IMPACT OF COW DUNG ADDITION ON THE THERMAL AND MECHANICAL PROPERTIES OF N'DJAMENA CLAY.

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Abstract

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This study investigates the effect of incorporating cow dung (1–10 wt%) into locally sourced clay from N'Djamena, with the objective of improving the thermal and mechanical performance of raw earth bricks used in social housing. Thermal conductivity was measured using the hot plate method, thermal diffusivity using the flash method (Degiovanni, 1987; Degiovanni, 1993), and compressive strength through standard mechanical testing. Results show a reduction of thermal conductivity from 0.99 to 0.42 $W\cdot m^{-1}\cdot K^{-1}$ at 10% cow dung, as well as a significant decrease in thermal diffusivity. Compressive strength increases with cow dung content, reaching 8.2 MPa at 10%. This optimal thermomechanical behaviour aligns with earlier reports on organic stabilisation in earthen materials (Gaye, 1998; Sow, 2014).

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Introduction:

Earthen materials remain central to housing in the Sahel, particularly in Chad where raw clay ("banco") is widely used. However, raw earth bricks often display limited mechanical resistance and inadequate thermal insulation, as confirmed in previous research on thermophysical characterisation of local soils (Charfadine, 2002; Ball, 2011). Traditional additions such as cow dung have been used historically to improve material behaviour (Sow, 2014). Previous studies on plant-fiber and organic additives indicate improvements in strength and thermal properties (Gaye, 1998; Voumbo et al., 2008). This study experimentally assesses the influence of cow dung on thermal conductivity (λ), thermal diffusivity (α) and compressive strength (Rc) to determine an optimal stabiliser percentage.

2. Materials and Methods

2.1 Materials

- Clay extracted from the Madagua site,
- Fresh, non-fermented cow dung,
- Addition rates: 1%, 3%, 5%, 10% by mass.

Specimens: thermal plates (10 × 10 × 2–3 cm) and mechanical test cubes (5 × 5 × 5 cm).

2.2 Thermal Methods

a) Thermal conductivity — Hot plate method

The hot-plate experimental arrangement follows established configurations for earthen materials (Charfadine, 2002; Thiam, 2011). The setup comprises two aluminium plates, a polystyrene insulator, three thermocouples (T_0, T_1, T_2) and a heating film supplying a heat flux Φ (schematic in Figure 1). The direction of heat flux is illustrated in Figure 2.

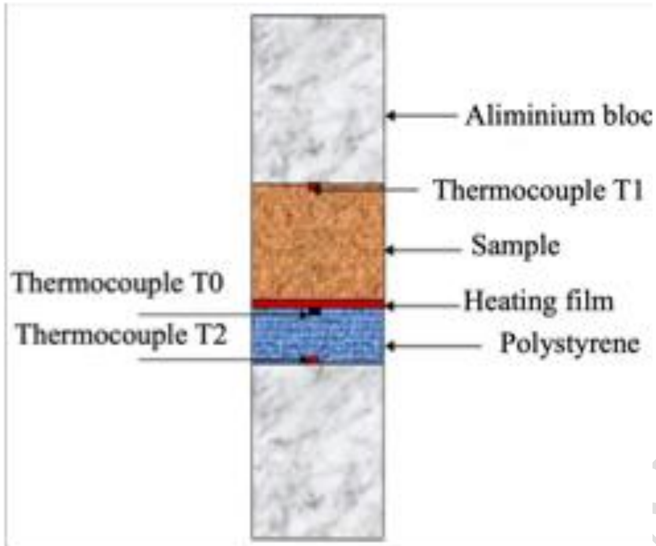

Figure 1. Schematic of the hot-plate experimental setup: aluminium plates, polystyrene insulator, thermocouples T_0, T_1, T_2, and heating film.

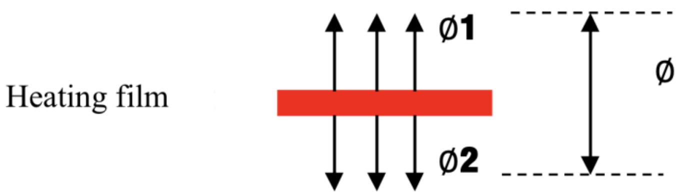

Figure 2. Direction of heat flux in the hot-plate configuration (schematic)

Thermal conductivity λ is derived from:

$$\lambda = \frac{e_1}{T_0 - T_1}\left[\frac{U^2}{RS} - \frac{\lambda_2}{e_2}(T_0 - T_2)\right] \qquad (1)$$

Where:

- U is applied voltage,
- R_s the film resistance,
- e_1 and e_2 the relevant thicknesses,
- and λ_2 the conductivity of the aluminium plate.

b) Thermal diffusivity — Flash method

Thermal diffusivity measurements used the flash method with rear-face temperature recording. The experimental arrangement is shown in Figures 3 and 4, while a representative rear-face thermogram is shown in Figure 5. Data were analysed according to the Degiovanni model (Degiovanni, 1987; Degiovanni, 1993), producing:

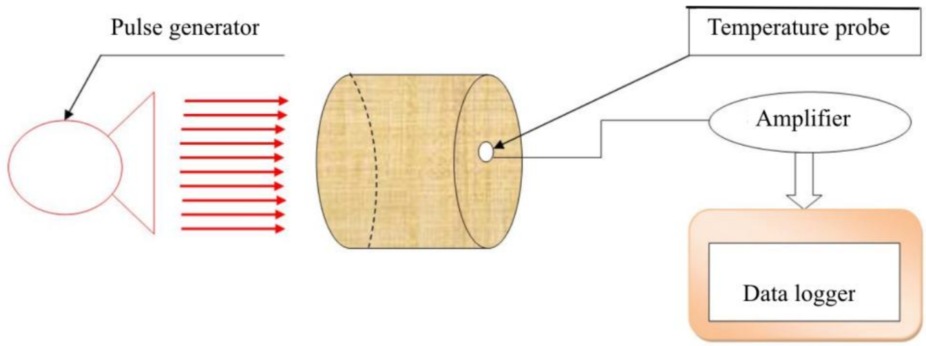

Figure 3. Flash method — experimental arrangement (front irradiation, rear-face temperature acquisition).

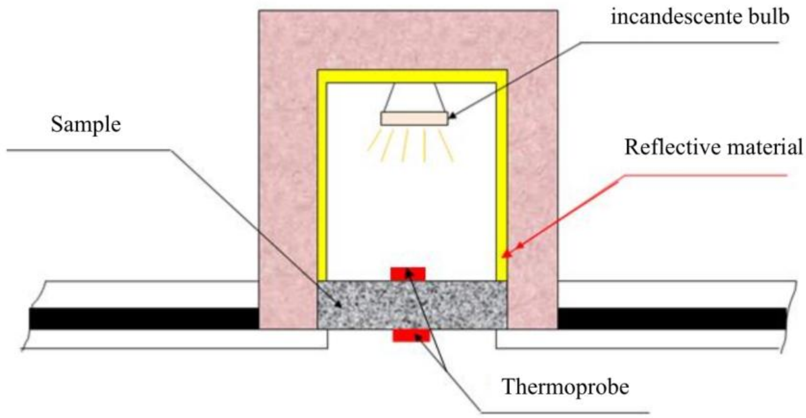

Figure 4: Cross-sectional view of the box method for measuring thermal diffusivity

The thermogram of the non-irradiated face of the specimen (Figure 5) allows the determination of thermal diffusivity α using the Degiovanni model based on Equation (2).

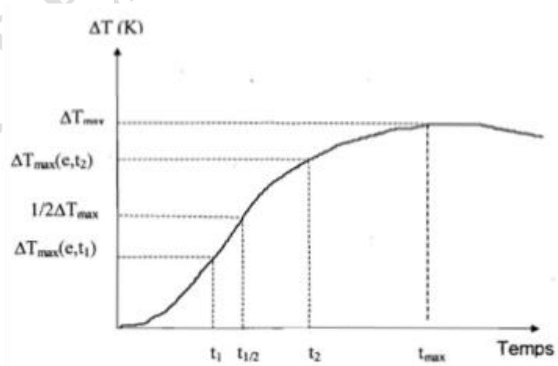

Figure 5. Representative rear-face thermogram from the flash test and definition of $t_{1/3}$, $t_{2/3}$, $t_{5/6}$ times used in the Degiovanni model.

$$\alpha = \frac{\alpha_1 + \alpha_2 + \alpha_3}{3} \qquad (2)$$

Where:

$$\alpha_1 = \frac{e^2}{t_{5/6}^2}\left[1{,}15 t_{\frac{5}{6}} - 1{,}25 t_{2/3}\right] \qquad (3)$$

$$\alpha_2 = \frac{e^2}{t_{5/6}^2}\left[0{,}761 t_{\frac{5}{6}} - 0{,}926 t_{1/3}\right] \quad (4)$$

$$\alpha_3 = \frac{e^2}{t_{5/6}^2}\left[0{,}617 t_{\frac{5}{6}} - 0{,}862 t_{2/3}\right] \quad (5)$$

3 Mechanical Methods

Compression tests were carried out on a hydraulic press following standard procedures (Dupain et al., 2000; Derriche&Kebaïli, 1998). Test setup and specimen loading are shown in Figure 6.

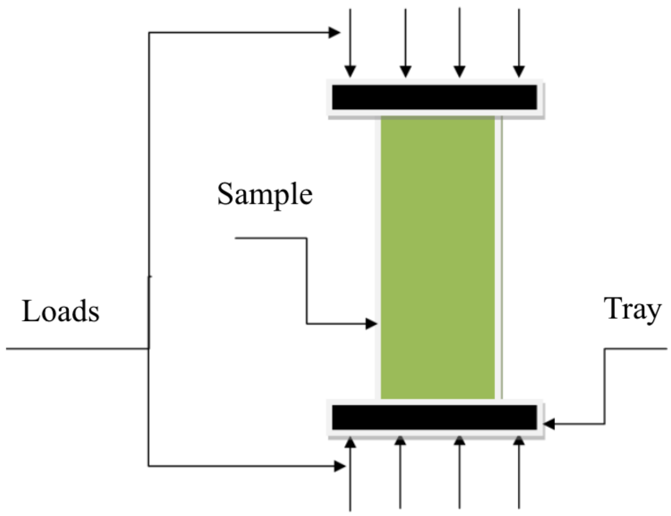

Figure 6. Mechanical test setup: hydraulic press and specimen instrumentation.

Compressive strength is:

$$R_c = \frac{F}{S} \quad (6)$$

Where:

- F is the maximum load
- and S the cross-sectional area.

3. Results

3.1 Thermal conductivity

Thermal conductivity progressively decreases with cow dung content and reaches 0.42 $W \cdot m^{-1} \cdot K^{-1}$ at 10% addition. The conductivity data are plotted in Figure 7. The reduction is attributed to the increased volume fraction of air (low conductivity) in the composite's pore network (Meukam et al., 2004; Voumbo et al., 2008).

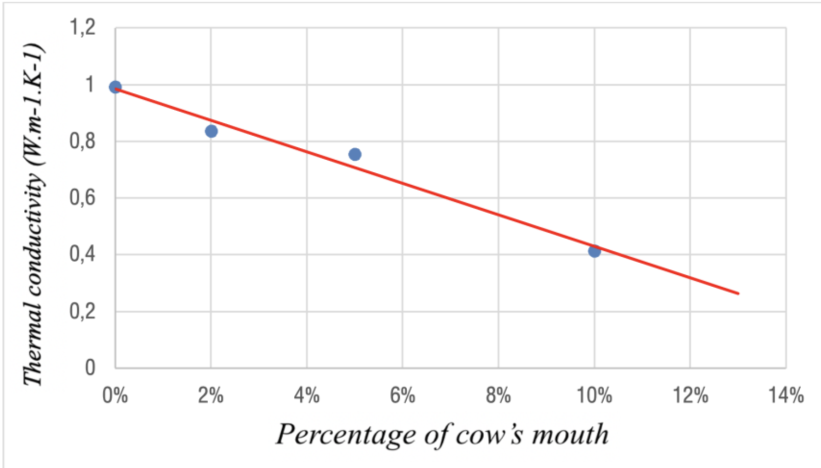

Figure 7. Thermal conductivity λ (W·m⁻¹·K⁻¹) as a function of cow dung content.

3.3 Thermal diffusivity

Measured thermal diffusivity decreases with increasing cow dung and is shown in Figure 8. The flash thermograms and corresponding fits (Degiovanni model) for representative specimens are given in Figure 5. Reduced diffusivity confirms a slower thermal response of the bio-modified matrix (Degiovanni, 1987; Maillet et al., 1993).

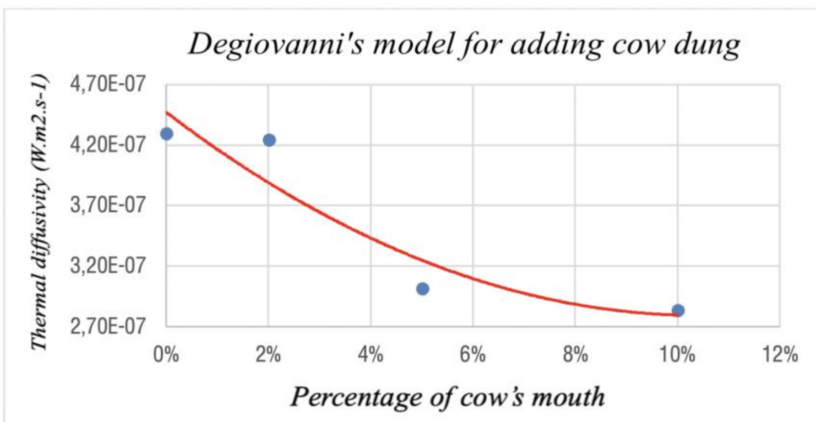

Figure 8. Thermal diffusivity α (m²·s⁻¹) as a function of cow dung content.

3.4 Mechanical strength

Compressive strength increases with cow dung content, reaching 8.2 MPa at 10% (Figure 11). The stress–strain curves for representative specimens are provided in Figure 9. The observed mechanical gain is consistent with binding effects of organic constituents previously reported (Gaye, 1998; Dadi et al., 2015).

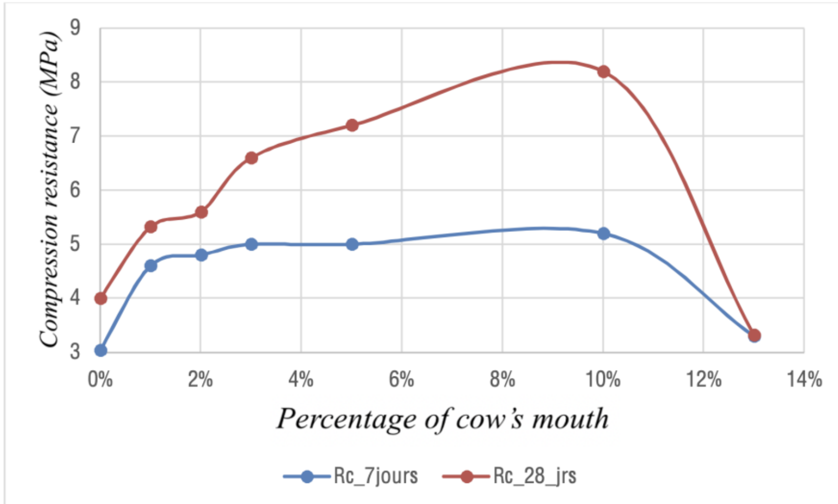

Figure 9. Compressive strength Rc (MPa) as a function of cow dung content

3.5 Thermomechanical optimum

Figure 10 overlays compressive strength and thermal conductivity as functions of cow dung content and demonstrates that 10% provides the optimal compromise: minimized λ and α together with maximized Rc.

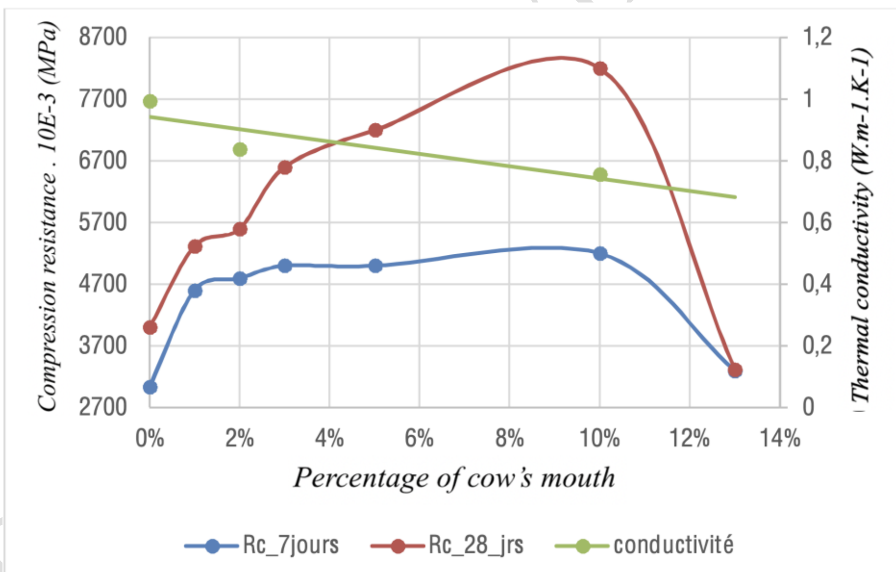

Figure 10. Combined plot: λ and Rc versus cow dung content (thermomechanical optimum illustration).

4. Discussions

4.1 Thermal effects

Cow dung's fibrous and organic composition introduces microcavities that trap air and lower effective thermal conductivity and diffusivity, as discussed in studies on porous bio-materials (Maillet et al., 1993; Sarr, 2008).

4.2 Mechanical effects

Organic constituents act as natural binders, enhancing interparticle cohesion and improving compressive behaviour. Similar mechanisms were described by Sow (2014) and Dadi (2016) for straw/clay and dung/clay composites.

4.3 Thermomechanical synergy

The dual effect—improved cohesion plus increased effective porosity—explains the thermomechanical optimum at 10%, consistent with field-oriented experimental literature on stabilised earth bricks (Meukam et al., 2004; Gaye, 1998).

5. Conclusion

Incorporating cow dung into N'Djamena clay significantly improves thermophysical and mechanical properties of raw earth bricks. A 10% mass fraction is recommended as the optimal stabiliser content for achieving a favourable balance between thermal resistance and mechanical strength. The approach supports low-cost, locally-sourced, and sustainable construction in Sahelian climates.

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