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Some mechanical and thermal properties of vegetable aggregates composites: comparison of new binders

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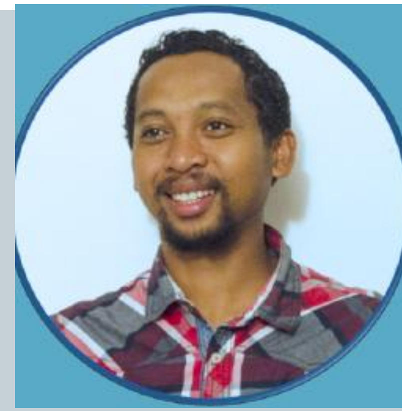
French – Brazilian collaboration

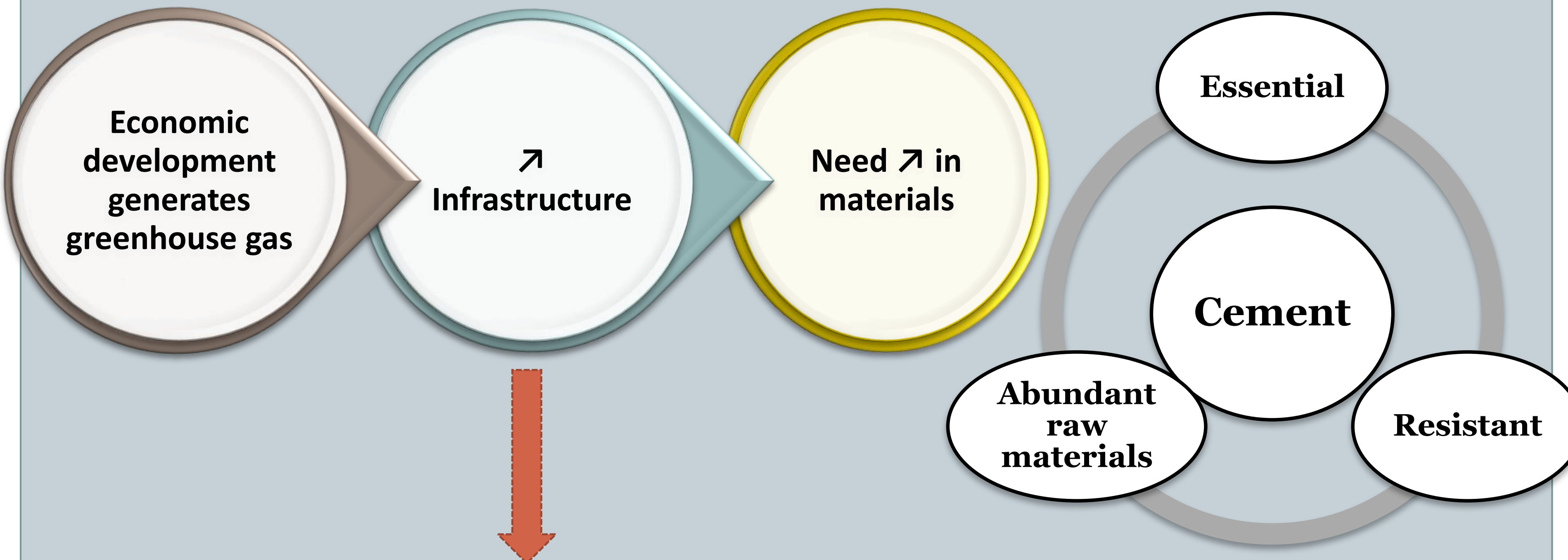
Some mechanical and thermal properties of vegetable aggregates composites: comparison of new binders



Outline

- **Context of the study**
- **Characterization of vegetable aggregates**
- **Results:** **- Cement - bagasse ashes composites**
  - Bagasse ashes - lime composites
- **Effect of the nature of binder and effect of nature/content of aggregates**
- **Conclusions & perspectives/application**

Context of the study



Cement industry ≈ 4,1 bill. de tons of emission of CO_2

≈ 5 % of emission of anthropogenic CO_2 (2005)

PRODUCE MORE CEMENTITIOUS MATERIALS WHILE REDUCING THEIR IMPACT ON THE ENVIRONMENT

Context of the study

↘ CO_2 in cement materials

- **Partial substitution of cement by mineral additions**
- **Alternative binder without Portland cement (hydrated lime)**

Vegetable materials

Renewable resources

Valorization and improvement of materials properties

Vegetable aggregates

Vegetable fibers

Context of the study

VALORIZATION OF AGROINDUSTRIAL RESIDUES AS MATERIALS FOR BUILDING AND HOUSING

CO_2 emission reduction, material properties, by-product management

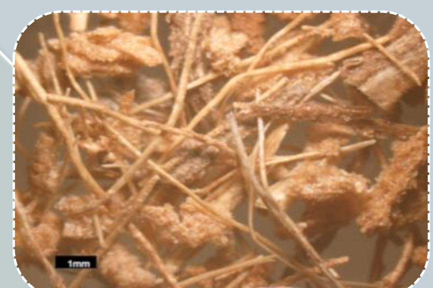
AERA 1 : Alternative binders

- Pozzolanic material
  - Lime
- Cement – pozzolanic material

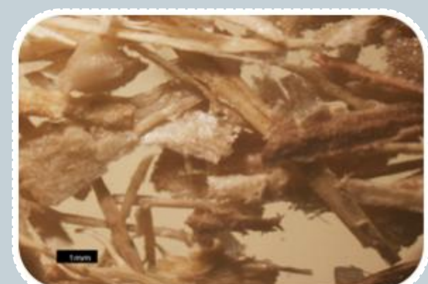
Sugar cane bagasse ashes

AERA 2 : Composites

- Alternative binder
- Vegetable aggregates



Coconut



Sugar cane bagasse

Materials

Cement "C"

- CEM I 52.5 R Portland cement

Hydrated lime "CH"

- VETEC / SIGMA-ALDRICH (95 % en $Ca(OH)_2$)

Sugar cane bagasse ashes "CBA"

- Recalcined sugar cane bagasse ashes (600°C /2h)

Vegetable materials

- Sugar cane bagasse "Ba" and Coconut "Co" aggregates (1 – 6 mm)

Additives

- SPP CHRYSO ® Fluid Premia 205 based on modified polycarboxylate
- K_2SO_4

RESULTS: characterization of vegetable aggregates

Morphology (binocular loupe)

Both are mainly composed of particles and vegetable fibers

Apparent and specific densities

Species	Density (kg / m^3) Apparent	Specific
Bagasse	73.1 ± 1.4	304 ± 21
Coconut	60.2 ± 0.6	1289 ± 13
Chenevotte	135.0	
Sunflower marrow	20.1	
Wood (cedar, spruce, …) [Stamm 1928]		1484 -1536
Cellulose [Chen 2014]		1500 -1588
Lignin [Stamm 1928]		1350 -1500

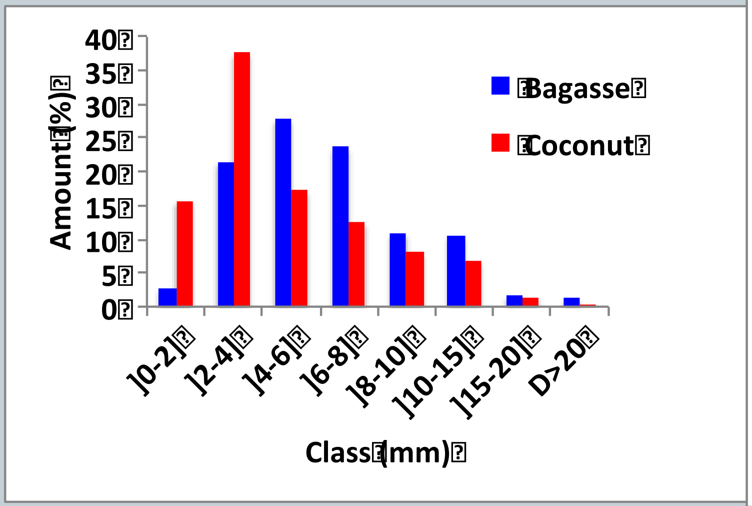
Specific density of cement = approx. 3000 kg.m^{-3}

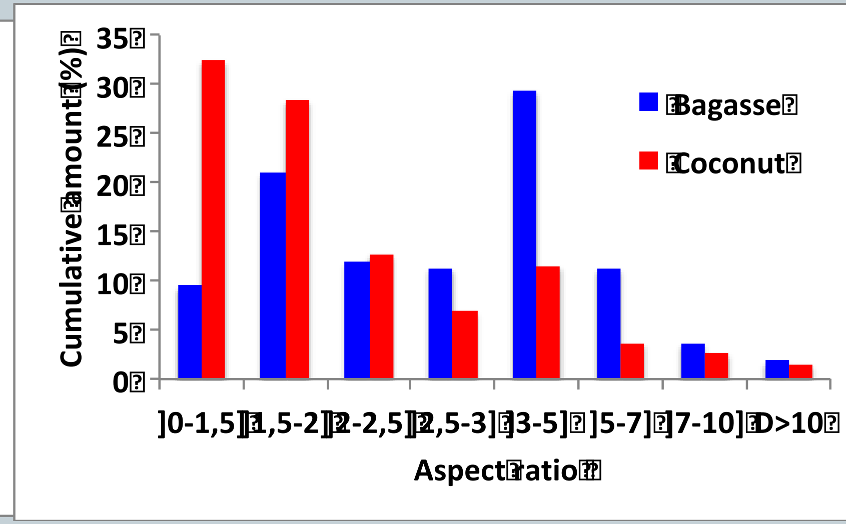
Adding vegetable aggregates should lighten the final composite.

RESULTS: characterization of vegetable aggregates

Granulometry

Maximum length = 25 mm





Coconut aggregates:

- more than 50% particles < 5 mm;
- more than 80% have an aspect ratio < 2.5.

Bagasse aggregates:

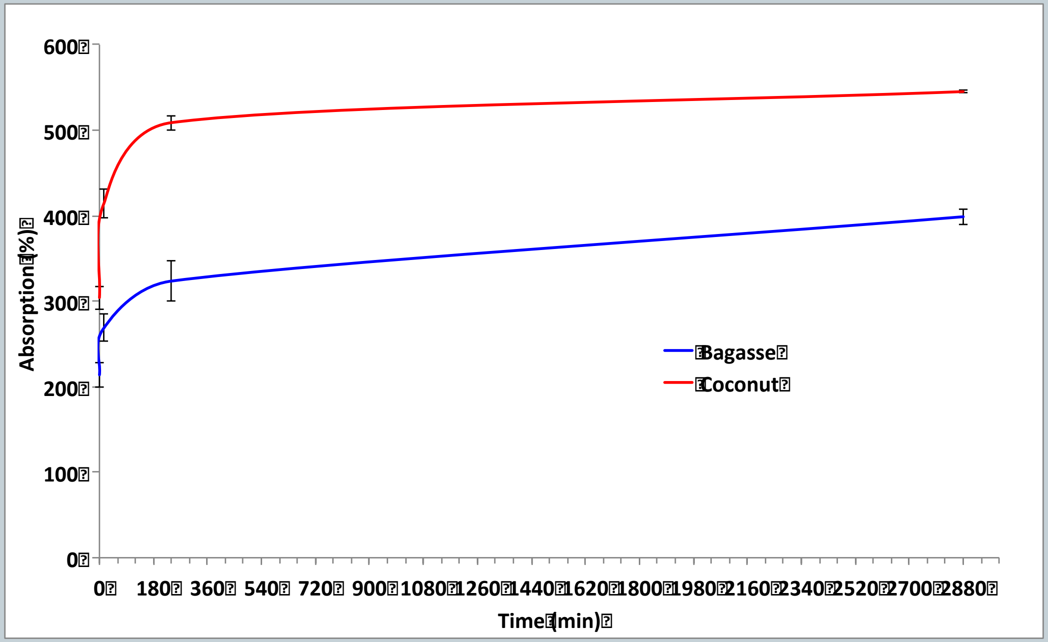
- less than 30% particles < 5 mm;
- more than 50% have an aspect ratio > 2.5

➔ more elongated than those of coconut.

Adding vegetable aggregates should reduce the flexural strength of the final composite (high aspect ratio is required).

RESULTS: characterization of vegetable aggregates

Water absorption



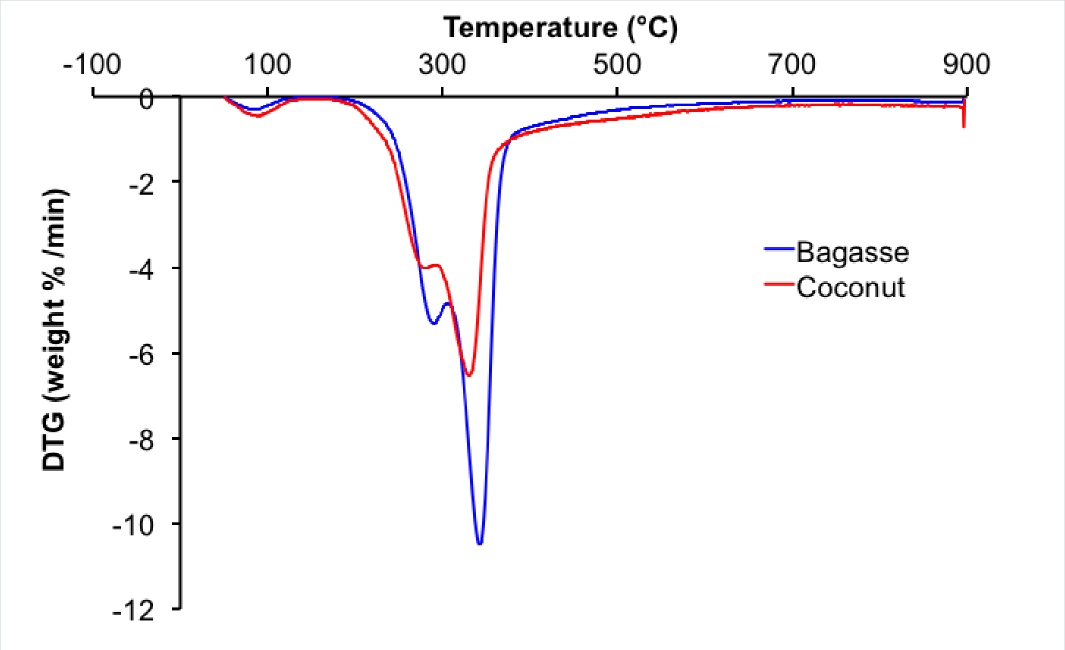
Coconut aggregates:
After 2 days, absorption of 545%.

Bagasse aggregates:
After 2 days, absorption of 400%.

Possible competition between the water necessary for the hydration of the matrix and the water absorbed by the aggregates ➔disturbing the process of hydration of the binder.

RESULTS: characterization of vegetable aggregates

Thermal decomposition



* 100°C: departure of free water

* 280°C: decomposition of hemicelluloses, pectins and extractives

* 160-650°C: decomposition of lignin

* 330°C: decomposition of cellulose (main peak)

Coconut aggregates are poorer in hemicelluloses and sugars (unfavorable to the hydration of the binder).

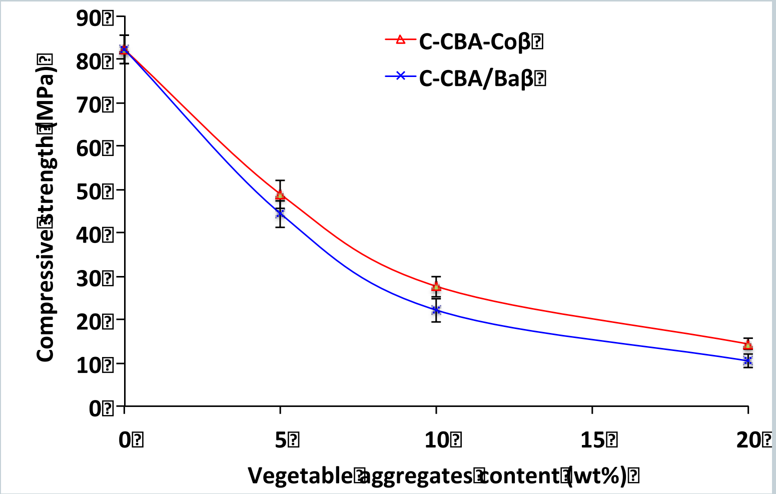
Cement - bagasse ashes composites reinforced by vegetable aggregates

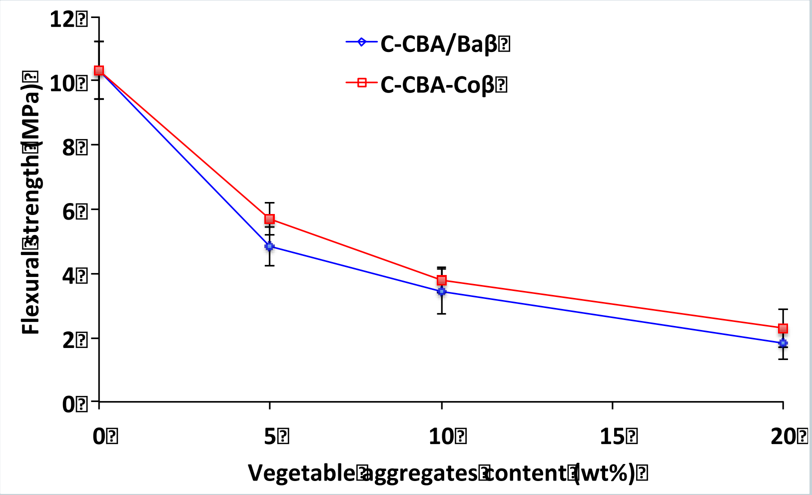
Formulations 70 wt% C+ 30 wt% CBA + βwt% vegetable aggregates

Samples	Cement mass (g)	CBA mass (g)	Binder mass (g)	Bagasse aggregates mass (g)	Coconut aggregates mass (g)	Water mass (g)	Pre-wetting water mass (g)	β (%)
C-CBA	70	30	100	-		0.48		0
C-CBA/Ba5	70	30	100	5		0.58	5	5
C-CBA/Ba10	70	30	100	10		0.58	10	10
C-CBA/Ba20	70	30	100	20		0.58	20	20
C-CBA/Co5	70	30	100		5	0.58	5	5
C-CBA/Co10	70	30	100		10	0.58	10	10
C-CBA/Co20	70	30	100		20	0.58	20	20

For all samples : mass of SPP = 1.8 g.

Cement - bagasse ashes composites: mechanical results (28 days)





Composites compressive strength ↘ as the mass content of the aggregates ↗.

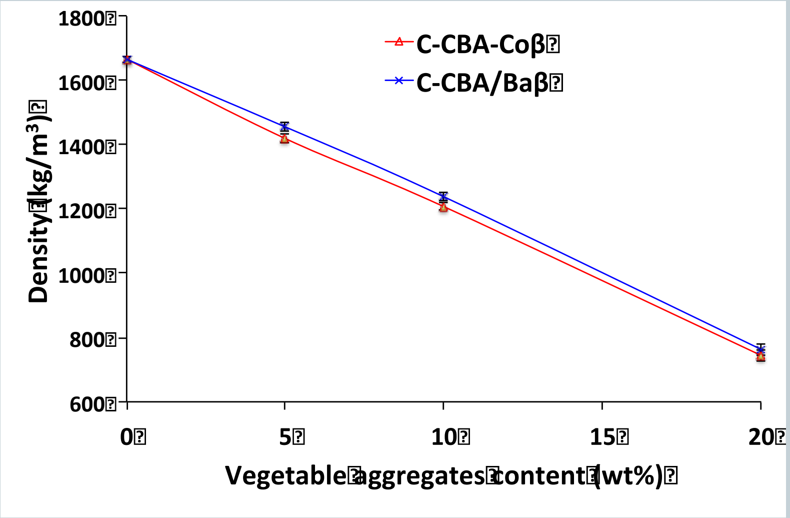
Composites flexural strength ↘ as the mass content of the aggregates ↗ (high aspect ratio required).

Higher compressive strength with coconut aggregates:

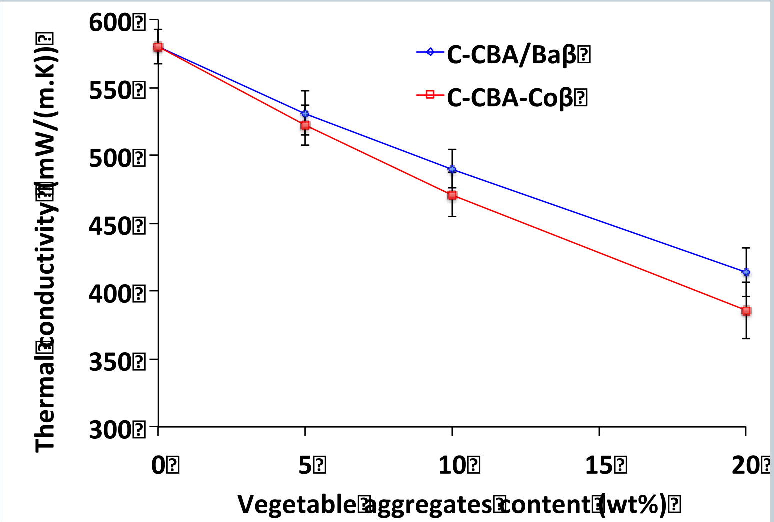
*** poorer in HC and water-soluble compounds (unfavorable to the hydration and strengthening of the cement matrix)**

*** absorb more H_2O**

Cement - bagasse ashes composites: density and thermal conductivity results (56 days)



Apparent densities of composites with bagasse aggregates » those of composites based on coconut ones.



$0.386 < \lambda < 0.580$ W / (m.K).

$\lambda_{concrete} = 0.92$ W/ (m.K)

➔No significant difference is found according to the nature of the aggregates.

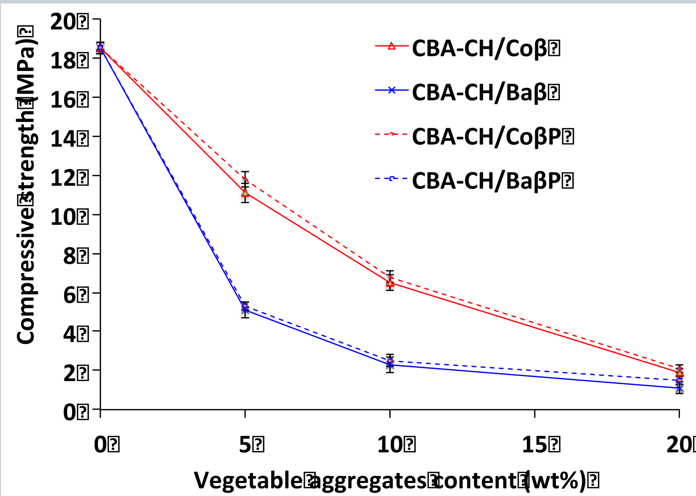
Bagasse ashes –lime composites reinforced by vegetable aggregates

Formulations 70 wt% CBA + 30 wt% CH + βwt% vegetable aggregates

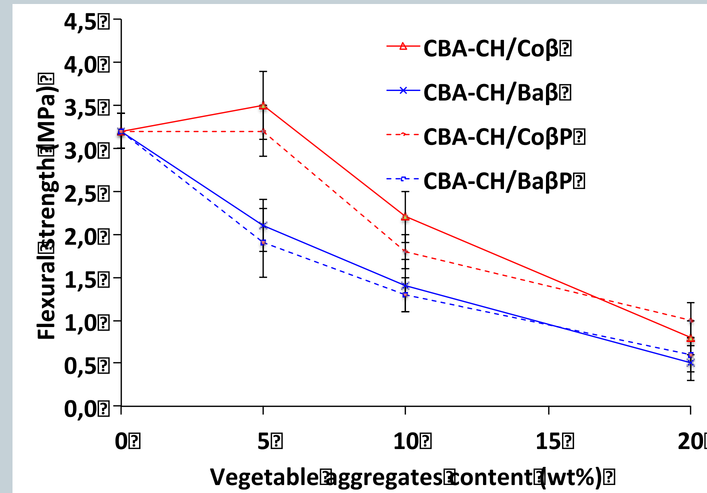
Samples	CBA mass (g)	Lime mass (g)	Binder mass (g)	Bagasse aggregates mass (g)	Coconut aggregates mass (g)	Water mass (g)	Pre-wetting water mass (g)	β (%)
CBA–CH	70	30	100	-		70		0
CBA–CH/Ba5(P)	70	30	100	5		80	5	5
CBA-CH/Ba10(P)	70	30	100	10		80	10	10
CBA–CH/Ba20(P)	70	30	100	20		80	20	20
CBA–CH/Co5(P)	70	30	100		5	80	5	5
CBA–CH/Co10(P)	70	30	100		10	80	10	10
CBA–CH/Co20(P)	70	30	100		20	80	20	20

For all samples : mass of SPP = 1.8 g.

Bagasse ashes –lime composites: mechanical results (28 days)



Optimal material: CBA – CH/Co5



* **Composites compressive strength ↘ as the mass content of the aggregates ↗** (up to 90% for 20 wt% of aggregates).

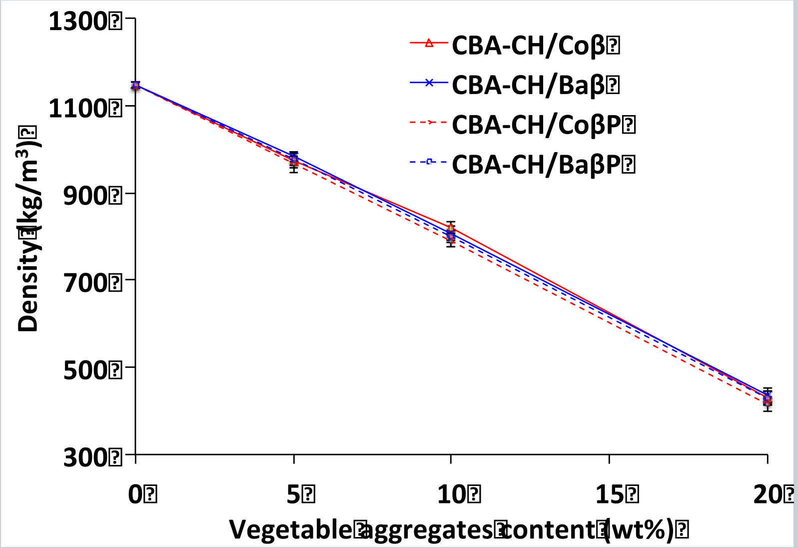
* **Coconut aggregates: more regular ↘**

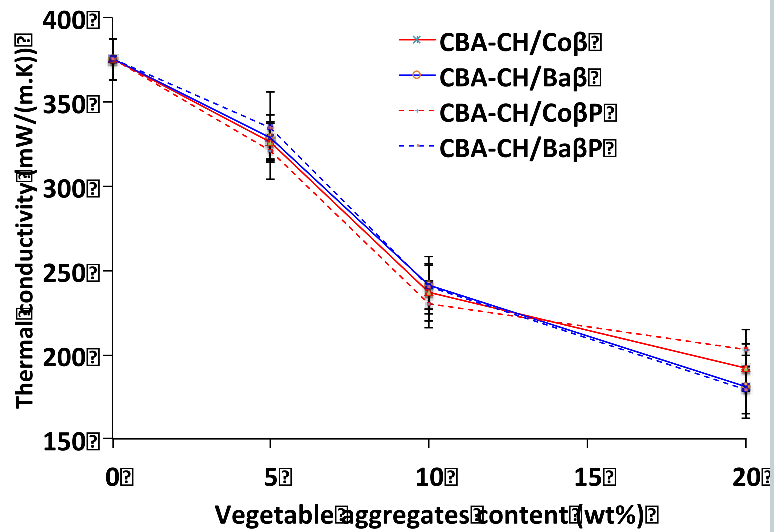
* **Composites flexural strength ↘ as the mass content of the** aggregates ↗ (up to 84% for 20 wt% of aggregates).

- **Bagasse aggregates: ↘**

- **No significant impact of aggregates treatment**
- **Bagasse aggregates: + ↘ of mechanical properties (richer in HC)**
- **↘ of the compactness of the composite (introduction of voids)**

Bagasse ashes –lime composites: density and thermal conductivity results (56 days)





Apparent density of the composites varies between 430 and 1147 kg / m³.

No noticeable effect of aggregates pyrolysis.

$0.181 < \lambda < 0.375$ W / (m.K).

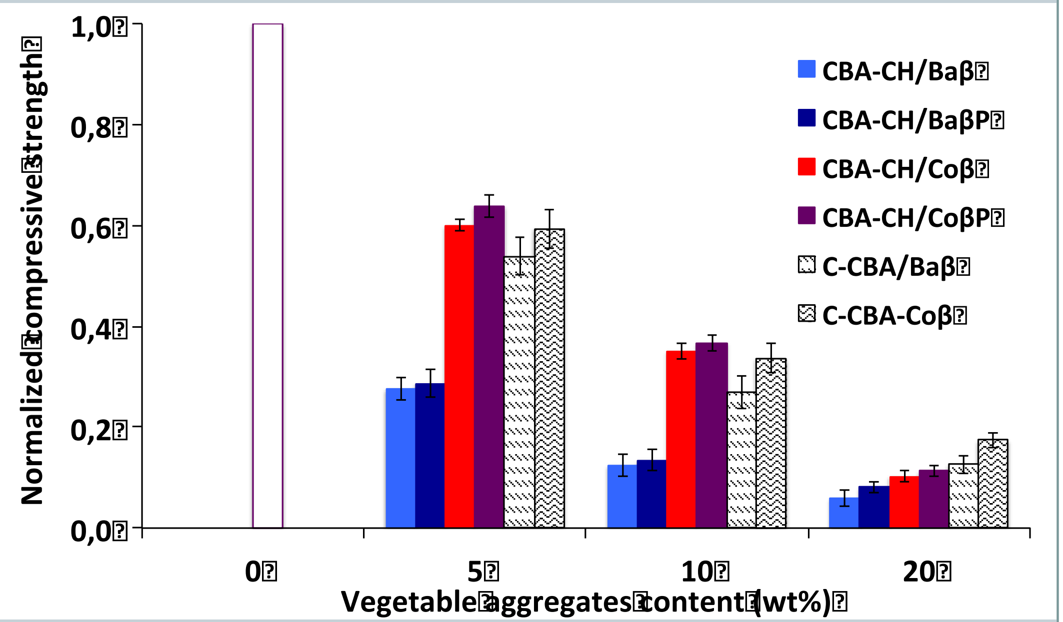
$\lambda_{concrete}$ = 0.92 W/ (m.K)

Ash-lime composites: more insulating composites than cement – bagasse ashes composites

Effect of aggregates and effect of nature of binder on compressive strength (28 days)

✓ **Aggregates:**
- ↘ of composites compressive strength with content
- Coconut better in CBA – CH binder
- Bagasse better in C – CBA binder

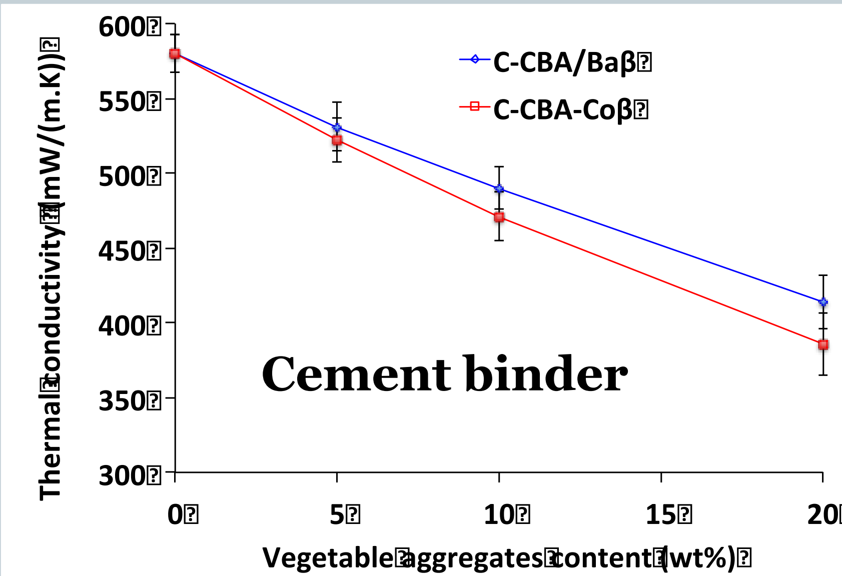
✓ **Binder:**
- No influence for coconut aggregates

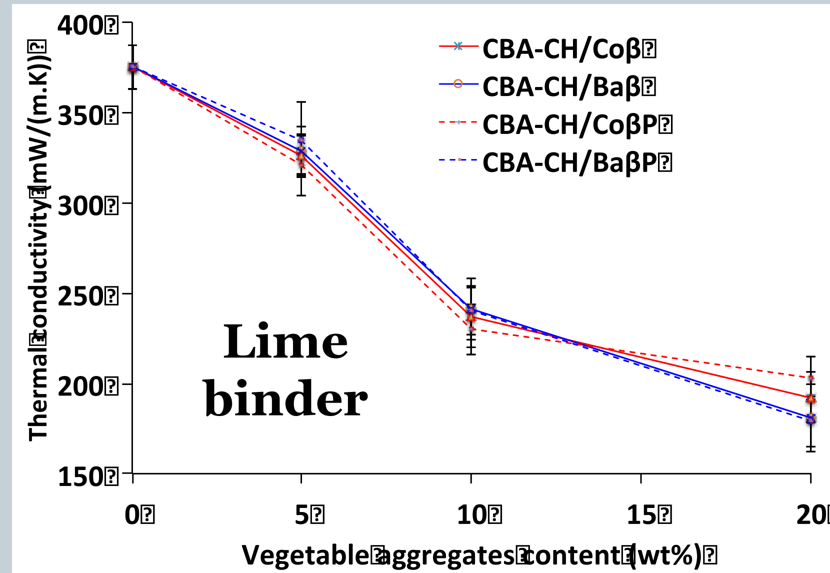


➔ weaker interface transition zone in CBA – CH composites, for bagasse

➔ optimal content of aggregates for compressive strength = 5 wt%

Effect of aggregates and effect of nature of binder on thermal conductivity (56 days)





- ✓ λ is reduced by a factor 2 with 20 wt% of aggregates
- ✓ Lime binder is more insulating than cement binder

Conclusions & perspectives/application

✓ **Binder:**
flexural and compressive strengths of cement – bagasse ashes binder = 2 to 4 x that of bagasse ashes – lime binder

✓ **Composites (5-20 wt%):**
↘ **of strength cement – bagasse ashes by 8 to 10**
lime – bagasse ashes by 4

Optimal aggregate" the binder = coconut

Ashes - lime binder:

- **Higher compressive strength than those in literature.**
- **More insulating composites than cement – bagasse ashes composites.**
- **Life cycle analysis has to be performed to assess CO_2 emission and to validate the environmental advantage of this alternative binder**

APPLICATION: internal wall in houses

Thank you for your attention!!!

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