improvement. While 20% replaced precursors are less reacted and used as fillers in the binder.
3. Both replaced precursors can increase the compressive strength but reduced the tensile and flexural strength by comparing with control AAS mortar samples
4. The added recycled tire fibers can be used as reinforcement for strength improvement and shrinkage reduction. The replaced glass sands can also help to reduce the shrinkage deformation

Acknowledgements

- Scrap Tire research grant by the Michigan Department of Environment, Great Lakes, and Energy.

EGLE
MICHIGAN DEPARTMENT OF ENVIRONMENT, GREAT LAKES, AND ENERGY

- MARQUETTE COUNTY SOLID WASTE MANAGEMENT AUTHORITY

Michigan Technological University

Thank you for your attentions!

Dr. Qingli (Barbara) Dai

Professor, Civil, Env. & Geospatial Engineering

Michigan Technological University

Email: qingdai@mtu.edu

Phone: (906) 487-2620