Growing *My-stone*: Bio-based Craftsmanship and *Slow Making* Through Living Mineralisation

T.A. Ningsih,[†‡] S. Akkermans,[‡] S. Van Bijlen,[†] J. F.M. Van Impe,[*‡] and R. Armstrong[†]

†RAAD, KU Leuven, Ghent, 9000, Flanders, Belgium
‡BioTeC+, KU Leuven, Ghent, 9000, Flanders, Belgium

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*Author for correspondence. Email: jan.vanimpe@kuleuven.be

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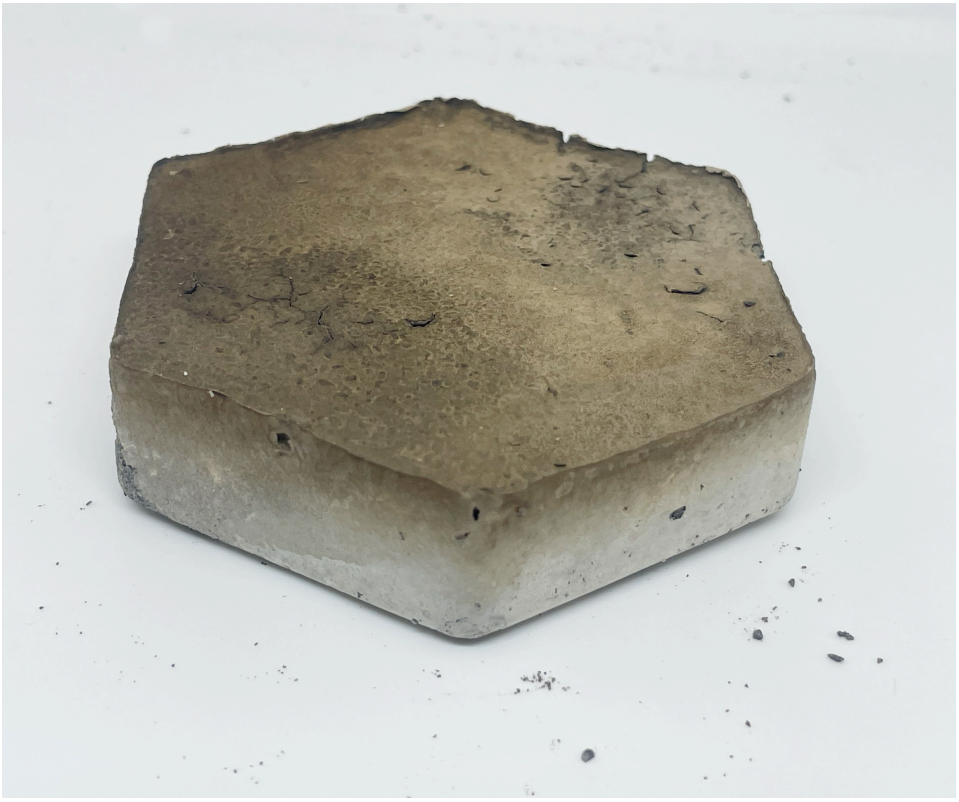
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Abstract

This pictorial investigates how biological processes can guide material fabrication, positioning microbial growth as a sustainable method for architectural construction. This approach frames bio-based craftsmanship as material making grounded in biological activity rather than industrial production. The research builds on ureolytic microbially induced calcium carbonate precipitation (MICP) applied to construction and demolition (C&D) waste, using the fungal strain *Trichoderma reesei*. The project, titled *My-stone*, documents a fabrication process that begins with the inoculation of C&D aggregates with living fungi and continues through weekly feeding with nutrients, calcium chloride, and urea. As the mycelium develops, it gradually binds aggregates into a stable composite with its biomass, cementing this process by inducing calcium carbonate precipitation. Through this staged formation, mineralised material emerges over time, which we term *slow making* as a way of producing locally sourced, site-specific, and context-dependent material as a craft-based technique for architectural and design practices.

Impact Statement

This research introduces a novel fabrication framework for biodesign by demonstrating how biomineralising fungal growth can be harnessed as a form of bio-based craftsmanship. It positions growth and material reuse, not as constraints but as integral, time-based parameters in architectural practice.



Biological Approaches as an Alternative

Bio-based masonry has been widely explored in design and material research as a response to the environmental impact of the conventional use of extractive materials in architectural construction (An et al 2022). Furthermore, the growing volume of construction and demolition (C&D) waste has driven interest in finding alternative ways to produce building materials. Ranging from bio-based mycelium composites that 'grow' rather than mine materials (Yang et al 2021), the new concrete formulations with reduced clinker content (American Cement Association 2026). However, while these approaches reduce reliance on virgin resources, many bio-based alternatives—particularly mycelium biocomposites—currently result in soft, form-like materials with limited structural applications. This limitation raises the question of whether bio-based processes can produce more durable, stone-like materials. Although concrete remains the dominant load-bearing construction material despite contributing to the global carbon emissions, this paper does not propose *My-stone* (see Figure 1) as concrete alternative. Instead, this research investigates whether biomineralisation can expand the material possibilities of bio-based fabrication beyond soft composites and in what context they might expand the material possibilities of bio-based fabrication beyond soft composites towards potentially more durable alternatives.

In nature, microorganisms can produce stone-like minerals through microbially induced calcium carbonate precipitation (MICP) (Ojha et al 2025). This process has been investigated in as a repair method in construction, where microorganisms such as bacteria and fungi heal concrete microfractures (Jonkers et al 2010), or bind loose mineral particles into a new solid material, often described as bio-cement (Choi et al 2017). A commonly used metabolic pathway is ureolytic MICP, where urea is converted to carbonate ion, which reacts with calcium ion to form calcium carbonate (Ojha et al 2025).

Fungi offer specific advantages compared to bacteria in both biomineralisation and composite formation. As fungi grow, their filamentous networks bind mineral particles while simultaneously creating conditions that support mineral formation on their surfaces (Bindschedler et al 2016). Fungi tolerate mineral-rich and variable environments and have been shown to stabilise soil and protect concrete (Van Wylick et al 2021). For these reasons, ureolytic fungi such as *Trichoderma reesei* are (see Figure 2) particularly promising for material fabrication: they can grow while promoting calcium carbonate precipitation, making them suitable for producing biomineralised mycelium composites (Ningsih et al 2025).

Building on these principles, fungal-mediated MICP is used as a biological binder to form stone-like materials from granular substrates. Material fabrication therefore shifts toward the biological process that actively shapes the composite. This active role of the organism transforms the act of making from simple assembly into a cultivation process, laying the groundwork for what we term "bio-based craftsmanship." These biological principles are explored in practice through the development of *My-stone* (see Figure 1), where fungal growth and biomineralisation are applied to material fabrication.

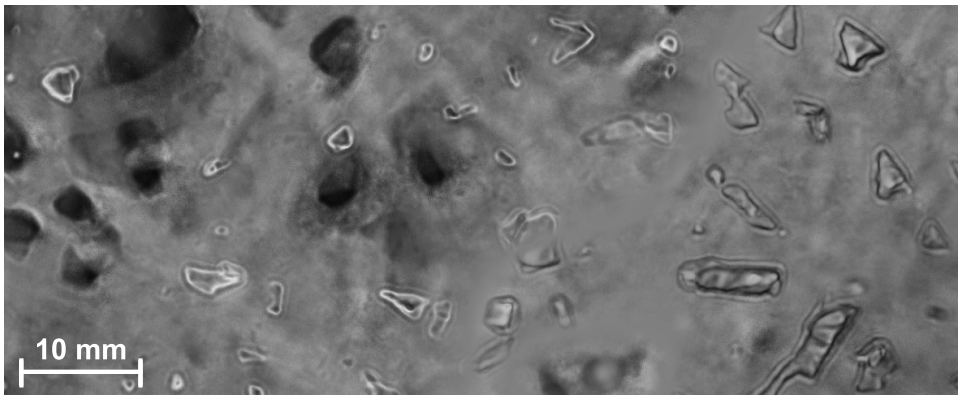


Figure 2. Microscopic image showing calcium carbonate precipitation induced by *Trichoderma reesei*.

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Growing *My-stone*

The mineral composite is made from a mixture of construction and demolition waste, fungal biomass, and calcium carbonate produced through fungal metabolism. The fungal strain *Trichoderma reesei* was selected for its ability to promote ureolytic MICP (Ningsih et al 2025). The production process takes place under controlled laboratory conditions and follows a sequence of cultivation, inoculation, and periodic nutrient feeding, allowing mineralisation to develop progressively over time. This process is carried out under controlled temperature and nutrient conditions to support fungal growth and biomineralisation. The production process involves several key steps using the ingredients shown in Figure 3. The fungus is first cultivated in a liquid medium containing glucose (i) and potato extract (ii) for two weeks to generate sufficient biomass (iii) for material fabrication.



Figure 3. Material components and ingredients for *My-stone* fabrication: (i) glucose, (ii) potato extract, (iii) fungal biomass, (iv) calcium chloride, (v) urea (vi) fine mineral aggregates.

After pre-cultivation, the biomass is harvested and mixed with fresh nutrients containing potato extract and glucose, a solution of calcium chloride (iv) and urea (v) for biomineralisation. Fine aggregates (vi) are then added, and the mixture is placed into silicone molds. During fabrication, the samples are fed weekly with nutrient solutions containing calcium chloride and urea to sustain fungal activity and mineral formation (see Figure 4).

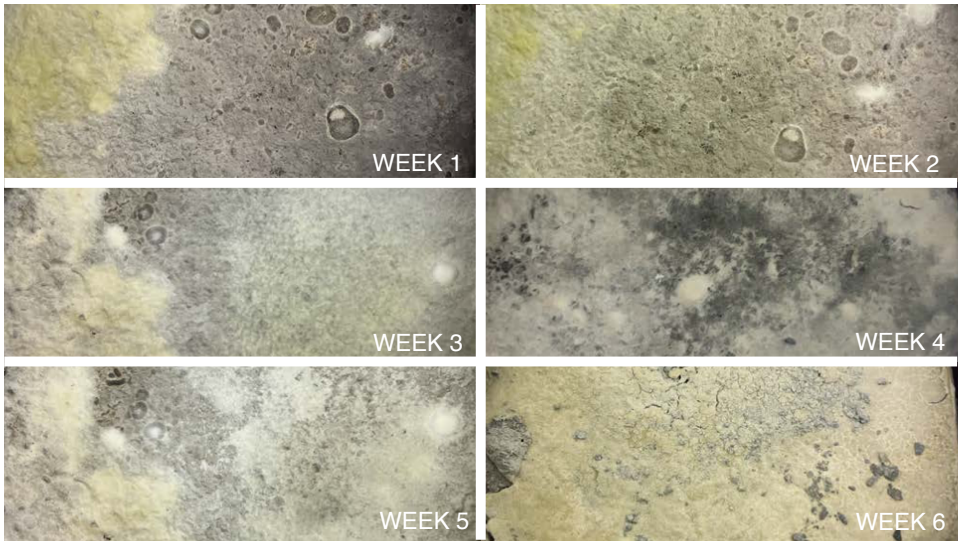


Figure 4. Weekly development of *My-stone* during mineralisation (Week 1-6), showing progressive surface formation.

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Figure 5. Final laboratory results of *My-stone* the biomineralised composite.

As the mycelium grows, its biomass extends between the aggregates particles while calcium carbonate begins to precipitate on the fungal network. This newly formed calcium carbonate crystallises around and between the aggregates, acting as a mineral binder. The crystals gradually fill the gaps between particles and connect them into a continuous matrix. Over time, the initially loose mixture becomes denser and stabilises into a solid, stone-like composite formed through biological activity. It is because the mycelium actively generates the mineral bonds that the material is called *My-stone*: the mycelium produces the calcium carbonate that unites aggregate particles into a coherent stone-like material (see Figure 5). Beyond its material outcome, this process also revealed a different way of making, which is further discussed through the lens of bio-based craftsmanship.

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Bio-based craftsmanship and *slow making*

Beyond material fabrication, this process became a way to reflect on how materials are made through biological growth. This study approaches bio-based craftsmanship as a method of constructing material through growth rather than extraction. Material formation unfolds over time and depends on repetition, environmental conditions, and biological activity. In this context, slowness is not treated as a limitation but as an inherent characteristic of working with living systems. The material does not appear at once; it develops gradually through continued biological and mineral activity.



Figure 6. Fabrication sequence of *My-stone*; (left) mixing of fungal biomass and nutrient solution; (middle) inoculating aggregates with the mixture inside the mould; (right) uniform mixing of fungal biomass, nutrients, and aggregates in the mould.

This methodology was further explored through laboratory experimentation, where material panels were developed using Voronoi geometries and custom silicone moulds. This approach follows a reseach-through-design methodology, where material experiments inform conceptual and architectural development. The fabrication process involved preparing aggregates, producing fungal biomass, and inoculating the substrate (see Figure 6). After inoculation, the samples were regularly fed with nutrient solutions to sustain mineralisation and growth (see Figure 7).

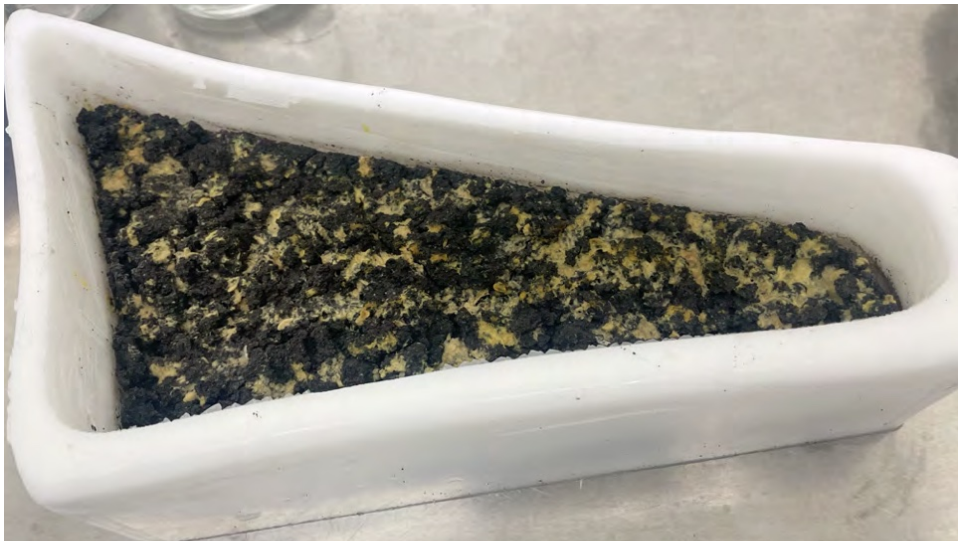


Figure 7. Progressive mineralisation of a panel sample during laboratory experimentation.

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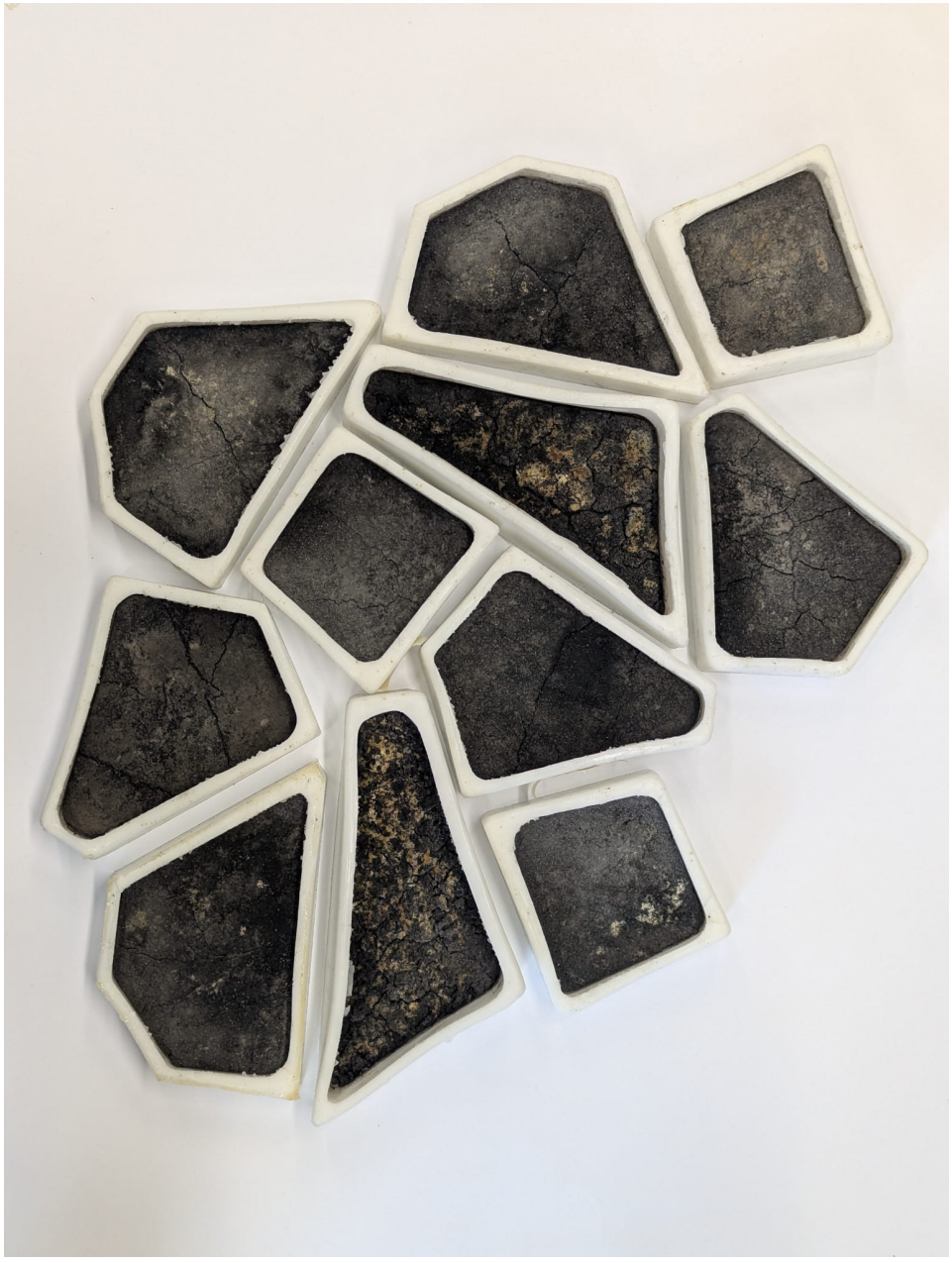


Figure 8. *My-stone* panels after pasteurisation.

By working directly with growing materials, fabrication became an ongoing process rather than a pursuit of a fixed outcome (see Figure 8). Using construction and demolition waste as a substrate reinforced the team's understanding of reuse and transformation. In this context, *slow making* became a practical framework for engaging with material responsibility.

Rather than imposing form onto inert matter, the *My-stone* panels are allowed to develop through continuous interaction with living material. This shift in making practice also suggests a different way of understanding form and material. As Ingold (2010) suggests, forms arise "within fields of force and flows of material," where the practitioner follows the behaviour of matter rather than fully determining it in advance. In the workshop, students could not force the panels to harden faster or behave predictably. Instead, they had to observe, adjust, and respond. Fabrication thus became a temporal engagement with material processes rather than an act of instant production. Bio-based craftsmanship, in this sense, shifts the role of the designer from controlling form to sustaining the conditions in which form can emerge. This understanding of material formation through time and accumulation provides the basis for translating the process into architectural thinking.

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Architecture by accretion

In biomineralisation, minerals form through accretion: the gradual accumulation of amorphous particles that later transform into a stable mineral phase. The gradual formation observed in the laboratory, referred to here as *slow making*, can be understood through the concept of accreation, where material develops through incremental accumulation over time (Macías-Sánchez et al 2017). Rather than appearing instantly, biological form develops through repeated, layered deposition, as seen in shell formation (see Figure 9, left). Accretion therefore describes growth as progressive consolidation instead of a single act of formation.



Figure 9. (left) Shells growing on submerged Venetian walls through biomineral accretion; (right) wooden pile foundations in Venice, where buildings stabilise over time through interaction with water and sediment (See Venice n.d.).

A comparable logic can be found in Venice, where buildings rest on thousands of wooden piles driven into lagoon sediment (see Figure 9, right) . Over time, the interaction between wood, water, and mineral-rich mud stabilised the foundations, allowing the city to emerge from its environment. In both cases, material stability results from sustained interaction between matter and surroundings rather than immediate assembly. These examples provide a historical and natural precedent for the *slow making* observed in the laboratory, where form is not built but accumulated.

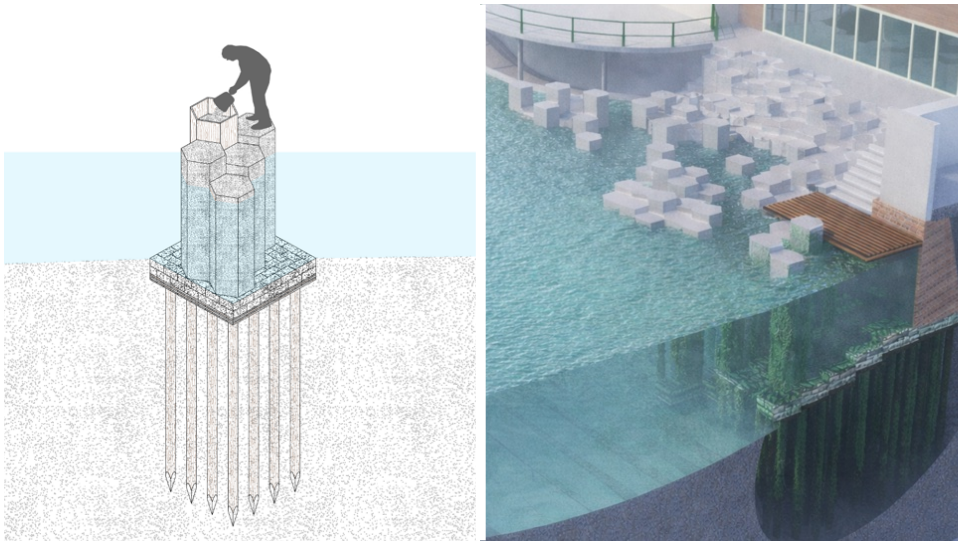


Figure 10. (left) Drawing of Pillar installation process; (right) Rendering of pillar design proposal using *My-stone* installed in the Schelde, Ghent (Design and visualisation by Van Bijlen, 2026).

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Building on these natural and historical precedents, the laboratory research on *slow making* was translated into architectural design through a student project based on accretion. Here, accretion refers to architectural form developing through repeated addition enabled by living mineralisation. The project proposes an architecture shaped by accumulation, use, and environmental influence.

The design applies this approach to a field of pillars placed in a river, inspired by foundation techniques that relied on gradual material deposition (see Figure 10). Using *My-stone*, each pillar is formed from construction and demolition waste as aggregates, while food and organic waste streams provide nutrients for fungal growth and mineralisation. The process requires long-term collection and biological transformation. Because of the quantity of material needed, the pillars cannot be produced quickly; they depend on sustained accumulation. Time thus becomes a building parameter (see Figure 11 and Figure 12). At present, the laboratory material remains under development, and further optimisation of its mechanical performance is required before such structural applications can be realised. The architectural proposal therefore operates as a speculative extension of the ongoing material research.

Working with living mineralisation in the laboratory revealed making as a direct interaction with active material. It involves "surrendering" to the material and "following where it leads" (Ingold 2013). In practice, this meant inoculating, feeding, waiting, and observing how mineral formation developed. The result could not be fully predetermined; it depended on how the material responded over time. Bio-based craftsmanship, therefore, became a way of working with material change as it unfolded.

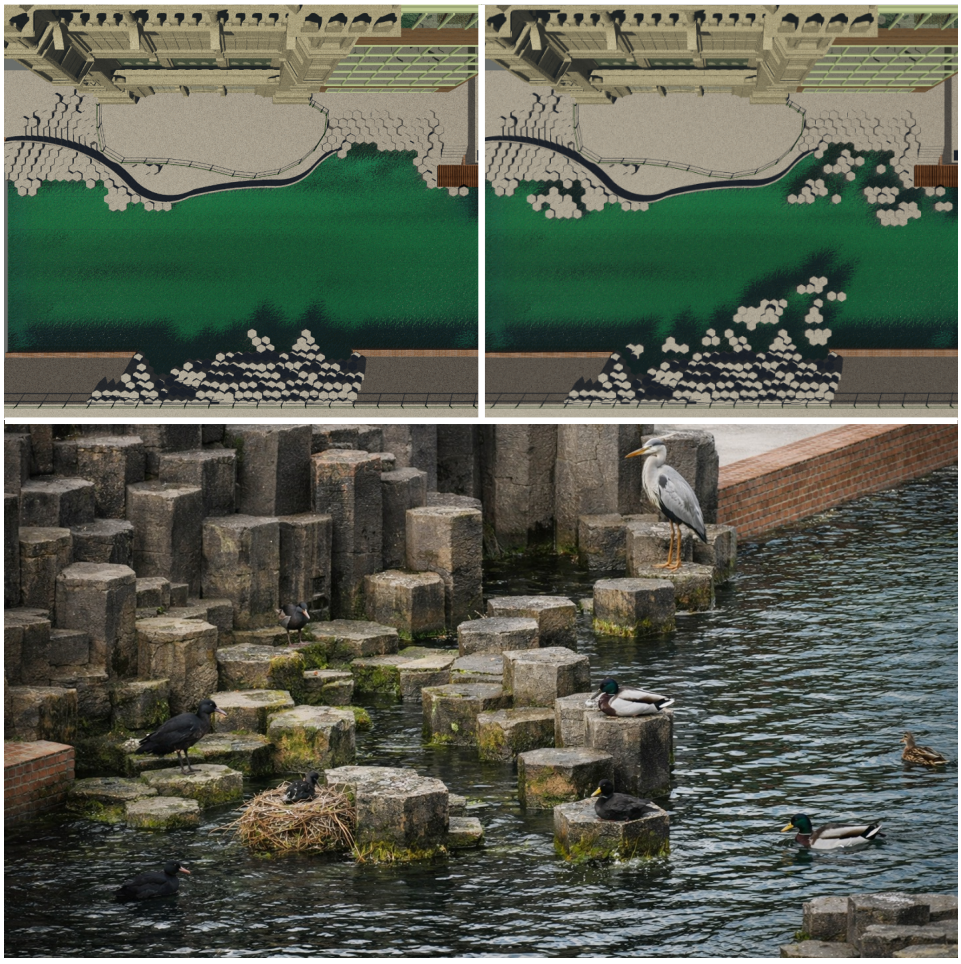


Figure 11. (top) temporal accumulation of *My-stone* pillars; (bottom) proposed placement of pillars along the river. (Architectural visualisation by Van Bijlen 2026)

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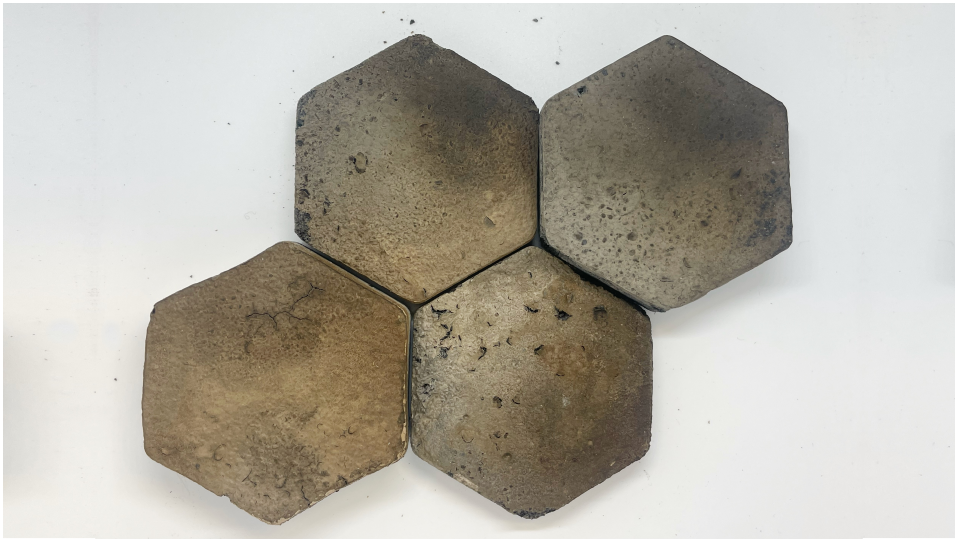


Figure 12. Modular *My-stone* units illustrating the pillar construction concept.

Architecture exists "not only *in but as* time" (Leatherbarrow 2021). The pillars are therefore not conceived as finished objects but as material formations shaped by duration. *Slow making* should not be considered as a delay, but as the time required for material formation to occur. Design, in this sense, must make space for continual change. Biological growth and environmental interaction are not secondary effects, but part of how the architecture comes into being.

Conclusion

This research demonstrates that architecture may emerge through growth, accretion, and biological transformation. By combining fungal biomineralisation with construction and demolition waste, *My-stone* shows how mineral bonding develops through sustained interaction between living organisms and granular materials. *Slow making* positions time and environmental interaction as active components in material formation. Ultimately, io-based craftsmanship frames architectural production as a practice grounded in growth, reuse, and material responsibility.

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Competing Interests None

Data Availability Statement For data available within the article or its supplementary materials: The authors confirm that the data supporting the findings of this study are available within the article.

Ethical Standards The research meets all ethical guidelines, including adherence to the legal requirements of the study country.

Author Contributions Conceptualization: T.A.N.; S.V.B Methodology: T.A.N; S.A. Data curation: T.A.N. Data visualisation: T.A.N (laboratory and prototype documentation); S.V.B (architectural visualisation and illustration). Writing original draft: T.A.N. Review and editing: S.A; R.A; J.F.M.V.I. All authors approved the final submitted draft.

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References

American Cement Association (2026). Blended cements and sustainability of concrete construction. Available at https://www.cement.org/a-sustainable-future/reaching-our-goal/blended-cements/ (Accessed 12 February 2026).

An, B., Wang, Y., Huang, Y., Wang, X., Liu, Y., Xun, D., Church, G. M., Dai, Z., Yi, X., Tang, T.-C., et al. (2022). Engineered living materials for sustainability. *Chemical Reviews*, 123(5), 2349–2419. https://doi.org/10.1021/acs.chemrev.2c00000

Bindschedler, S., Cailleau, G., and Verrecchia, E. (2016). Role of fungi in the biomineralization of calcite. *Minerals*, 6(2), 41. https://doi.org/10.3390/min6020041

Choi, S. G., Chu, J., Brown, R. C., Wang, K., and Wen, Z. (2017). Sustainable biocement production via microbially induced calcium carbonate precipitation: Use of limestone and acetic acid derived from pyrolysis of lignocellulosic biomass. *ACS Sustainable Chemistry & Engineering*, 5(6), 5183–5190. https://doi.org/10.1021/acssuschemeng.7b00355

Ingold, T. (2010). The textility of making. *Cambridge Journal of Economics*, 34(1), 91–102. https://doi.org/10.1093/cje/bep042

Ingold, T. (2013). *Making: Anthropology, Archaeology, Art and Architecture*. London and New York: Routledge.

Jonkers, H. M., Thijssen, A., Muyzer, G., Copuroglu, O., and Schlangen, E. (2010). Application of bacteria as self-healing agent for the development of sustainable concrete. *Ecological Engineering*, 36(2), 230–235. https://doi.org/10.1016/j.ecoleng.2008.12.036

Leatherbarrow, D. (2021). *Building Time: Architecture, Event, and Experience*. London: Bloomsbury Visual Arts. https://doi.org/10.5040/9781350165229

Macías-Sánchez, E., Willinger, M. G., Pina, C. M., and Checa, A. G. (2017). Transformation of ACC into aragonite and the origin of the nanogranular structure of nacre. *Scientific Reports*, 7, 12728. https://doi.org/10.1038/s41598-017-13240-1

Ningsih, T. A., Akkermans, S., De Vreese, P., Matthijs, E., Armstrong, R., and Van Impe, J. F. M. (2025). Towards mineralised mycelium biocomposites: Optimising fungal growth and ureolytic biomineralisation. *Journal of Cleaner Production*, 499, 145120. https://doi.org/10.1016/j.jclepro.2025.145120

Ojha, A., Bandyopadhyay, T. K., and Das, D. (2025). Unveiling the role of microbial urease in ureolysis-induced calcium carbonate precipitation: Mechanistic insights and emerging applications. *World Journal of Microbiology and Biotechnology*, 41(7), 227. https://doi.org/10.1007/s11274-025-03909-4

See Venice (n.d.). Wood in Venice: Almost invisible but ever-present. Available at https://www.seevenice.it/en/wood-in-venice-almost-invisible-but-ever-present/ (Accessed 12 February 2026).

Van Wylick, A., Monclaro, A. V., Elsacker, E., Vandelook, S., Rahier, H., De Laet, L., Cannella, D., and Peeters, E. (2021). A review on the potential of filamentous fungi for microbial self-healing of concrete. *Fungal Biology and Biotechnology*, 8, 16. https://doi.org/10.1186/s40694-021-00120-2

Yang, L., Park, D., and Qin, Z. (2021). Material function of mycelium-based bio-composite: A review. *Frontiers in Materials*, 8, 737377. https://doi.org/10.3389/fmats.2021.737377

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