IIBCC 2024 International Inorganic-Bonded Fiber Composite Conference

Sisal fiber-reinforced geopolymer composites:

tailoring durability via matrix composition

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ASCE

Theoretical and Experimental Strategy for the
Control

M

Henrique.

Abstract: Compared with portland-ce
of geopolymeric matrices have brough
can cause efflorescence, a phenomeno
structures. This article proposes apply
geopolymeric matrices, to evaluate an
made using metakaolin as a precursor,
lowest efflorescence formation, highes
9.02 M, and the ratios Na_2O/Al_2O_3, S
Na_2O/Al_2O_3 ratio was the predominan
viable alternative for minimizing free
Society of Civil Engineers.

Author keywords: Efflorescence; G

Construction and Building Materials 364 (2023) 129921

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Asbestos-cement wastes as supplementary
NaOH-activated binders

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ARTICLE INFO

Keywords:
Alkali-activated binder
Asbestos-cement waste
Supplementary precursor
Efflorescence
Electrical conductivity
Mechanical strength

ABSTRACT

The need to remove, eliminat
or incorrectly in the environn
(ACW) and application thereo
activated binders (AAB) with
a sustainable alternative for t
were used. Through the statis
strength, and the skeletal den
the unreacted sodium content
pastes was proposed. The resu
activation products, although
tion. The paste with the lo
compressive strength, equal to
quantifying unreacted sodium
character of this binder.

Waste Management 182 (2024) 225–236

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Waste Management

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Research Paper

Thermally-treated asbestos-
geopolymeric binders: CO_2

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Brant Walkley[a], Cleber M. R. Dias

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Vegetable fibers behavior in geopolymers and alkali-activated cement based matrices: A review

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ARTICLE INFO

Keywords:
Vegetable fiber
Durability
Geopolymer
Alkaline degradation
Cement

ABSTRACT

Alkali-activated binders (AAB) are materials based mainly on silica, alumina, and/or calcium precursors, activated by an alkaline solution, and have mechanical properties equivalent to Portland cement-based matrices. However, their brittle behavior requires the use of reinforcements to make them suitable for dynamic or tensile load applications. Vegetable fibers (VF) could reinforce fragile construction materials, such as mortar and concrete, improving toughness and post-cracking strength. However, little is known about VF durability when used as a reinforcement of AAB. Thus, this work is a literature review regarding the use of VF as an AAB reinforcement, discussing the durability aspects of these fibers as well as future challenges for consideration of the composite. Mechanism of degradation of vegetable fibers in alkali-activated matrices based on sodium has been introduced. Furthermore, this review concluded that surface protection through direct treatments can be an important factor for the durability of vegetable fibers. The main effects of the degradation of composites observed were the reduction in flexural strength and the reduction of matrix/fiber adhesion.

Highlights

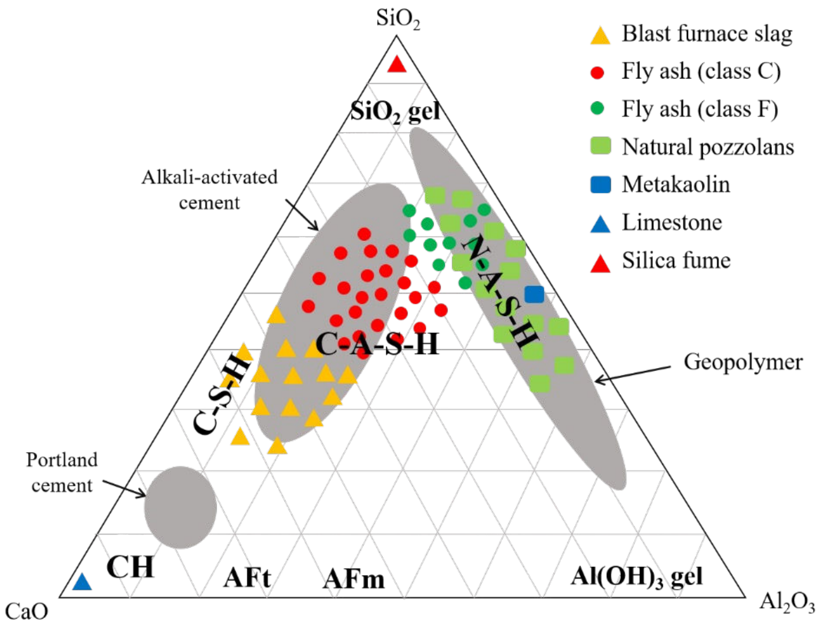
- The matrices of alkali-activated composites (AAC) can be as aggressive to sisal fibers as those of cement-based matrices
- The content of free ions in AAC is a critical factor affecting the degradation rate of vegetable fibers
- A high content of free ions in AAC can lead to rapid composite degradation, even under laboratory exposure
- After 120 days of natural weathering, sisal fibers play a significant role in maintaining the post-cracking load capacity

Topics of this presentation

- Brief contextualization
- Experimental procedures
    - Materials
    - Mixture design and optimization
    - Durability study
        - Lab exposure and natural weathering
- Results
- Conclusions

Brief contextualization

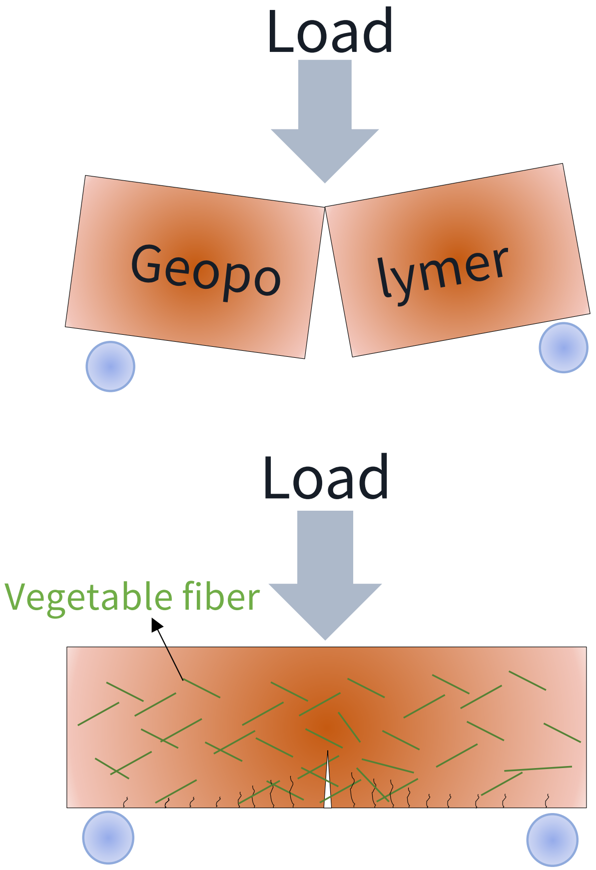
Geopolymers and alkali-activated binders



Adapted from Scrivener and Nonat (2011)

- Geopolymers or alkali-activated binders (AAB) are produced using a precursor material combined with an alkaline activator
- They can be classified as one-part or two-part AAB
- Research on vegetable fibers reinforced AAC is still in its early stages

Fiber-reinforced alkali-activated composites



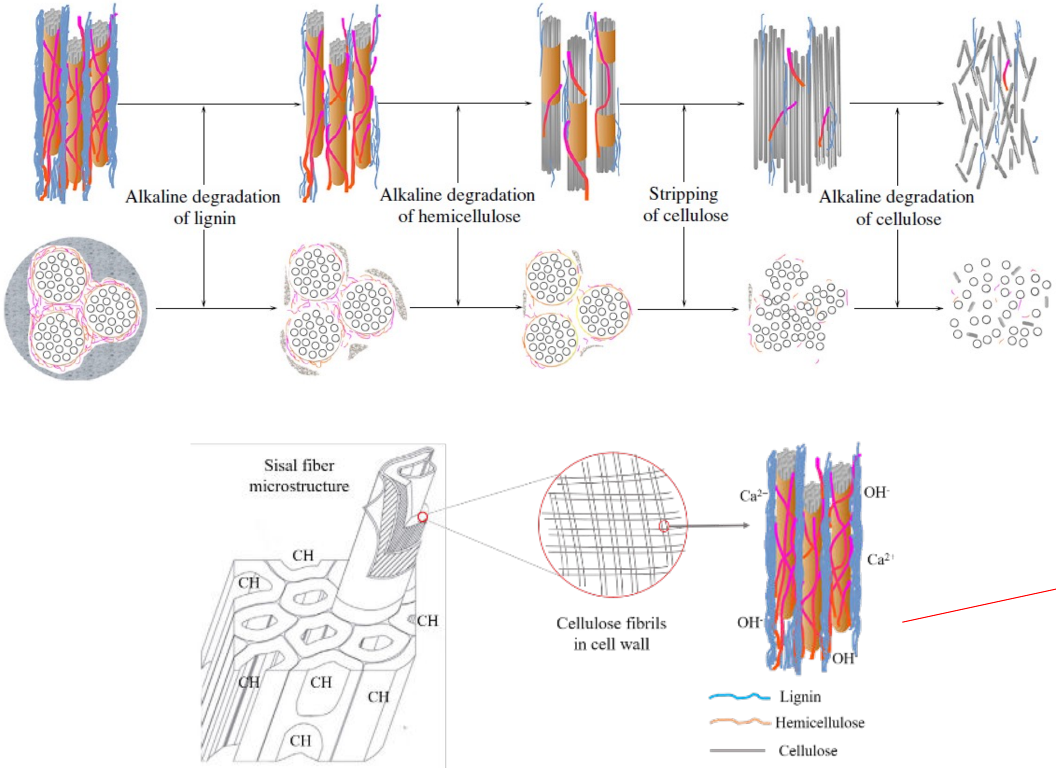
Geopolymers or alkali-activated binder (AAB)

- High strength if well dosed
- Resistance to aggressive environment
- Low CO_2 depending on the precursor
- Like PC-based matrices, geopolymers presents a brittle fracture and low toughness

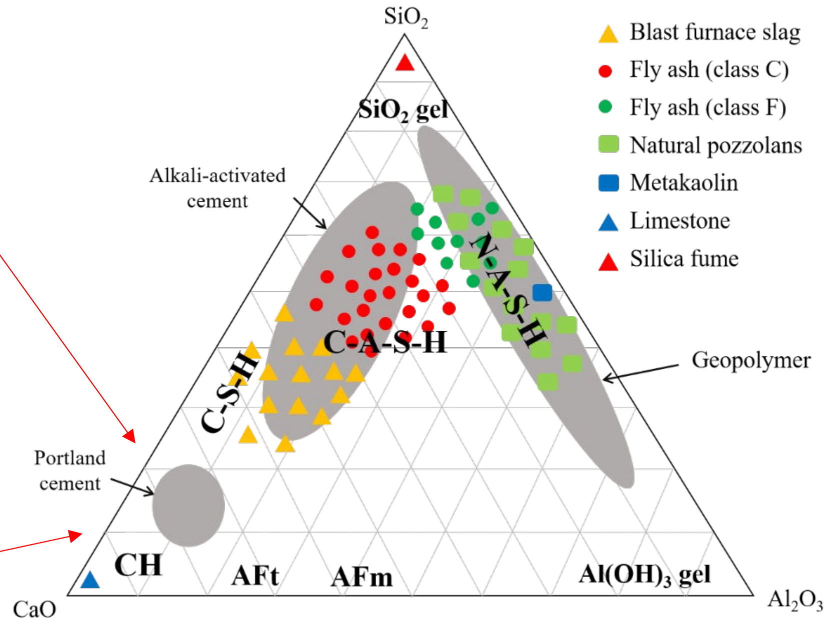
Vegetable fibers

- Improve strength and toughness
- Renewable
- Low cost
- Available in several developing countries

Known degradation mechanisms of fibers



Wei and Meyer (2015)



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Durability studies

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Weathering results were not published

Main questions

- Do vegetable fibers deteriorate in alkali-activated matrices?
- What are the possible mechanisms of degradation?
- How to mitigate the fibers degradation?
  - The use of pozzolans and carbonation for this purpose does not seem reasonable

Experimental procedures

Materials

- Precursors
    - Metakaolin
    - Heat-treated asbestos-cement waste (ACW_T)
- Activators
    - Liquid sodium silicate solution (LSS)
    - Liquid potassium silicate solution (LKS)
- 25 mm-long sisal fibers without treatment

Precursors


Metakaolin


ACW_T

Materials used for activator preparation


NaOH / KOH flakes


Silica fume

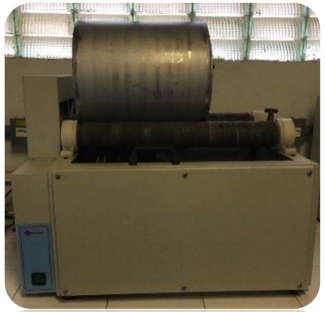

Distilled Water

Obtaining the ACW_T

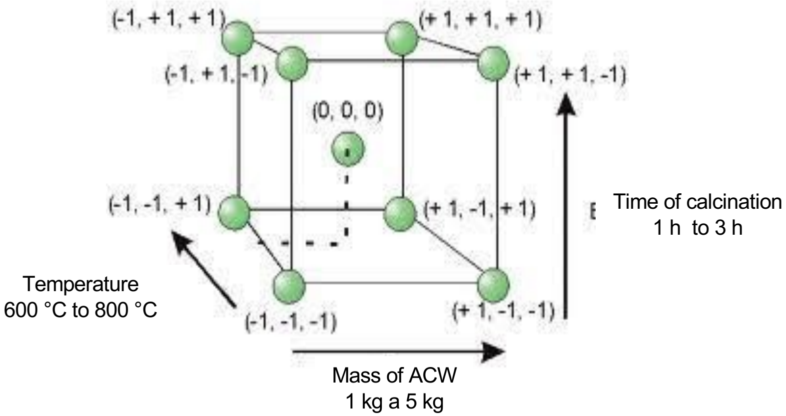
Fragmented asbestos-cement wastes (ACW)

Thermal treatment

Milling



Sieving



TGA and XRD

- % crysotile= 0%
- Max. % C_2S
- Min. CO_2 emission
- Min. energy

$\mathbf{ACW_T}$

Precursors

Determination	Chemical composition (wt/wt %)	
	Metakaolin	ACW_T
SiO_2	44.88	18.20
Al_2O_3	42.86	4.06
Fe_2O_3	4.82	2.35
K_2O	0.72	0.34
SO_3	0.13	1.66
MgO	0.67	7.27
MnO	0.11	-
CaO	-	48.69
Others	1.41	1.13
LOI (1000 °C)	4.23	16.30

Skeletal density (g/cm^3)	2.80	2.95
Surface area BET (m^2/g)	30.52	6.68

Preparation of activators

LSS	27% SiO_2	52% H_2O	21% NaOH
LKS	27% SiO_2	49% H_2O	24% KOH

Stirred for 2 minutes

Mixture design

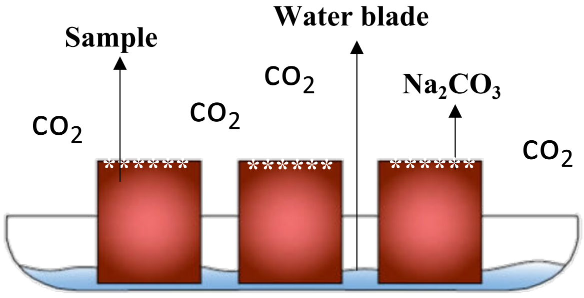
Series	Mass fraction		
	MK	ACW_T	Silicate solution
F1	0.436	0.040	0.525
F2	0.311	0.089	0.600
F3 e F12	0.251	0.200	0.549
F4, F10 e F11	0.350	0.100	0.550
F5	0.400	0.100	0.500
F6	0.200	0.200	0.600
F7 e F15	0.414	0.000	0.586
F8	0.500	0.000	0.500
F9 e F16	0.325	0.175	0.500
F13	0.360	0.040	0.600
F14	0.254	0.146	0.600
Min.	**0.200**	**0.000**	**0.500**
Max.	**0.500**	**0.200**	**0.600**

Molar ratios

- SiO_2/Al_2O_3 varied from 2.93 to 5.03
- CaO/SiO_2 varied from 0 to 0.39
- Na_2O/Al_2O_3 varied from 0.66 to 1.79 for LSS series
- K_2O/Al_2O_3 varied from 0.54 to 1.46 for LKS series

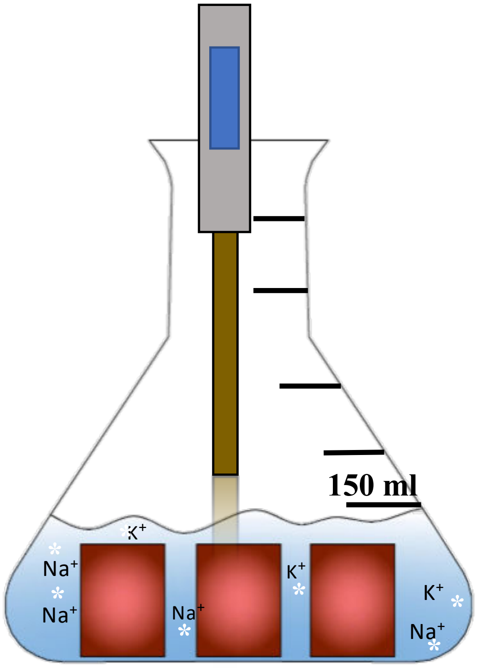
Main experimental responses

- Electrical conductivity
  - Depends on the content of free ions in the mixture
  - Obtained using cubes immersed in distilled deionized water and measuring the conductivity of solution after 2 h
- Compressive strength of cubes with 40 mm edges



Efflorescence test

Conductivity meter



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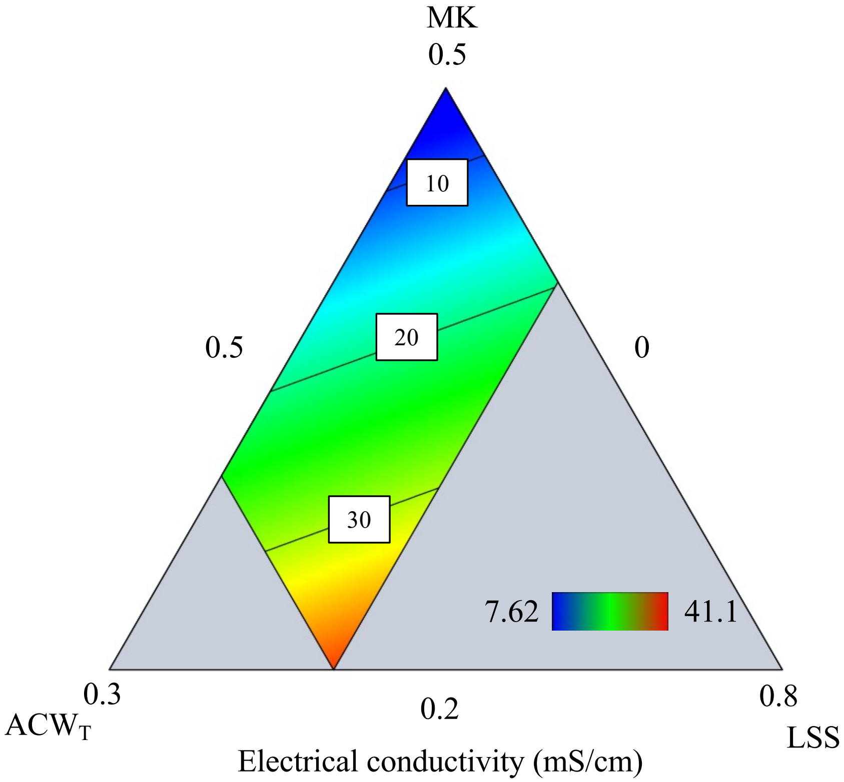
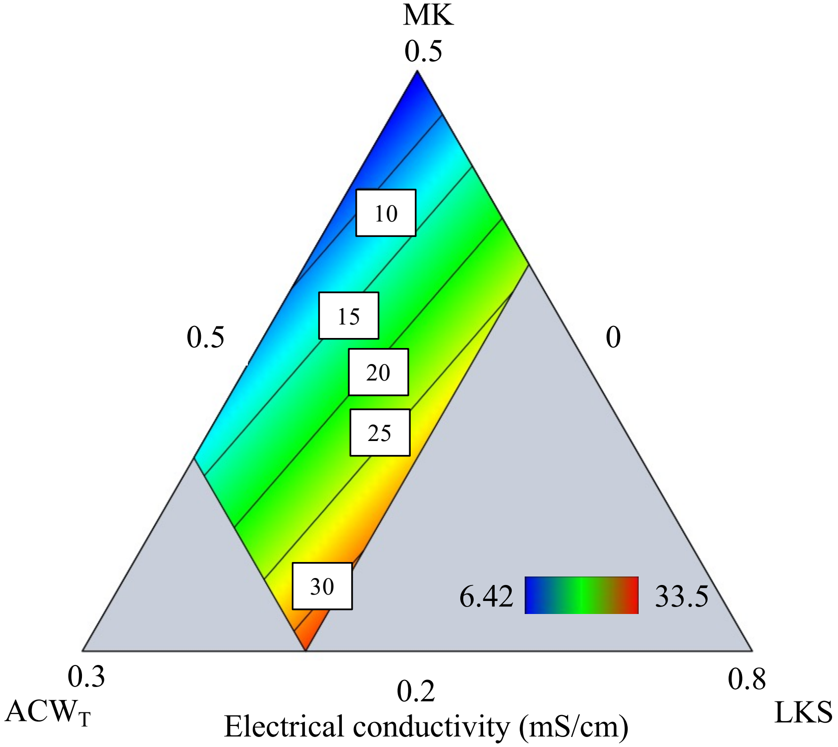


$$\sigma = -69{,}55 \times MK + 27{,}24 \times ACW_T + 79{,}24 \times \mathrm{LSS}$$

$$R^2_{adj} = 0.95$$

Main experimental responses

- Electrical conductivity
  - Depends on the content of free ions in the mixture
  - Obtained using cubes immersed in distilled deionized water, with the conductivity of the solution recorded after 2 hours
- Compressive strength test conducted on cubes with 40 mm edges



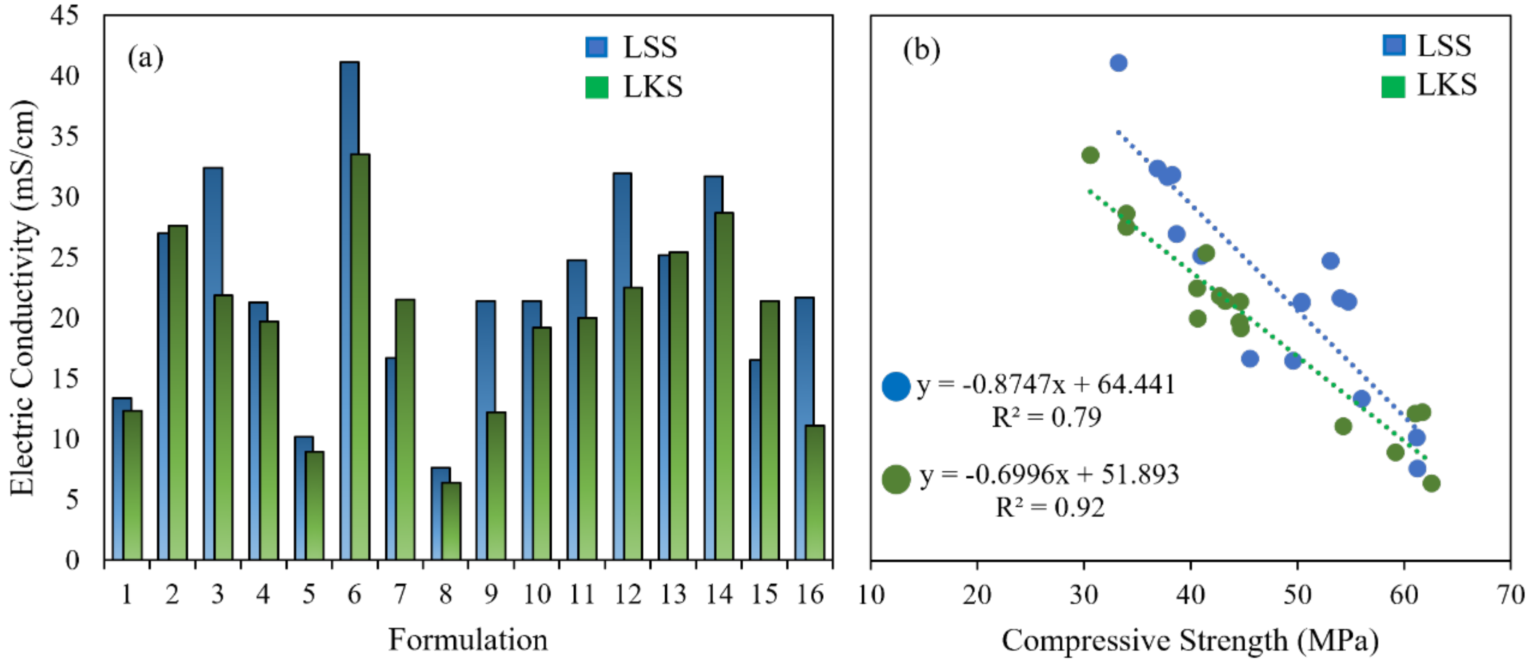
Electrical conductivity (mS/cm)

$$\sigma = -87{,}59 \times MK - 50{,}23 \times ACW_T + 99{,}16 \times \mathrm{LKS}$$

$$R^2_{adj} = 0.99$$

Main experimental responses

- Compressive strength of cubes with 40 mm edges

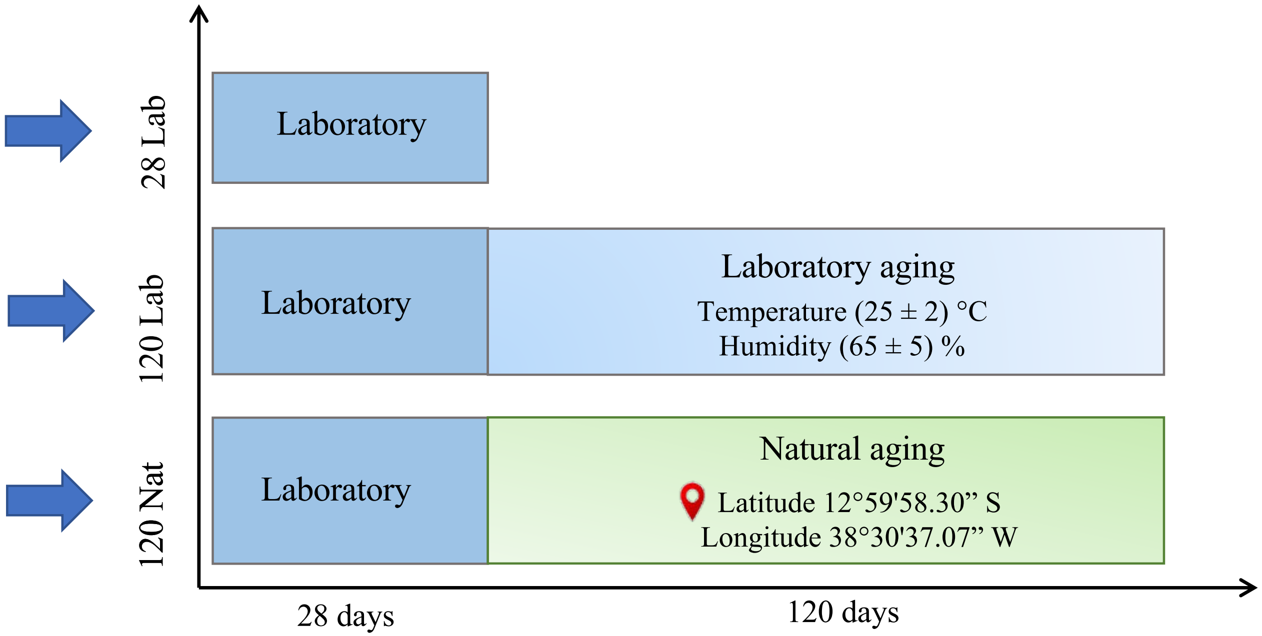


Optimized matrices

Series*	Mass fraction			Properties		
	MK	ACWT	Silicate solution	Compressive strength (MPa)	ρ (g/cm²)	σ (mS/cm)
Na_{min}	0.474	0.013	0.513	60.35	2.35	7.88
Na_{max}	0.286	0.127	0.586	40.42	2.14	28.60
K_{min}	0.490	0.000	0.510	57.36	2.44	7.58
K_{max}	0.252	0.148	0.600	33.55	2.25	28.50

Natural weathering

- Fiber content was 2.5% by mass of the precursor
- Prismatic specimens with 230 mm x 50 mm x 10 mm
    - LOP and specific energy from 3-point bending tests were the indicators of degradation



28 Lab

Laboratory

120 Lab

Laboratory

Laboratory aging

Temperature (25 ± 2) °C

Humidity (65 ± 5) %

120 Nat

Laboratory

Natural aging

Latitude 12°59'58.30” S

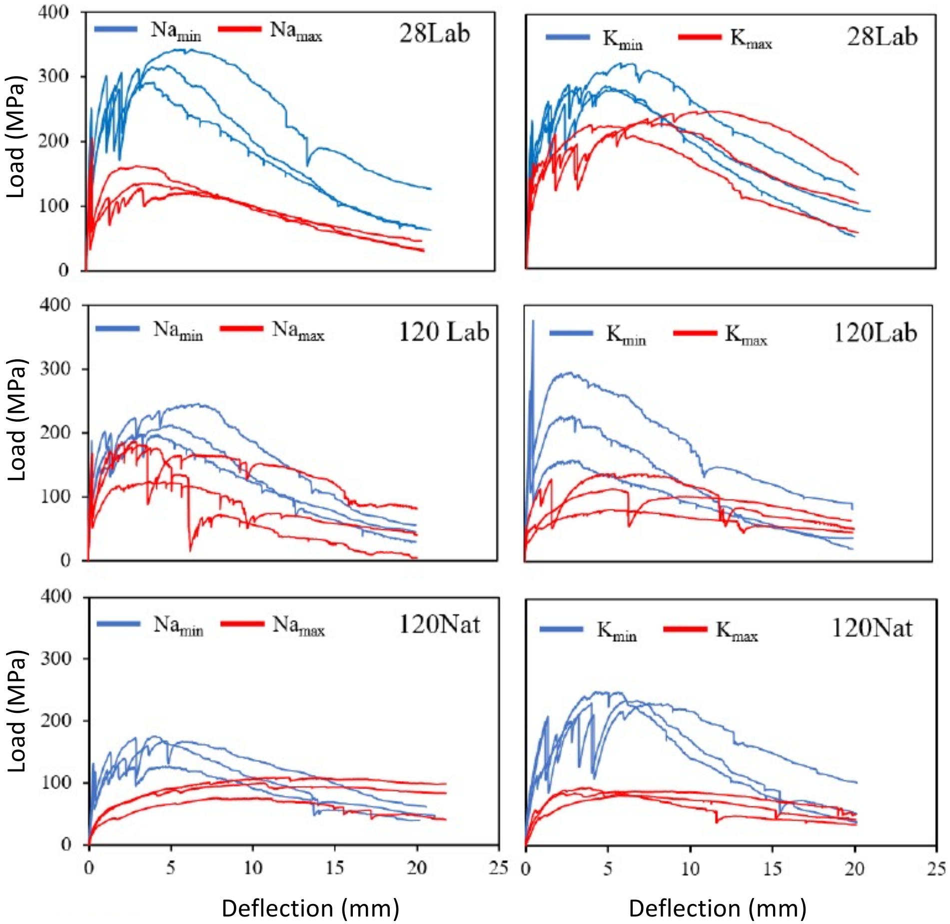
Longitude 38°30'37.07” W

28 days

120 days

Results

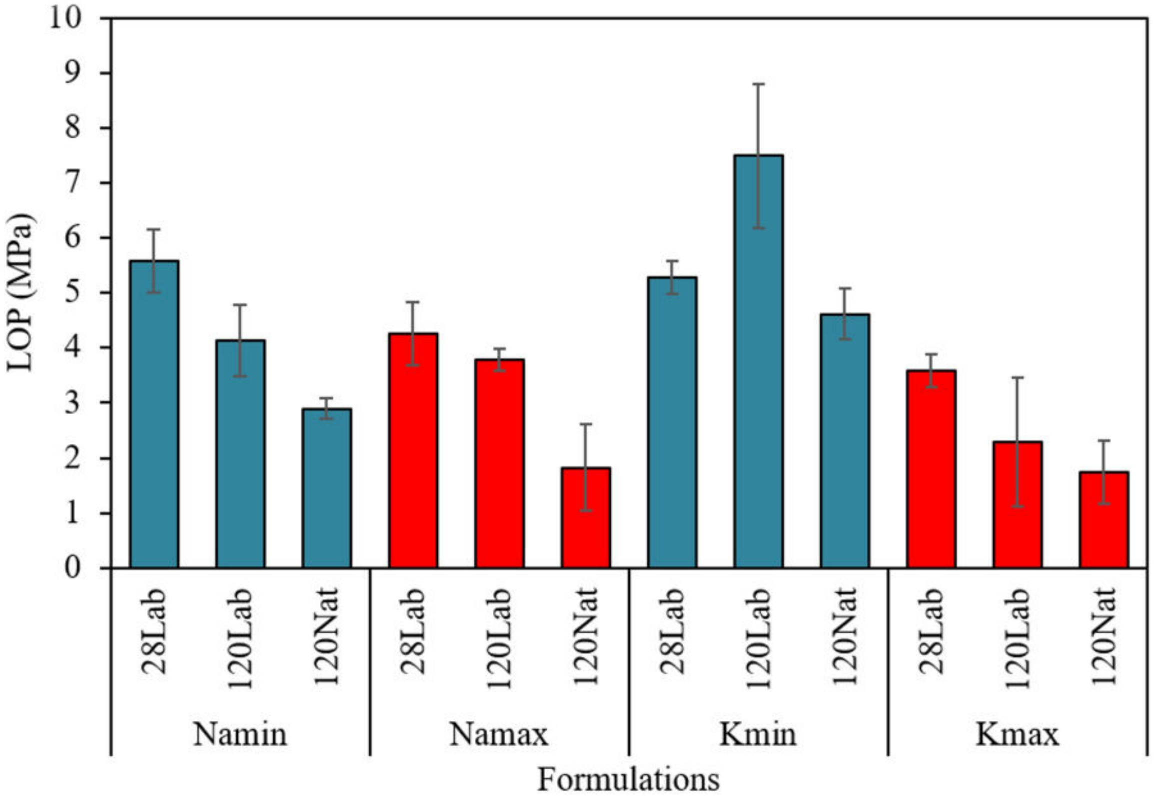
Load x deflection curves



Main findings

- Sisal fibers are promoting post-cracking strength for all series even after 120 day of exposure
- Series with a higher content of free ions exhibited lower performance, regardless of the type of exposure
- Natural weathering proved to be more severe than laboratory conditions
- Under natural weathering, the K$_{min}$ series demonstrated the best performance
- At the maximum free ion content, both Na and K series caused significant changes in the behavior of the composites

Limite of proportionality



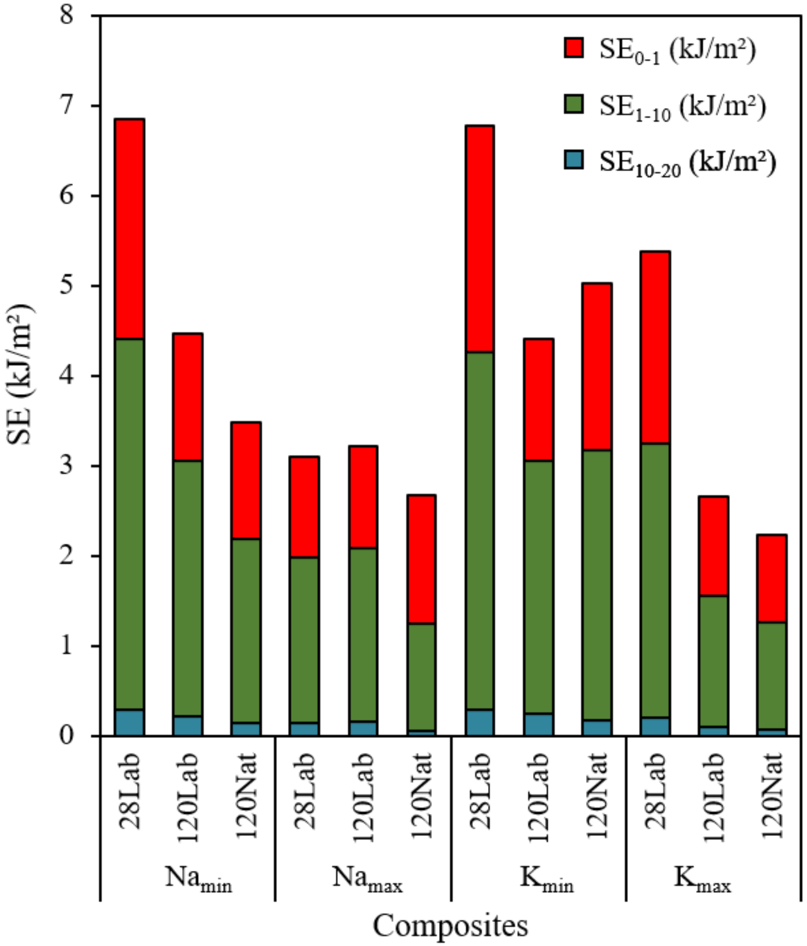
Main findings

- Natural weathering caused greater reductions in the LOP compared to laboratory conditions
- Even at minimum concentrations, Na ions seem to induce a rapid decrease in the LOP
- For the K_{min} series, changes in the LOP were minimal
- At the maximum free ion content, both Na and K series significantly affected the LOP

Specific energy

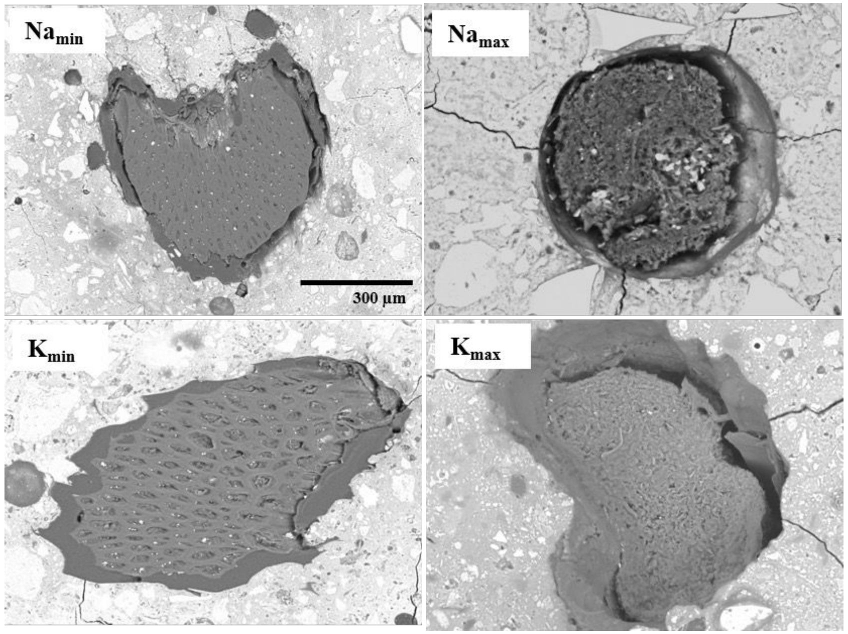
Main findings

- Specific energy (SE) decreases over time, even under laboratory conditions
- Na ions appear to be more aggressive than K ions
- Even at minimum concentrations, Na-free ions cause rapid changes in specific energy
- The matrices of the K_{min} series seem to be the least severe for fiber deterioration
- At the maximum free ion content, both Na and K series significantly impacted SE, regardless of the exposure conditions

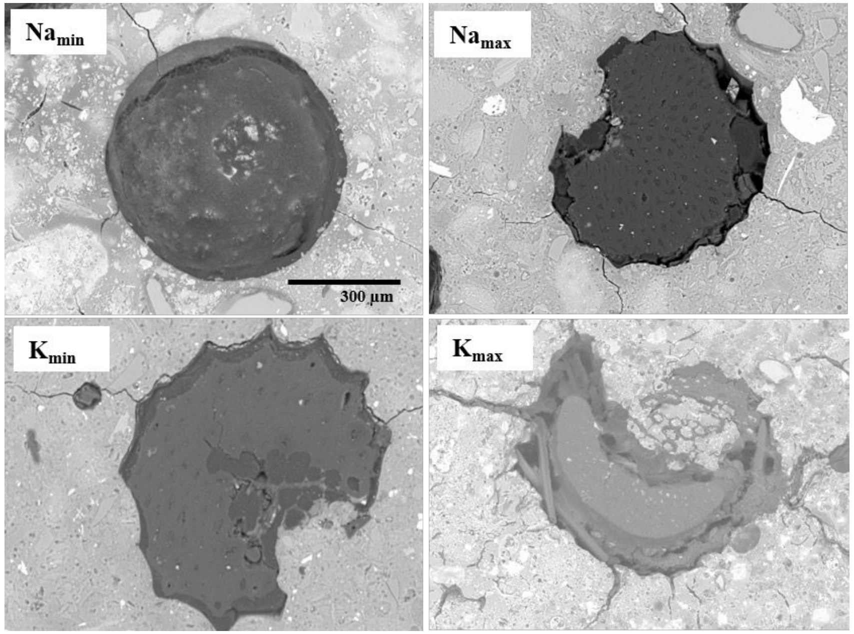


Microstructural analysis

120Lab



120Nat



Main finding

- At the maximum free ion content, both Na and K series significantly affected fiber integrity and caused damage to the fiber-matrix interface zones

The main conclusions

- Sisal fibers continue to provide post-cracking strength to composites, regardless of the free ion concentration or type of exposure
- The concentration of free ions is a critical factor influencing the degradation rate of vegetable fibers
- Even under laboratory conditions, fiber degradation in AAC is inevitable
- Controlling the aggressiveness of the matrix is a promising strategy to mitigate sisal fiber degradation in alkali-activated composites

Thank you!

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