A comparative study of thermal and mechanical properties of two composites with mineral matrix and vegetable fibres for use in the field of construction

by

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Introduction (cont...)

CEMENT (MINERAL MATRIX) and **CELLULOSE FIBRES**

(Strength, High density and High thermal conductivity)

(Weakness, Lightweight and Low thermal conductivity)

Why this combination of materials with different properties ?

Lightweight Composite with low conductivity and Acceptable strength

- **Insulated material**
- **Construction material**

What has been done in this work

- Mechanical, physical and micro structural tests for characterization of binary composition (cement + fibres)
- Tests of the tertiary composition (3rd component : crushed bricks) in order to reduce the coast
- Studies of some durability aspect

Raw Materials

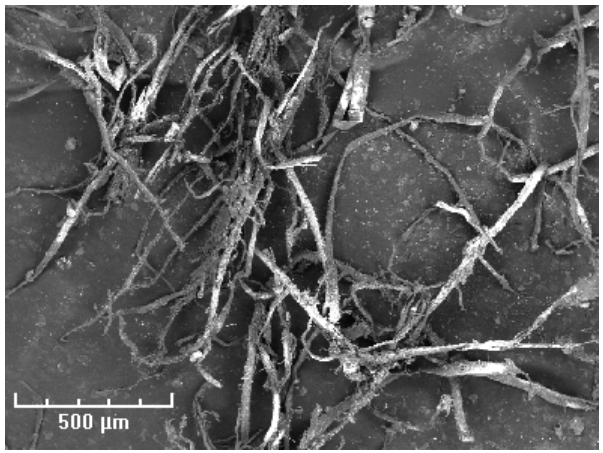
- Cement : CEM I 42.5 N (Normo 4) SN EN 197-1 (European standards)

→ Cement paste (0% fibre) with W/C = 0.36 : Reference

- Crushed ceramic bricks : 0 ÷ 5mm

- Fibres : waste papers and packages

l = 1.2 ÷ 1.7 mm
Φ = 20 ÷ 40 µm



Selection by sieving

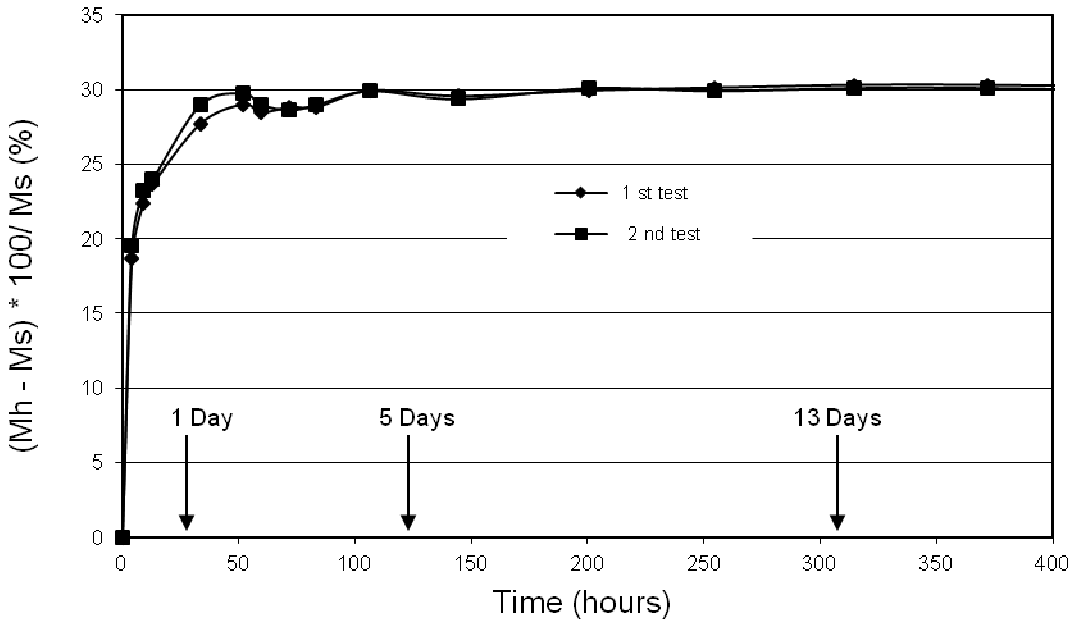
Fine separate (Φ<1.25mm)

Coarse agglomerates

(1.25<Φ< 5 mm)

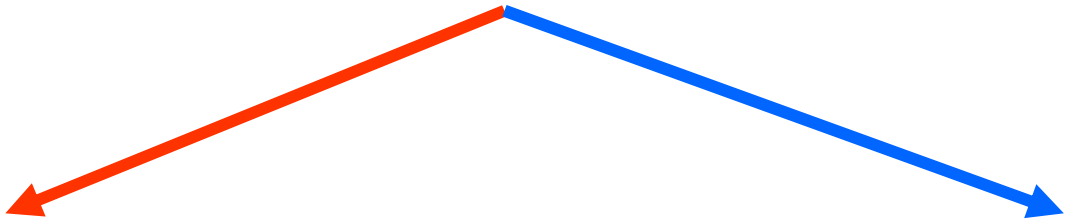
Fibres

Kinetic of absorption water by fibres



Mh: humid mass of fibres sample
Ms : dry mass of fibres sample

Necessary water



Cement paste (Reference 0 %)

W/C = 0.36

Composite with X % of fibres

W/C = f (% en fibres)

$$= \frac{W(0\%) + 35\% .m_{fibres}}{C}$$

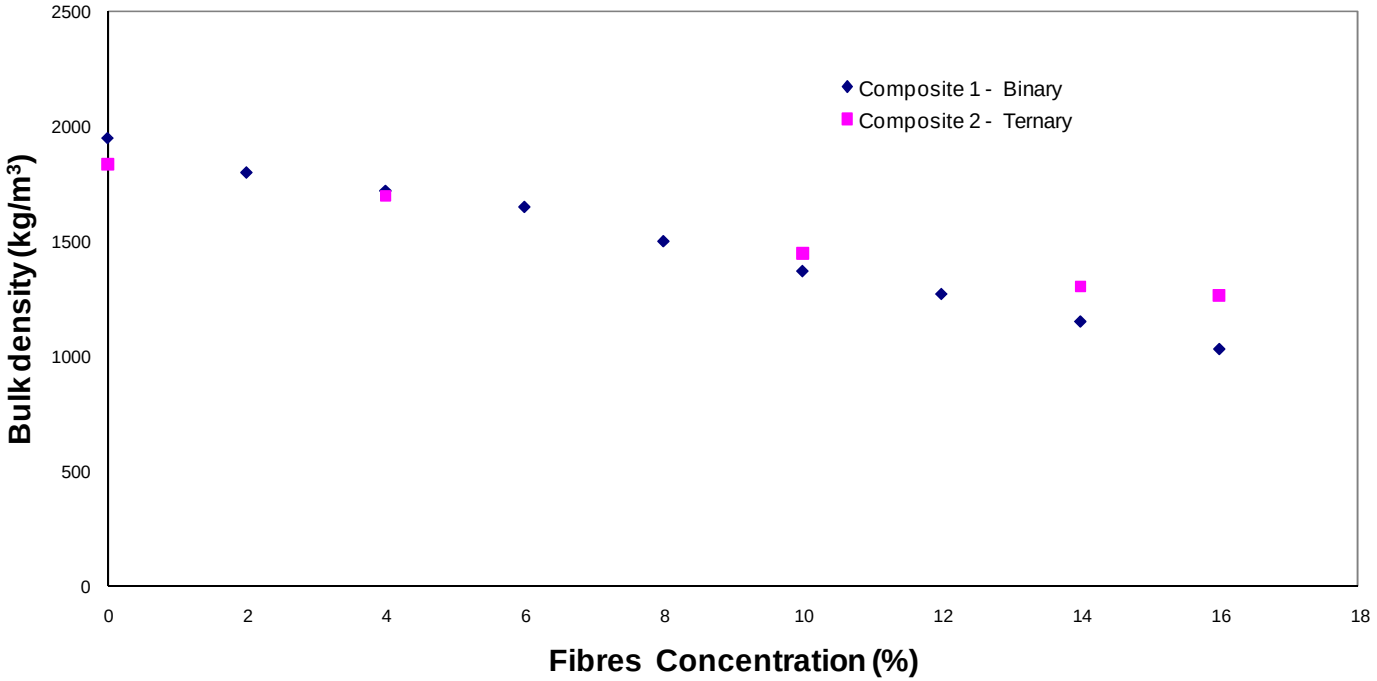
W/C versus fibres content

Concentration (%)		0	4	8	10	16
W/C	Composite 1 (binary)	0.36	0.4	0.52	0.56	0.68
	Composite 2 (ternary)	0.51	0.59	-	0.83	0.99

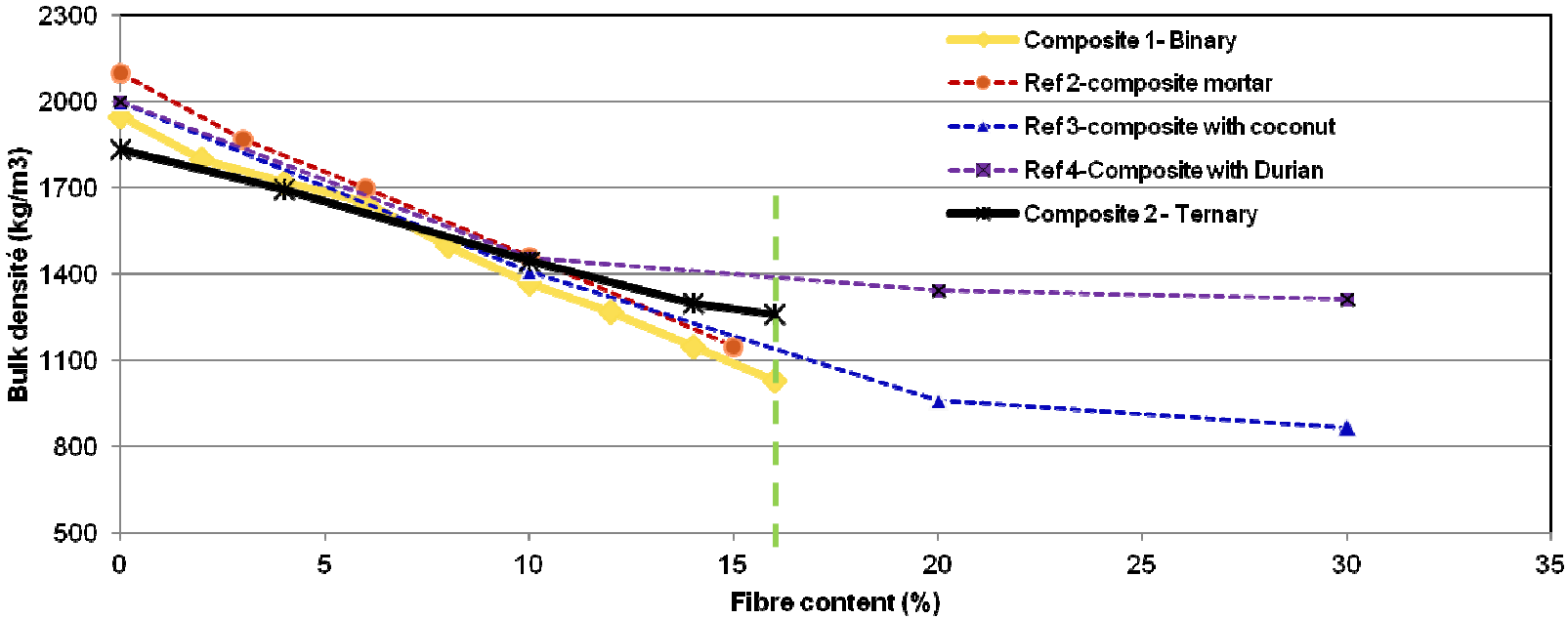
Results

Physical Characteristics of the composites

Apparent Bulk density



Apparent Bulk density (Cont…)



Ref 2 Bentchikou M, Hanini S, Silhadi K, Guidoum A (2007) : Elaboration et étude d'un mortier composite à matrice minérale et fibres cellulosiques : application à l'isolation thermique en bâtiment. Can. J. Civ. Eng. 34: 37- 45.

Ref 3 and 4 Khedari J, Suttisonk B, Pratinthong N and Hirunlabh J (2001): Newlightweight composite construction materials with low thermal conductivity, Cement & Concrete Composites. 23, 65-70.

Specific Heat / volumetric heat transfer coefficient

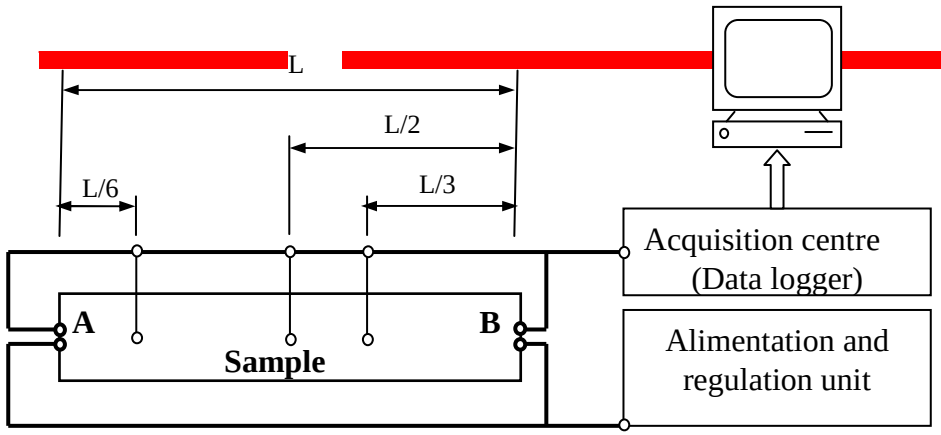
Fiber content (%)		**0**	**4**	**10**	**16**
composite 1 (Binary)	Specific Heat (J/kg. °C)	990	1030	1080	1130
	volumetric heat transfer coefficient (J/m³. °C)	1.9305	1.7716	1.4796	1.1639
composite 2 (Ternary)	Specific Heat (J/kg. °C)	910	990	1020	1041
	volumetric heat transfer coefficient (J/m³. °C)	1.778	1.679	1.475	1.310

- Trend
- For the Ternary , this increase is little be more slowly than for the Binary
- *Specific heat,* compared with volumetric heat transfer coefficient) :

opposite tendency is observed

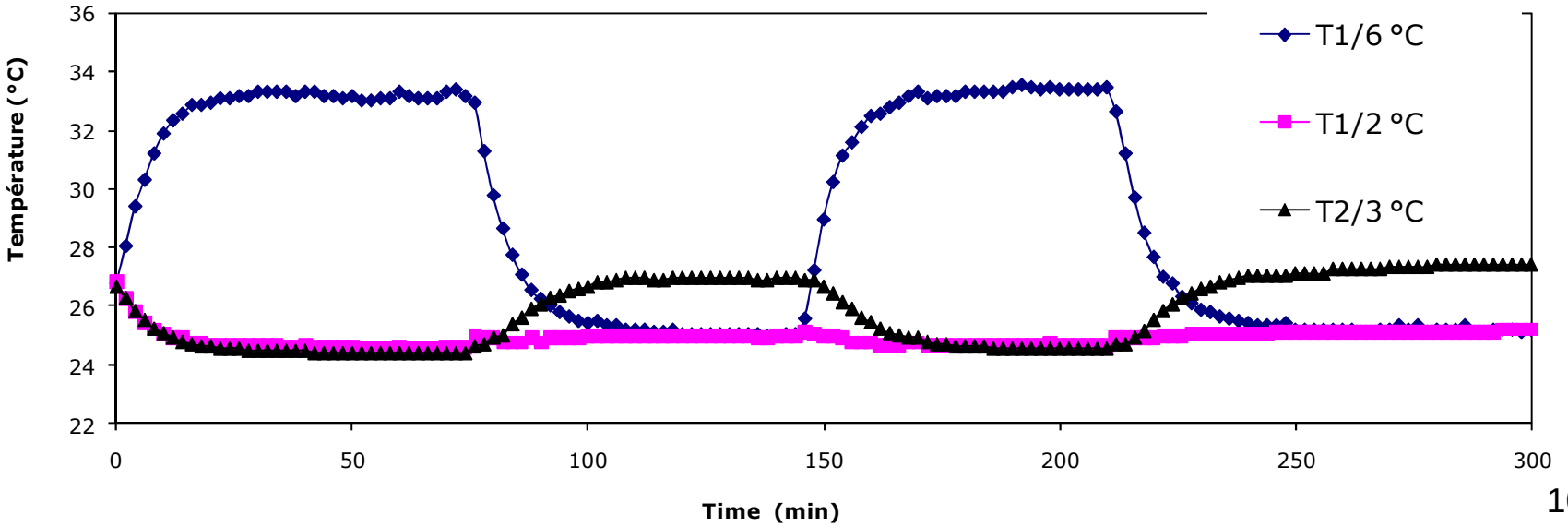
Ternary composite store more energy than the Binary one

Design of device for experimental tests of thermal conductivity

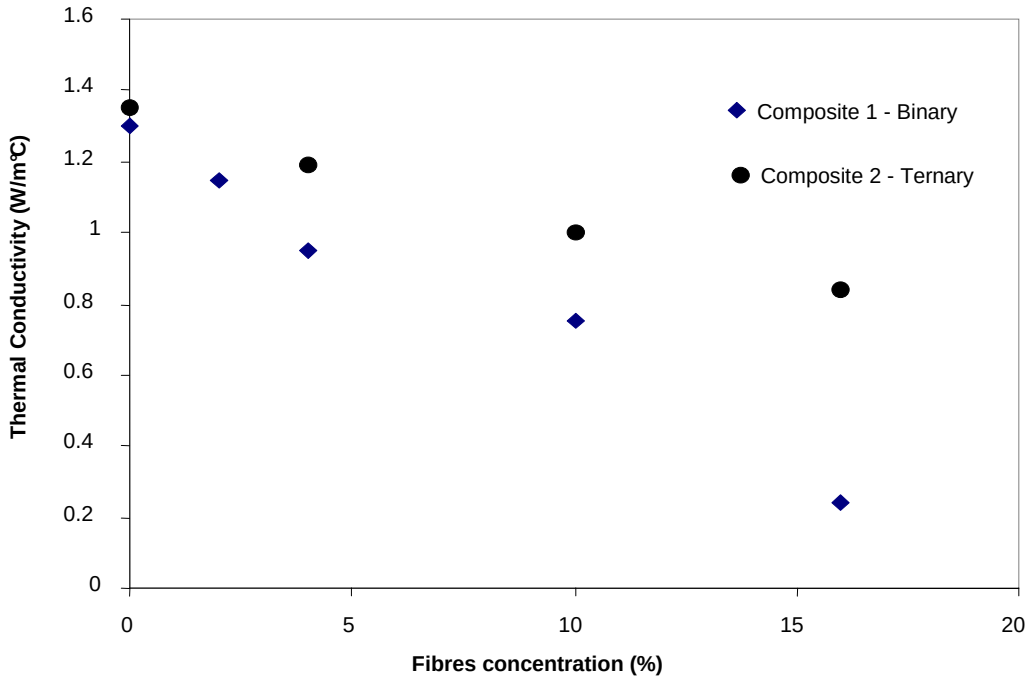


$$\lambda = \frac{\rho C R}{\frac{B\mathrm{P}}{S} + \frac{4\pi^2}{L^2}}$$

$$h = B\lambda = \frac{4S}{L^2\mathbf{P}}\left(ar\cosh\frac{T_A - T_B}{2T_{L/2}}\right)^2\lambda$$

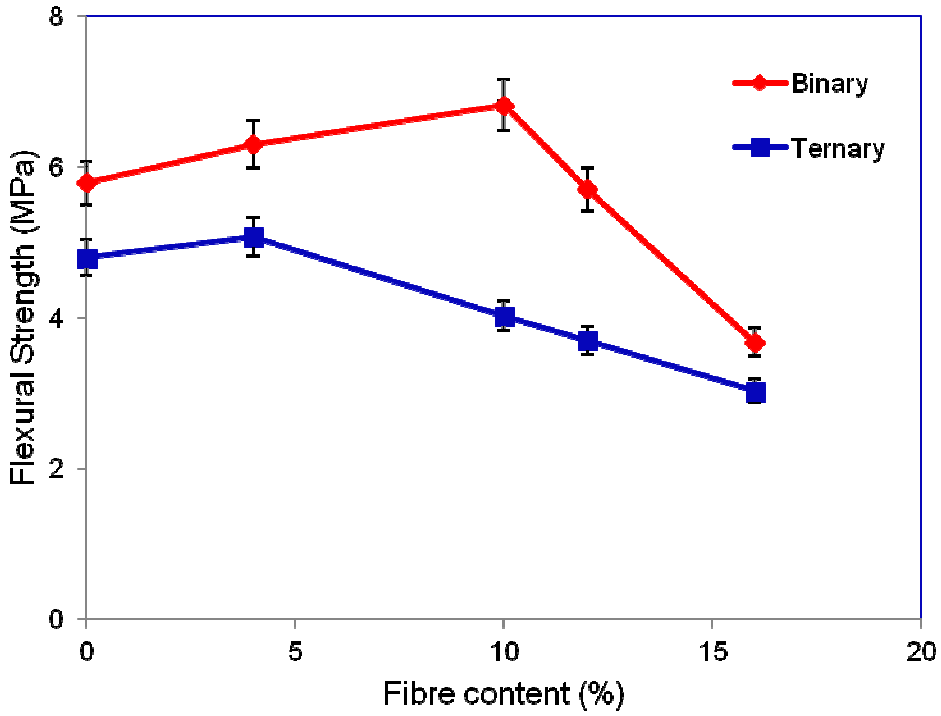


Apparent thermal conductivity

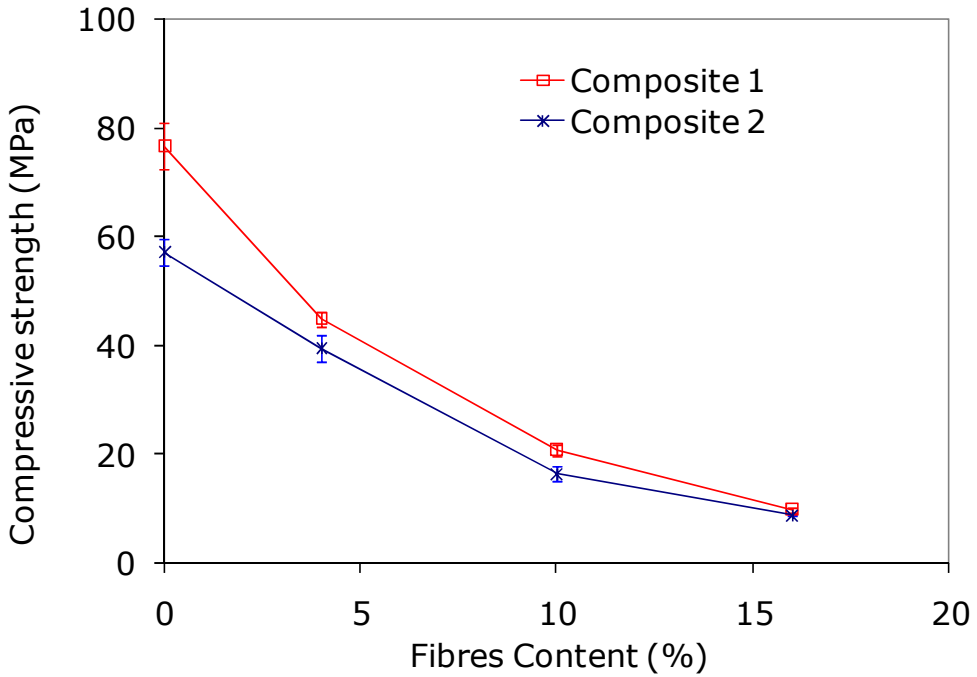


Mechanical Characteristics of materials (cont...)

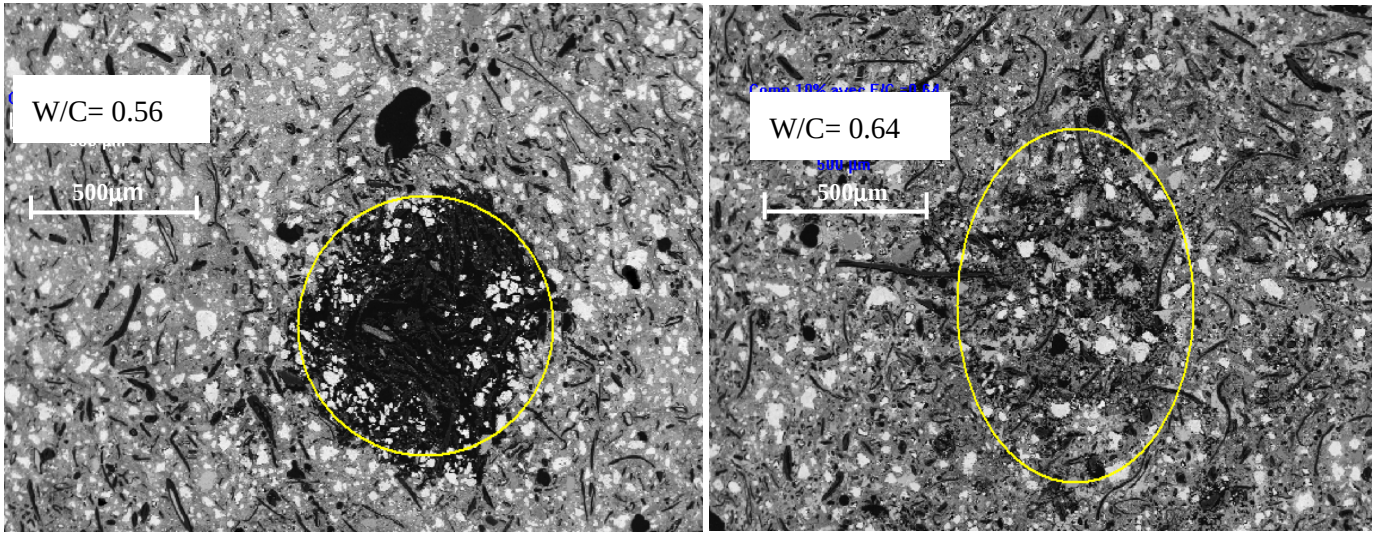
Flexural Strength



Compressive Strength

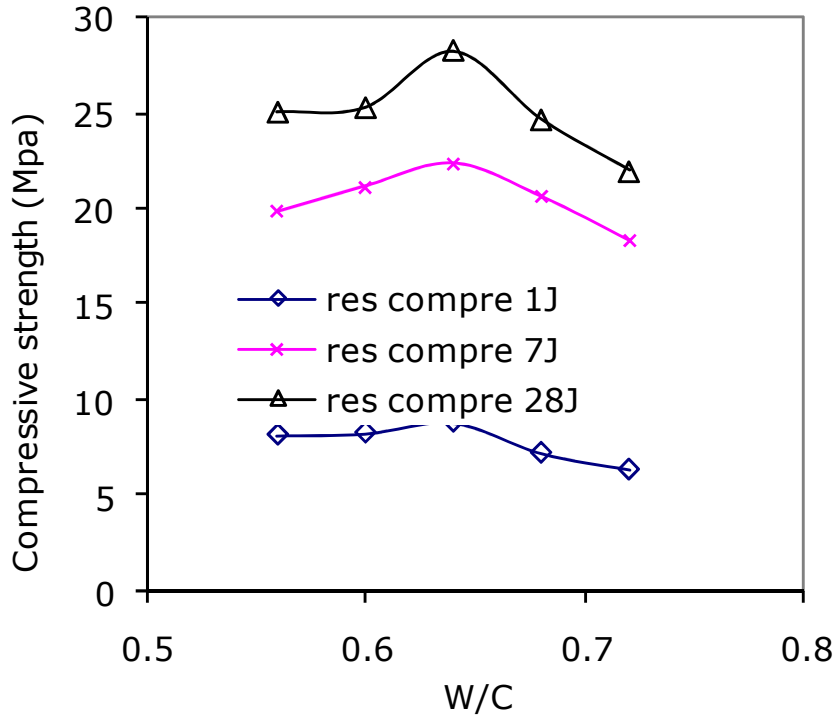


Effect of W/C



Effect of W/C on the dispersion of fibres in the matrix.

Effet of W/C (cont…)

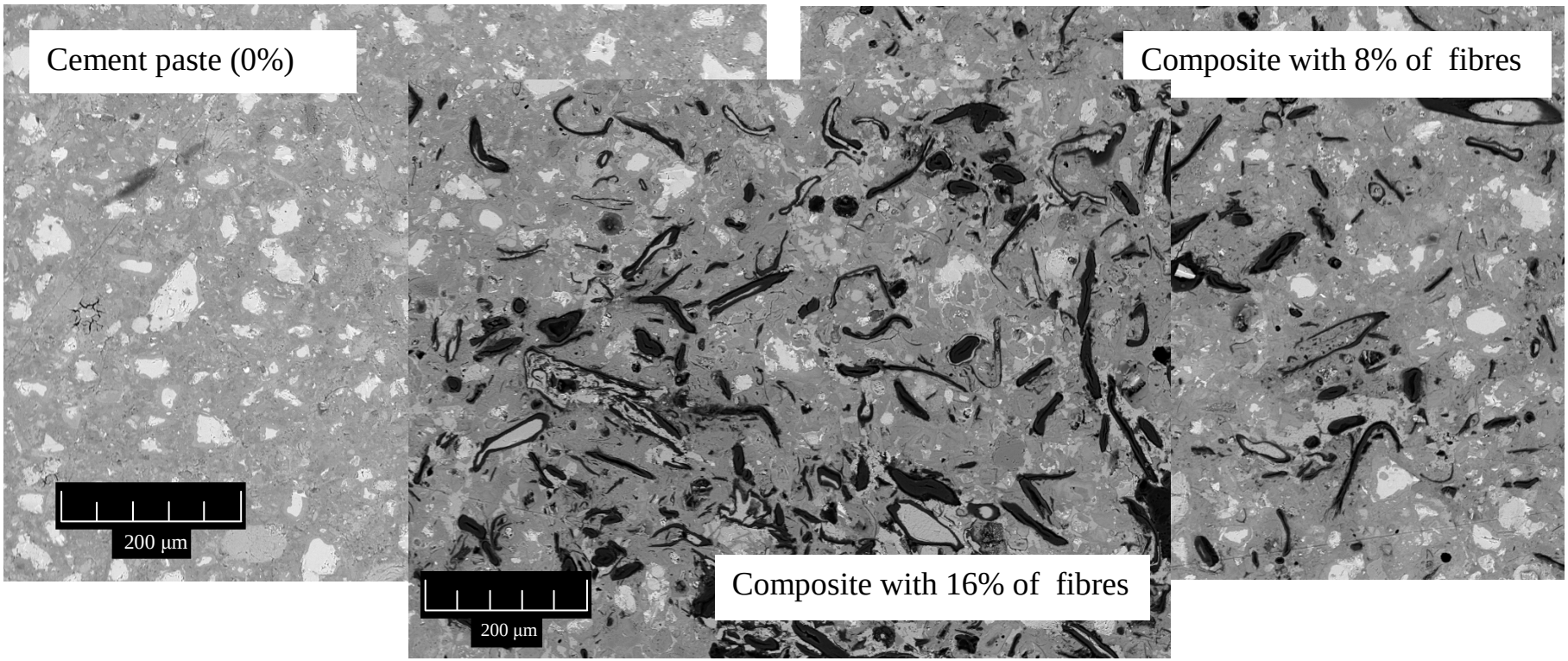


Concentration (%)	0	2	4	6	8	10	12	14	16
$W/C_{optimum}$	0.23	0.32	0.41	0.49	0.57	0.66	0.75	0.83	0.92

Results (Cont....)

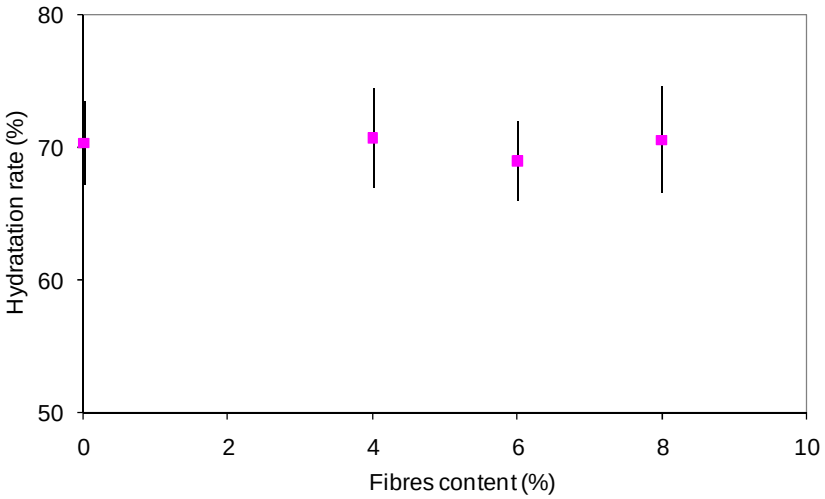
Microstructure changes with fibres content

105 days Curring humide medium

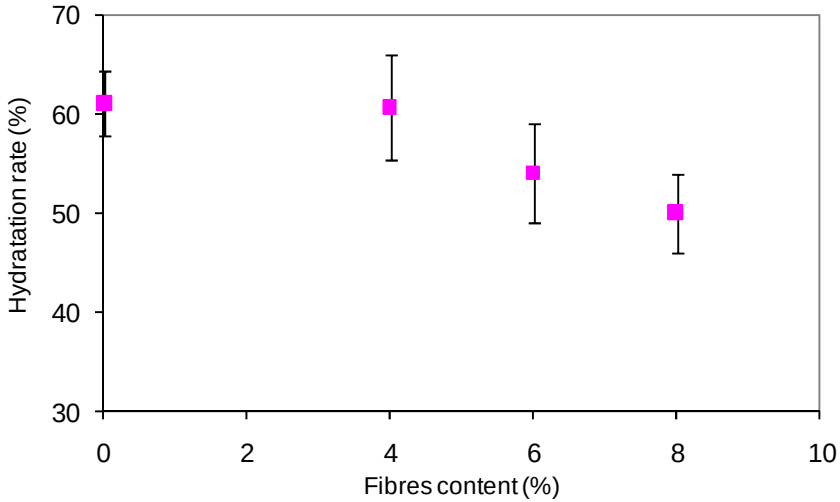


Hydration rate of cement

$$TH\,(\%) = \frac{100\,(F_c - F_a)}{F_c}$$



hydration rate of cement versus fibres concentration for curing at 20°C and 100% HR (saturated medium)



hydration rate of cement versus fibres concentration for curing at 20°C and 50% HR (dry medium)

Results (Cont....)

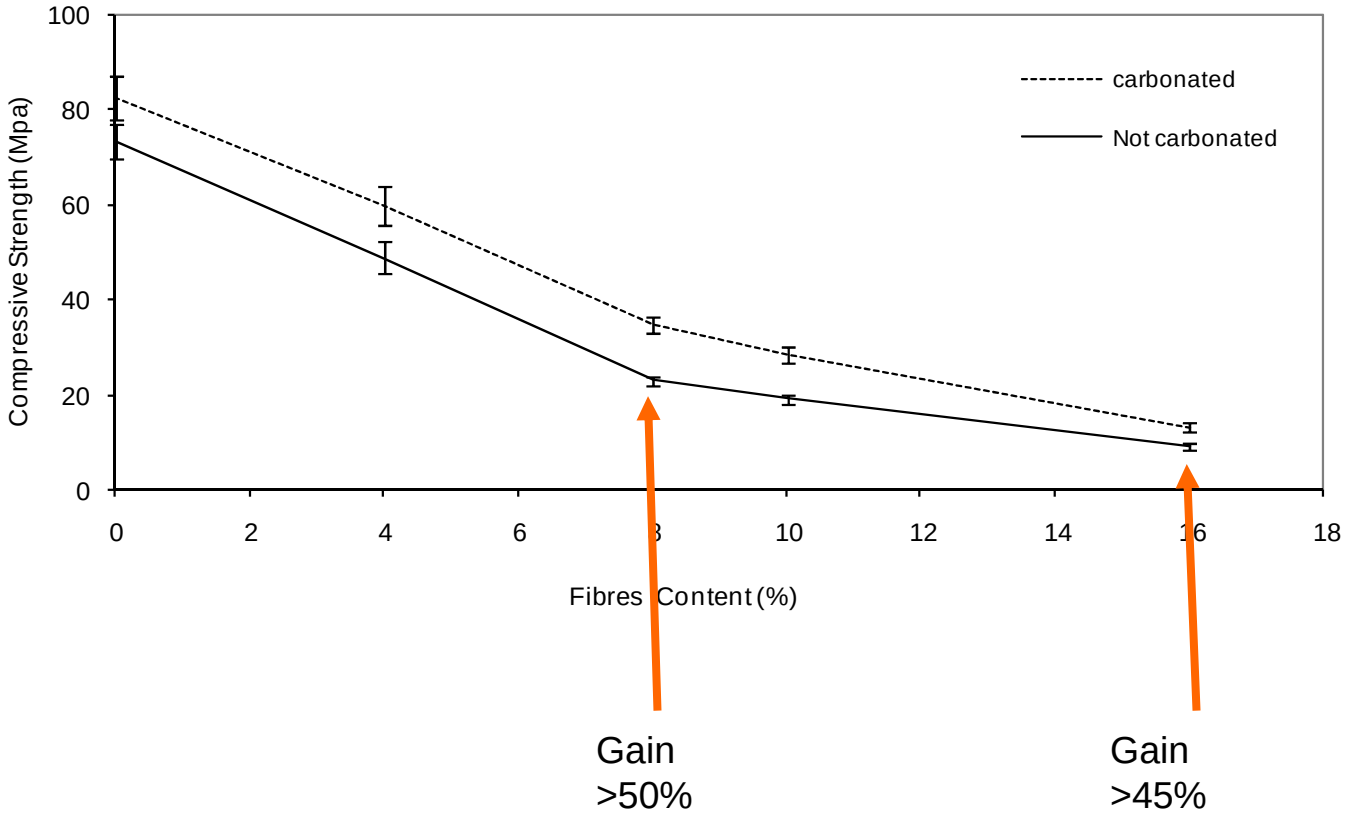
Microstructure (Cont…)

Porosity (by SEM):

Porosity (by MIP):

Durability Aspects

Carbonation



Conclusion

- Incorporation of fibres in mineral matrix decrease thermal conductivity.

- Incorporation of fibres in mineral matrix decrease compressive strength but for 16%, the composite is still in the acceptable range for hollow non-load bearing concrete (ASTMC 109/C 109 M-98) .

- The tertiary composite has less strength than the binary for low concentration of fibres but for high fibre content there is no big difference

Conclusion (cont...)

- At 16%, the tertiary is less efficient than the binary from insulation efficiency point of view but its capacity of storing Energy is better than that of the binary.

- the carbonation induce amelioration of mechanical strength (50% gain)

Projects in progress

- Incorporation of more fibres in the matrix
- Evaluation of thermal conductivity of the composite at **≠ saturation degree**
- Composites DURABILITY to wet - Dry cycling

Projects in future

- Using **admixtures** to improve strength and finding **applications in structure uses,**
- Conceive industrial mean for manufacturing the product,
- Application of coating or film for outside applications

Thank You