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Sisal Fibers Degradation in Cement-Based Composites:

The effects of thermal curing conditions and metakaolin content

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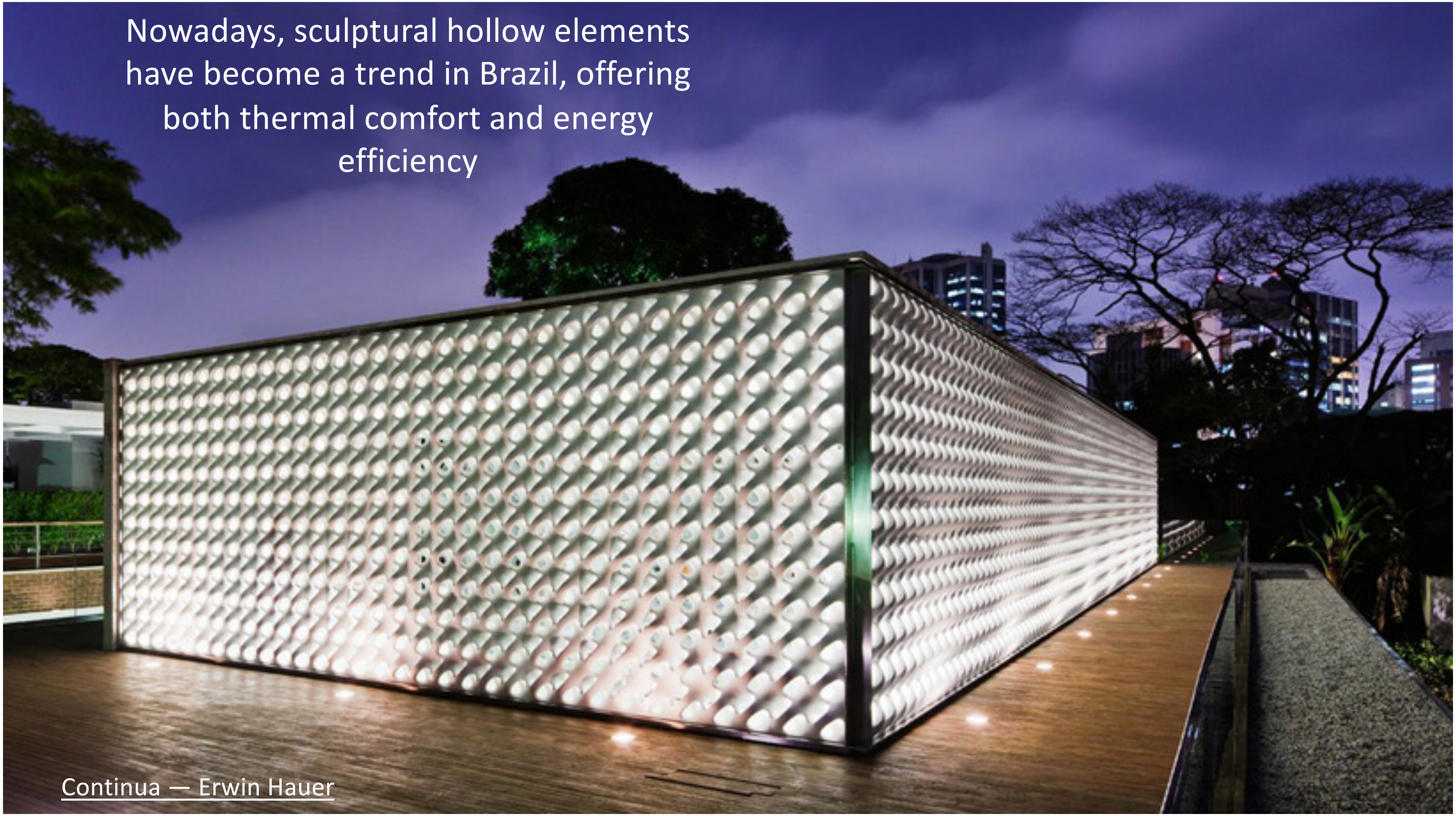
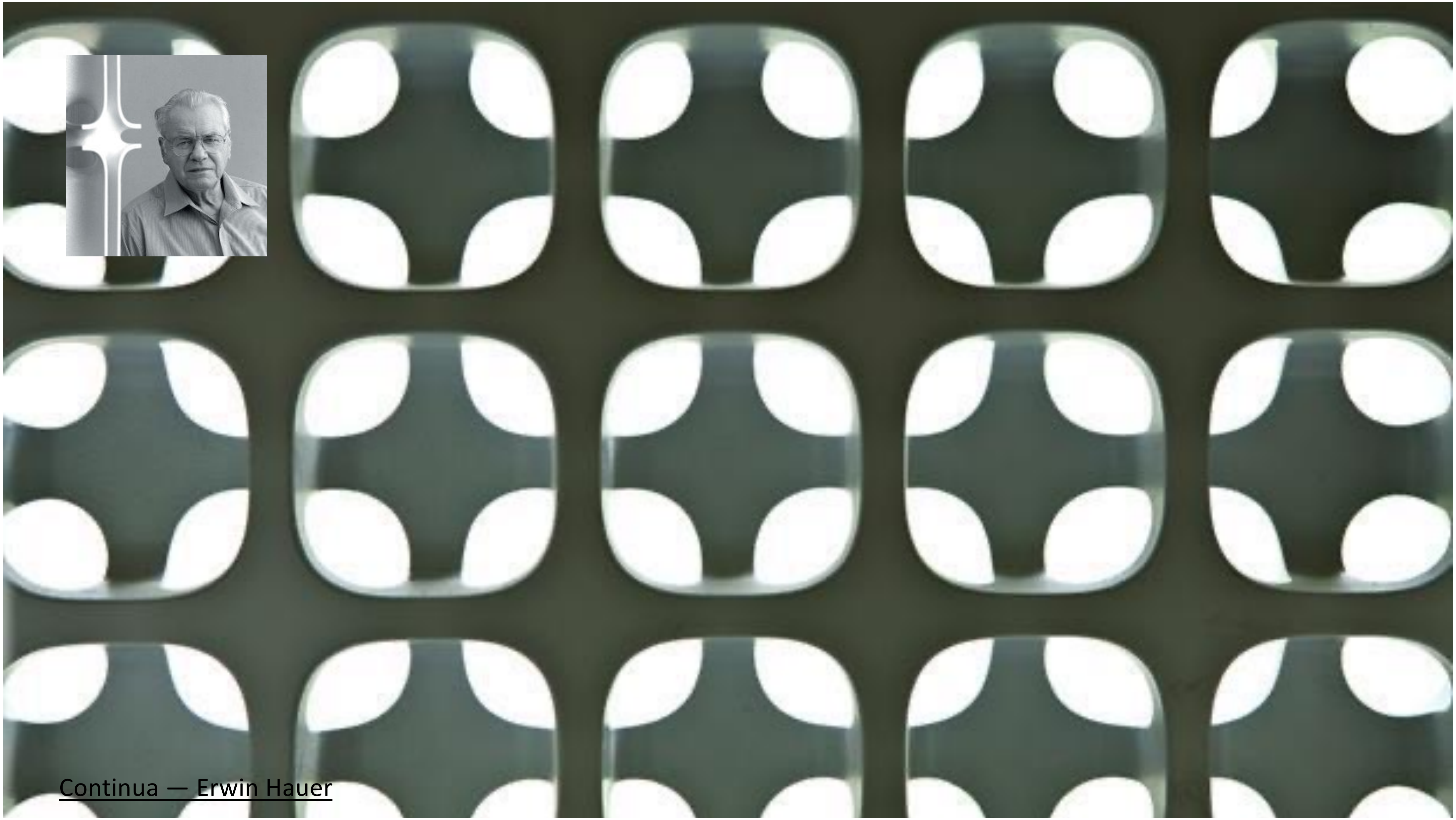
Topics of this presentation

- Brief contextualization
- Experimental procedure
    - Materials
    - 2^k factorial design
    - Strand-in-cement test
        - XRD of the matrix
        - Tensile strength of fibers
- Results
- Main findings

Brief contextualization


Aiming for thermal comfort, hollow elements were common in Brazilian architectural designs in the mid-20th century.
http://www.eng.ufba.br/historia


Nowadays, sculptural hollow elements have become a trend in Brazil, offering both thermal comfort and energy efficiency
Continua — Erwin Hauer



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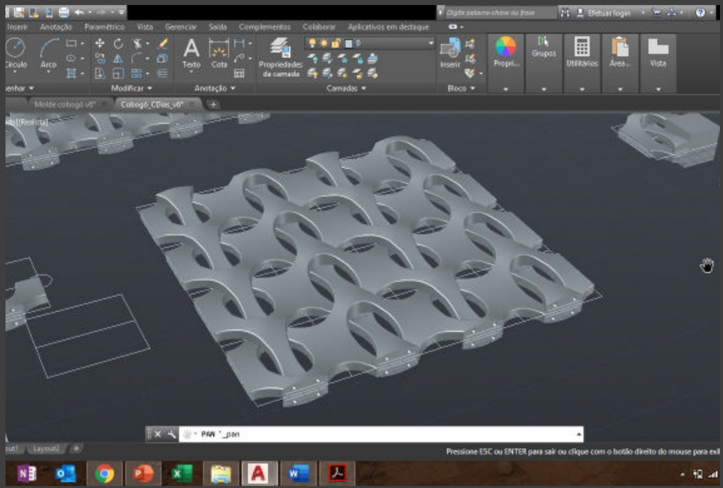
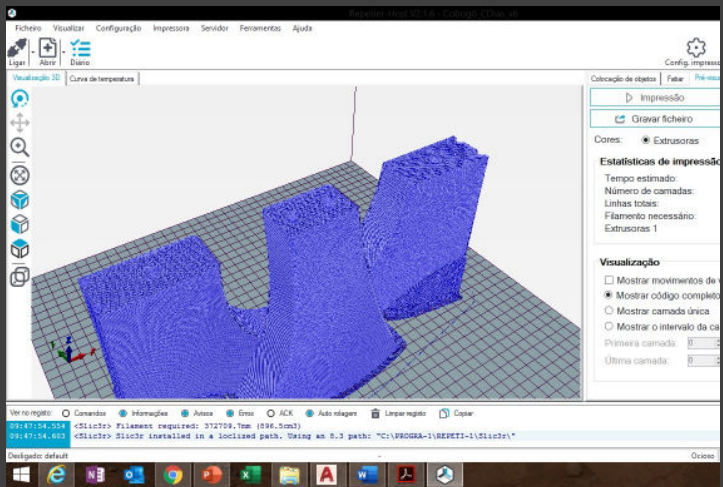
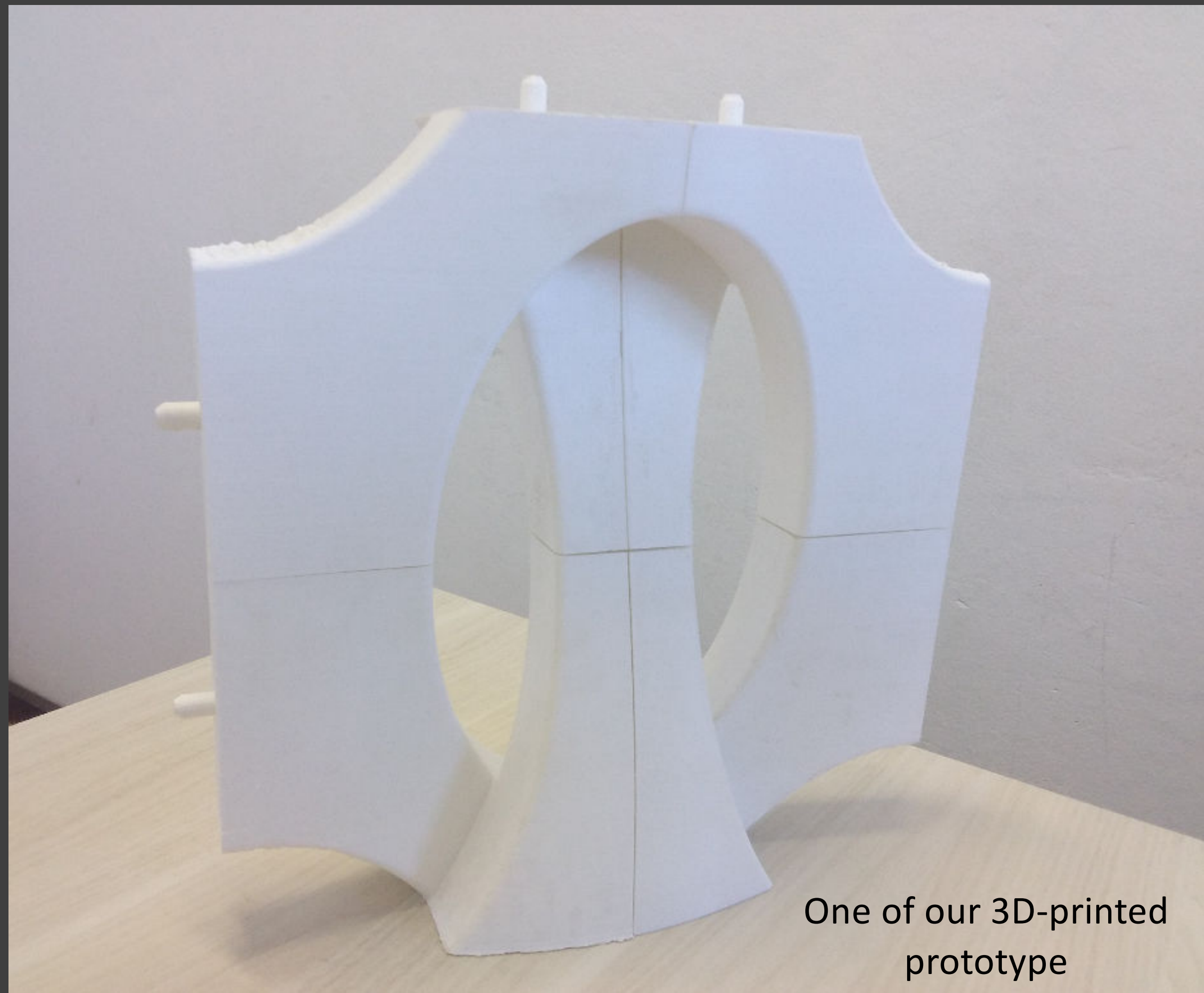






One of our 3D-printed prototype

Questions

If hollow elements are produced using sisal fiber-reinforced cementitious composites:

- Can thermal curing be applied to accelerate strength development and reduce demolding time without causing sisal fiber degradation?
- Can metakaolin be used to mitigate sisal fiber degradation during thermal curing?

Experimental

Materials

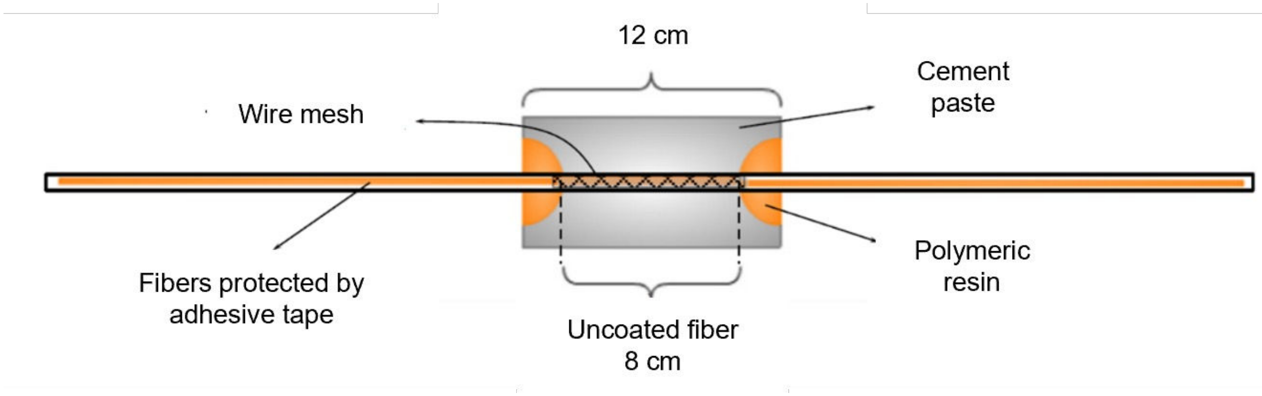
- High-early-strength Portland cement
  - Approx.10% limestone filler
- Metakaolin
- Sisal fibers subjected to hornification
  - 5 wetting-and-drying cycles
  - Sisal fibers exhibited a tensile strength of (317.80 ± 36.16) MPa after hornification treatment

2^k factorial design

Factors	Minimum	Maximum
Metakaolin content **MK**	0	40%
Curing temperature **T**	25°C	80°C
Curing time **t**	24 h	72 h

Series		Codified level of factors			Actual level of factors		
Run order	Label	MK	T	t	MK (%)	T (°C)	t (h)
S10	MK40%_80°C_72H	+1	+1	+1	40	80	72
S2	MK40%_80°C_24H	+1	+1	-1	40	80	24
S7	MK40%_25°C_72H	+1	-1	+1	40	25	72
S8	MK40%_25°C_24H	+1	-1	-1	40	25	24
S6	MK0%_80°C_72H	-1	+1	+1	0	80	72
S11	MK0%_80°C_24H	-1	+1	-1	0	80	24
S3	MK0%_25°C_72H	-1	-1	+1	0	25	72
S9	MK0%_25°C_24H	-1	-1	-1	0	25	24
S1	MK20%_52.5°C_48H	0	0	0	20	52.5	48
S4	MK20%_52.5°C_48H	0	0	0	20	52.5	48
S5	MK20%_52.5°C_48H	0	0	0	20	52.5	48
Minimum		**-1**	**-1**	**-1**	**0**	**25**	**24**
Maximum		**+1**	**+1**	**+1**	**40**	**80**	**72**

Strand-in-cement test



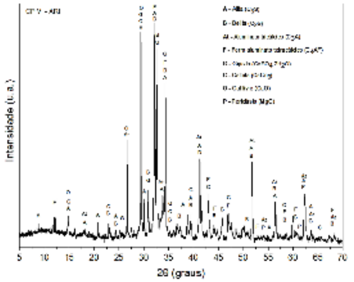
Based on the Wei and Meyer (2014) procedure

- The strand-in-cement test allows contact between the fibers and pore water without matrix adhesion

Water bath

Experimental responses

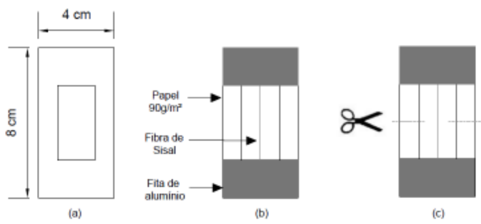
Matrix phases analyzed by XRD after hydration stoppage



Specimen after the curing process

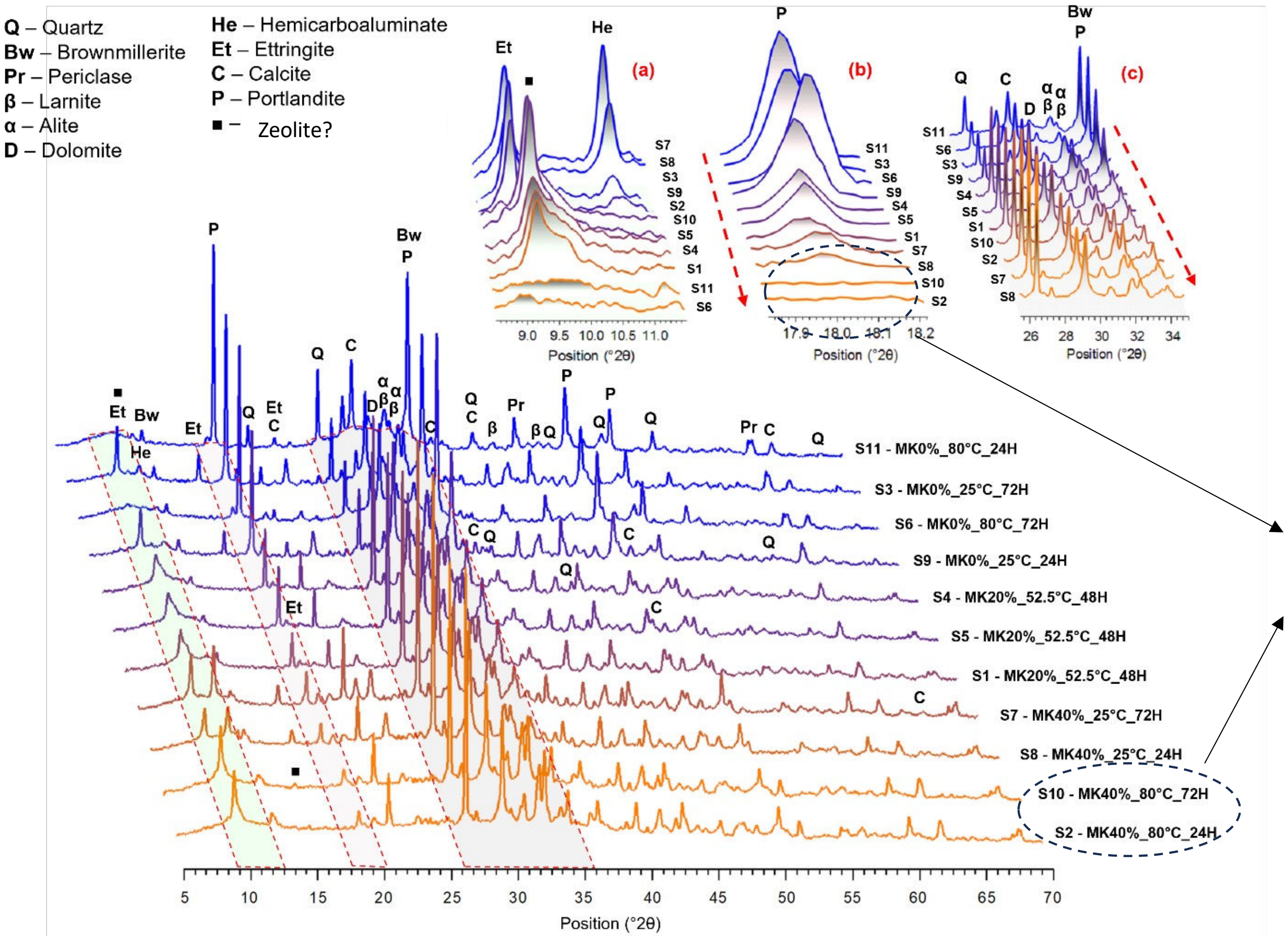
Sisal fiber strand after being extracted from the specimen

Tensile strength



Results

Phases in the matrix



Absence of portlandite

Phases in the matrix

Series		Phases by qualitative XRD analysis[a]										S_t (MPa)
		β	*α*	*Bw*	*Pr*	*C*	*Q*	*Et*	*Z or Th?*	*P*	*He*	
MK40%_80°C_72H	S10	Strong	Strong	Moderate	Low	Moderate	Strong	Traces	Strong	Absence	Absence	296 ± 29
MK40%_80°C_24H	S2	Strong	Strong	Moderate	Low	Moderate	Strong	Traces	Strong	Absence	Absence	297 ± 20
MK40%_25°C_72H	S7	Low	Low	Moderate	Low	Moderate	Strong	Strong	Absence	Low	Strong	141 ± 59
MK40%_25°C_24H	S8	Low	Low	Moderate	Low	Strong	Strong	Moderate	Absence	Traces	Moderate	239 ± 16
MK0%_80°C_72H	S6	Low	Low	Moderate	Low	Moderate	Moderate	Absence	Low	Strong	Absence	---
MK0%_80°C_24H	S11	Low	Low	Moderate	Low	Absence	Moderate	Absence	Low	Strong	Absence	---
MK0%_25°C_72H	S3	Strong	Strong	Strong	Low	Moderate	Moderate	Strong	Absence	Strong	Low	99 ± 13
MK0%_25°C_24H	S9	Strong	Strong	Moderate	Low	Strong	Moderate	Moderate	Absence	Moderate	Low	97 ± 43
MK20%_52.5°C_48H	S1	Low	Low	Moderate	Low	Strong	Low	Absence	Moderate	Low	Absence	227 ± 31
MK20%_52.5°C_48H	S4	Low	Low	Moderate	Low	Moderate	Low	Absence	Moderate	Moderate	Absence	113 ± 65
MK20%_52.5°C_48H	S5	Low	Low	Moderate	Low	Moderate	Low	Absence	Moderate	Moderate	Absence	157 ± 22
Minimum		---										**0**
Maximum		---										**297**

[a] *β–Larnite, α - Alite; Bw - brownmillerite; Pr - Periclase; C - Calcite, Q - Quartz, Et - ettringite, Z - Zeolite, Th - Thaumasite, P - Portlandite, He - Hemicarboaluminate.*

Low intensity | Moderate intensity | Strong intensity | Traces | Absence

Main finding

- Portlandite is completely consumed in the series with 40% metakaolin cured at 80°C; however, unreacted clinker phases, including C_3S, remain.

Main finding

- Sisal fibers lost their total strength in cement-based matrix without metakaolin when the highest curing temperature (80°C) was used.

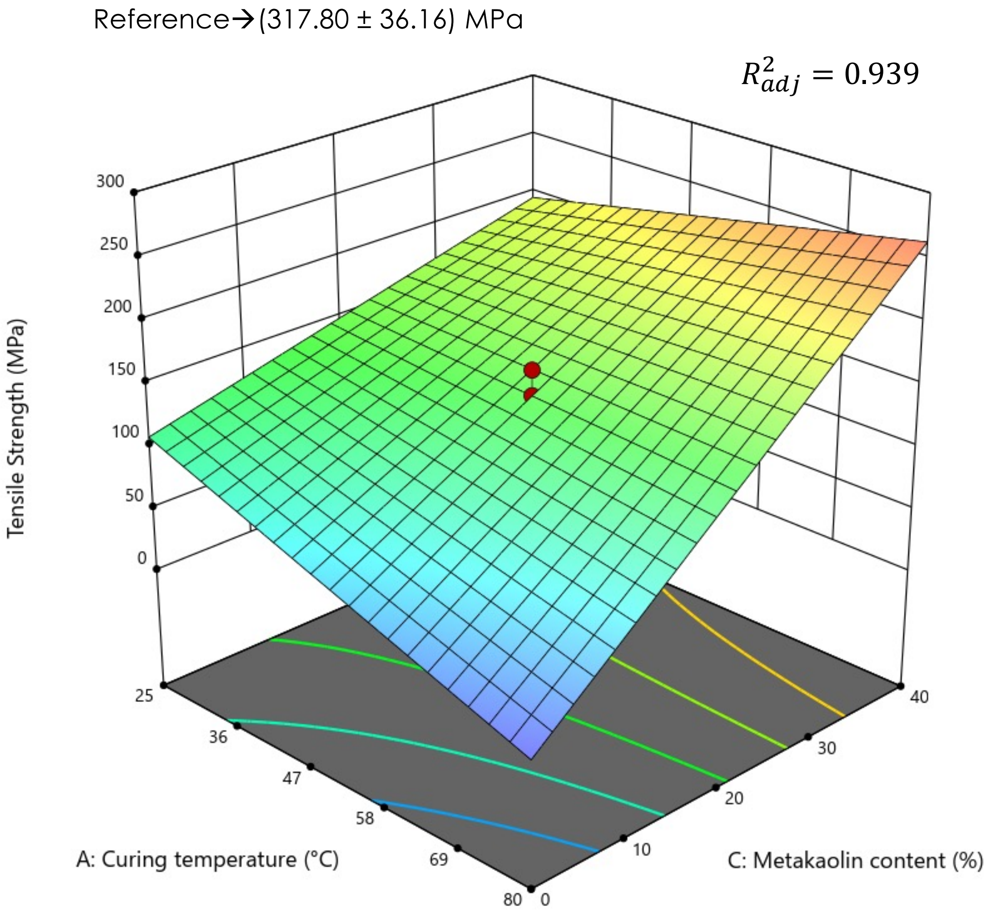
S6_MK0%_80°C_72H

S11_MK0%_80°C_24H

Tensile strength of fibers

Main findings

- Curing temperature, metakaolin content, and their interaction significantly influenced the tensile strength of sisal fibers.
- Sisal fibers completely lost their strength in a cement-based matrix without metakaolin when the highest curing temperature (80°C) was applied.
- Metakaolin contributes to preserving the mechanical strength of the fibers, regardless of the curing temperature.



Thank you!