A light brick from fly ash and coconut fibre that absorbs CO2: a short account of one worked example

Shortened preprint version — NOT peer reviewed

Author: Prof. (H.c.) Duong Van Sinh, DSc

Affiliations: (1) Institute for Applied Blockchain Technology, Legal Studies and Intellectual Property, Ho Chi Minh City, Vietnam; (2) Institute for Natural Disaster and Environmental Research (RIDES), HCMC Branch, 38 D15A, Phuoc Long, Ho Chi Minh City, Vietnam

Corresponding author: vienridehcm@gmail.com — **ORCID:** 0009-0000-7223-0188

> **About this version.** This is a shortened, plain-language preprint, to be posted on engrXiv, of a full manuscript submitted to *Építőanyag – Journal of Silicate Based and Composite Materials* by email on 14 November 2026, currently awaiting editor screening. The full paper was framed and submitted **as a case study, not as original research**: it describes a specified material and its manufacture, and reports one worked example exactly as stated in its source dossier. This short version reports the same material, example and numbers — nothing added, no number changed. The full paper is the version under review; this short version exists so the work can be read and shared quickly. It is a preprint: it has **not** been peer reviewed. If the *Építőanyag* paper is published, this preprint will be updated with its DOI.

>

> **Licence.** This preprint is posted under a Creative Commons Attribution 4.0 (CC BY 4.0) licence, as assigned by engrXiv. The journal version, if published by *Építőanyag*, will be under the journal's CC BY-NC licence; the two licences cover different versions of the work.

>

> **AI disclosure.** AI assistance was used in drafting this manuscript. The author is responsible for every claim in it. The AI tool used was Muse (Meta's AI assistant), used for drafting and language editing; the author reviewed and verified every claim, number and reference.

>

> **Competing interest.** The author is the applicant for Vietnamese patent application 1-2025-06337, which covers the material and method reported here. The application is

pending examination — it is **not** a granted patent. The author also holds Copyright Registration Certificate No. 9704/2025/QTG (9 November 2025) for the work; a copyright registration is not a patent grant.

Keywords: fly ash; geopolymer; coconut fibre; CO2 absorption; lightweight brick; alkali activation

Abstract

Fired brick and Portland-cement concrete dominate construction at a heavy cost: brick firing consumes soil and fuel, and cement production emits roughly a tonne of CO2 per tonne of clinker. Meanwhile fly ash from Vietnam's coal power stations keeps accumulating. This short paper describes a construction material made from that waste: a fly-ash geopolymer reinforced with coconut fibre, activated with sodium hydroxide and sodium silicate, and designed to absorb CO2 during curing and in service. The composition is fly ash 60–85% (best 70–80%) with natural fibre 1–10% (best coconut fibre 1–3%), the remainder alkali activator at NaOH:Na2SiO3 1:1 to 1:3 (best 1:1.5–1:2). Fibre is pre-treated and cut to 2–10 cm (best 3–4 cm); the brick is pressed, soaked 5–10 days, and cured at 20–30 °C and above 80% humidity for 20–30 days, with optional CO2 sparging. One worked example is reported, exactly as stated in the source dossier: a 10 × 20 × 6 cm brick from 7 kg fly ash, 0.2 kg coconut fibre, 2.5 kg activator and 0.1 kg Sika R7N, pressed 3 minutes, dried at 60 °C for 1 hour, soaked 7 days, and cured at above 90% relative humidity and 25 °C for 28 days, with periodic CO2 sparging. The dossier reports for that brick a density of about 400 kg/m³, compressive strength of about 16–20 MPa, water absorption below 8%, and CO2 uptake of about 4.5 wt% in the first 24 hours. Those are values for one example brick, made once. This paper presents the material as specified, reports the example as reported, and sets out the validation tests still needed.

1. Why build with fly ash and coconut fibre?

Fired brick needs clay soil and a kiln; Portland-cement concrete needs limestone and a kiln running near 1,450 °C. Both lock construction into a cycle of extraction, firing and emission. Fly ash is the other side of that cycle: Vietnam's coal power stations, cement works and metallurgical plants produce large quantities of it. Fly ash is not inert dust: it contains reactive silica, alumina and calcium oxide, and under a strong alkali it forms a geopolymer network — a hardened binder needing no Portland cement and no firing. What has limited its use is practical. Fly-ash geopolymer is brittle: low tensile and flexural strength, easy cracking, and curing that often depends on heat.

Natural fibre is an old answer to brittleness in a new setting: straw, coir, sisal and bamboo have reinforced mud brick for centuries by bridging cracks and carrying tension. Coconut fibre is plentiful in Vietnam, cheap and light. The material described here combines the two ideas — fly-ash geopolymer as binder, natural fibre as reinforcement — and adds a third: the material is

designed to absorb CO2, first during curing and then in service, by fixing carbon dioxide as carbonate salts in the alkaline matrix. The question is narrow: what composition and method are specified, what does one worked example report, and what must be measured to show the material performs as claimed? It does not claim the example proves the material meets any construction standard (Section 4).

Published work puts the specification in context — and sets the traps. Duxson et al. and Provis and van Deventer showed that precursor chemistry, activator composition and curing determine the result, so the activator's silica modulus and the fly ash's glass chemistry must be recorded — and neither is given in the dossier. For coconut fibre, published optima span 0.5–2% by mass of binder (Burhanudin and Setiawan 2025; Zhou et al. 2026): Burhanudin and Setiawan found the optimum at 0.5% (compressive strength up 48.8%, tensile up 32.5% against the fibre-free mix, both falling at 1%), while Zhou et al. found the best balance of flow and strength at 2% fibre in a slag–fly ash mortar. The dossier's 2.0% sits at the top of that range, but it reports no mechanical test of its own. Worse, Tolêdo Filho et al. found sisal and coconut fibres kept in calcium hydroxide solution at pH 12 had completely lost flexibility and strength after 300 days; the dossier's pre-treatment addresses bonding, not that long-term alkaline attack, so its claim of CO2 uptake "throughout the product's service life" assumes the fibre survives for years in a highly alkaline matrix — untested. For CO2 uptake, values of the same order as the dossier's 4.5 wt% were measured only at stated, aggressive doses — 4.8 wt% after three days under pure CO2 at 4 bar (Harirchi and Yang) and 4.46 wt% after 6 hours at 30% CO2 (Dou et al.) — while the dossier states no dose, so its figure cannot be placed against any of these. For density, Wang et al. prepared lightweight geopolymers at around 630 kg/m³ reaching only 1.86–2.66 MPa.

2. What the material is and how it is made

Composition. The material has three parts: fly ash, natural fibre, and an alkali activator solution (Table 1). The preferred composition is the worked example's: 71.4% fly ash, 2.0% coconut fibre, and 25.5% activator (plus 1.0% Sika R7N). The dossier's preferred ranges (fly ash 70–80%, fibre 1–3%, activator 20–30%) sum to 91–113% and cannot all hold at once.

Component	**Range (% of dry weight)**	**Preferred range**

|---|---|---|

Fly ash	**60–85%**	**70–80%**
Natural fibre	1–10%	1–3% coconut fibre
Alkali activator (NaOH + Na2SiO3)	Remainder	20–30%

Table 1. Composition as specified in the dossier (ranges, not measured results).

Fly ash here is the residue from coal burning, containing reactive SiO2, Al2O3 and CaO. The dossier gives no chemical analysis of the fly ash used in the worked example — no oxide percentages, loss on ignition, or particle-size distribution — yet fly ash varies between plants and batches. Coconut fibre is the preferred reinforcement; the alternatives listed are not used in the example and no comparison between fibre types is reported.

Preparation and treatment. Fly ash is sieved and dried before use, at 50–80 °C or by sun-drying; no sieve size or moisture target is stated. Untreated fibre is weak in an alkaline matrix, so it is not mixed straight into the binder. The treatment has four steps: washing; soaking in dilute calcium hydroxide, Ca(OH)2, at 5–10% for 24–48 hours; optional heating at 80–150 °C; rinsing, drying, and cutting to 2–10 cm (best 3–4 cm); and soaking in sodium silicate, Na2SiO3, for 12–36 hours. The heating step is optional, and the dossier does not state whether it was used in the example, nor the exact Ca(OH)2 concentration and soak time.

Forming, curing and the stated mechanism. The activator is sodium hydroxide, NaOH, and sodium silicate, Na2SiO3. Solid NaOH is dissolved in water to 3–10 M, then mixed with Na2SiO3 solution at NaOH:Na2SiO3 1:1 to 1:3 (best 1:1.5–1:2); the worked example uses 5 M NaOH at 1:2. The dossier does not give the Na2SiO3 solution's concentration or its silica modulus (the SiO2:Na2O ratio). Fly ash and coconut fibre are mixed dry in the ratio 70:2, the activator is added gradually, and the mixture is placed in a mould and formed by hydraulic pressing. In the worked example the brick was pressed for 3 minutes and dried at 60 °C for 1 hour. The press pressure is not stated anywhere in the dossier — neither a force nor a pressure in MPa. After drying, the product is soaked and cured on the preferred schedule: a 7-day soak followed by 28 days at above 90% relative humidity and 25 °C. CO2 gas may be sparged into the mixture or the curing chamber; in the worked example it was sparged periodically for 30 minutes during curing. The dossier does not state how often "periodically" means, at what flow rate, or at what CO2 concentration, so the CO2 dose cannot be reconstructed. The dossier's stated mechanism — CO2 fixed as carbonate salts and hydrated silica — is untested by any measurement in the dossier.

3. The one worked example — what was reported

The dossier gives one worked example, presented here exactly as stated in Table 2. The batch totals 9.8 kg: 7 kg fly ash (71.4%), 0.2 kg coconut fibre (2.0%), 2.5 kg activator (25.5%), and 0.1 kg Sika R7N (1.0%) — percentages are arithmetic on the stated masses. One inconsistency is noted: the stated masses give 70:2, while the mixing step states 73:2, which is inconsistent with the stated masses and is not used here. This paper uses 70:2.

Item	As stated in the dossier

|---|---|

Fly ash	**7 kg, sieved, sun-dried**
Coconut fibre	0.2 kg, washed and treated as in Section 2
Activator	2.5 kg: 1.67 kg Na2SiO3 + 0.83 kg NaOH 5 M solution (ratio 1:2)
Additive	0.1 kg Sika R7N
Mould	10 × 20 × 6 cm brick
Forming	Hydraulic press, 3 min
Drying after forming	60 °C, 1 h
Water soak	7 days
Humid curing	>90% RH, 25 °C, 28 days
CO2 exposure	Sparged periodically, 30 min per sparge (frequency and flow rate not stated)

Table 2. Worked example: batch and process, as stated in the dossier.

Property	**Reported value**	**What is NOT given in the dossier**

|---|---|---|

Density	**~400 kg/m³**	**Sample size, replicates, test method**
Compressive strength	~16–20 MPa	Sample size, replicates, standard deviation, test standard and method, specimen age at test
Water absorption	<8%	Test method, immersion time, replicates
CO2 uptake	~4.5 wt% in the first 24 h, continuing to rise thereafter	Measurement method, CO2 dose, replicates, time series beyond 24 h

Table 3. Properties reported for the worked example (single-example values).

The density is about 400 kg/m³, or 0.4 g/cm³. The dossier compares it with conventional non-fired brick, concrete, and cladding, stating that it is lower by about one third — but no baseline density is given, so the figure cannot be checked from the dossier. Arithmetic on the dossier's own figure implies a baseline of about 600 kg/m³ (400 ÷ (1 − 1/3)), which the dossier does not name; so the comparison cannot be checked as stated.

Compressive strength is stated as about 16–20 MPa. The dossier does not say whether that range covers several specimens, several batches, or a single specimen tested with an uncertainty band. It names no test standard and no loading rate, and it does not state the age of the brick at testing, so the range cannot be compared with a standard requirement, and this paper does not make that comparison. Water absorption is stated as below 8%, with no immersion time, no drying condition before immersion, and no number of specimens given. CO2 uptake is stated as about 4.5% by weight in the first 24 hours, continuing to rise thereafter. No measurement method is given — mass gain, gas analysis, or another method is not stated — and no time series beyond the first 24 hours is given, so the rate after day one and the eventual total are unknown. At the stated density the example brick weighs about 0.48 kg, so 4.5 wt% corresponds to about 22 g of CO2 per brick — arithmetic on the dossier's values, not a measurement, saying nothing about how much is fixed as carbonate.

Three things must be kept separate, because only the first exists in the source files: the material as specified (a complete recipe and process); its performance, which exists only as four single-example values, without the information that would make them testable; and its performance in service — durability and long-term CO2 uptake — which does not exist at all.

4. What it means — and what it does not

A brick at about 400 kg/m³ is light: a 10 × 20 × 6 cm brick weighs roughly half a kilogram, which matters for handling and dead load, and suits cladding and infill better than load-bearing use. Lightweight geopolymers at around 630 kg/m³ reach only 1.86–2.66 MPa, so a pressed brick at about 400 kg/m³ reporting 16–20 MPa sits well outside that range — pressing is not foaming, so the value is a reason to test, not to dismiss. Coconut fibre is supposed to lift the geopolymer past its brittleness, and the pre-treatment is where that claim stands or falls — but none of those failure modes is tested in the dossier, and the validation study should test fibre pull-out and flexural strength, not only compressive strength.

A value of 4.5 wt% CO2 uptake in 24 hours is large enough to matter, if real and lasting. It is also the hardest value in this paper to interpret, because the dose is not stated: uptake depends on CO2 concentration, flow, humidity, temperature, and the surface area exposed, and none of those is given for the sparging in the example. What is needed is a time series at a stated concentration, with an unsparged control and a chemical check of fixation. Until that exists, 4.5 wt% is a reported example value, not a validated uptake rate. The inputs are ordinary, which shortens the path to production — and limits the novelty claim, since none of them is new. What is new, on the dossier's own account, is their combination into a specified lightweight material that absorbs

CO2 (15 claims). The environmental case is the same: real in principle, unmeasured in practice — no life-cycle assessment or energy balance is given.

The limits must be stated plainly. This paper describes a material and a method as specified in a dossier, and reports one worked example. It has no measured dataset, and that is its central limitation: no sample size, no number of replicates, and no standard deviation are given for any of the four reported properties, and no test standard or method is named for any of them. The composition is not fully specified either. The fibre treatment ranges are wide, the CO2 dose is not stated, and no durability data or flexural strength exist. That is a specification and a single example, not a validated result. The next step is a validation study: replicate bricks to a fixed recipe with fully recorded fly-ash analysis, activator specification, fibre treatment and press pressure; test density, compressive and flexural strength, and water absorption to TCVN 6477:2016, reporting n, mean and standard deviation; and measure CO2 uptake over time at a stated concentration, with an unsparged control and a chemical check of fixation. Until those measurements exist, the material should be presented as specified here — a plausible recipe whose performance is still to be shown.

Acknowledgements

The author thanks colleagues for discussions on the dossier. No external funding was received for this work.

Data availability

No test dataset exists beyond the single worked example in Section 3. The source dossier, patent application, and copyright registration are held by the author. Measured replicate data do not exist yet.

References

Burhanudin, I., & Setiawan, A. A. (2025). Effect of coconut fibre on the compressive and tensile strength of geopolymer concrete. *Jurnal Komposit*, *9*(1), 73–78. https://doi.org/10.32832/komposit.v9i1.16456

Dou, G., et al. (2025). Alkali-activated CO2-capturing backfill material for coal mining incorporating municipal solid waste incinerated bottom ash. *ACS Omega*, *10*, 26776–26790. https://doi.org/10.1021/acsomega.5c01445

Duong Van Sinh. (2025). Construction material absorbing CO2 and method for manufacturing this material. Invention dossier (Vietnamese). Dossier on file with the author; 15 claims.

Duxson, P., et al. (2007). Geopolymer technology: the current state of the art. *Journal of Materials Science*, *42*, 2917–2933. https://doi.org/10.1007/s10853-006-0637-z

Harirchi, P., & Yang, M. (2022). Exploration of carbon dioxide curing of low reactive alkali-activated fly ash. *Materials, 15*, 3357. https://doi.org/10.3390/ma15093357

Intellectual Property Office of Vietnam. (2025). Decision 215655/QD-SHTT.IP, 24 September 2025 — patent application 1-2025-06337 (filed 29 August 2025), pending examination, not granted.

Provis, J. L., & van Deventer, J. S. J. (Eds.). (2009). *Geopolymers: Structures, Processing, Properties and Industrial Applications*. Woodhead Publishing.

Tolêdo Filho, R. D., et al. (2000). Durability of alkali-sensitive sisal and coconut fibres. *Cement and Concrete Composites, 22*, 127–143. https://doi.org/10.1016/S0958-9465(99)00039-6

Vietnamese Standard TCVN 6477:2016. Gạch bê tông [Concrete bricks].

Wang, T., et al. (2024). Lightweight geopolymer by bio-based foaming agent. *Materials, 17*, 3167. https://doi.org/10.3390/ma17133167

Zhou, S., et al. (2026). Effect of coconut fiber on the rheological and mechanical properties of geopolymer mortar. *Frontiers in Materials, 13*, 1837370. https://doi.org/10.3389/fmats.2026.1837370

Copyright Office of Vietnam. (2025). Copyright Registration Certificate No. 9704/2025/QTG, 9 November 2025. Copyright registration only — not a patent grant.

Draft prepared 15 November 2026 from the Építőanyag manuscript (14 November 2026) and the source manuscript. No number was changed; every figure above appears in the full manuscript. Figures 1–2 of the full paper are not reproduced here.