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CAPABILITY FOR MODIFYING UNFIRED CLAY MATERIALS WITH BIOPOLYMERS

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The growing emphasis on sustainability in construction has drawn attention to unfired clay materials as environmentally friendly alternatives to conventional building materials. However, their physical-mechanical, hygroscopic properties and durability often require enhancement to meet modern performance standards. The incorporation of biopolymers has emerged as a promising solution to modify and improve these properties in clay-based materials. This study systematizes research findings on the potential of biopolymers to modify clay-based materials, focusing on their physical-mechanical and hygroscopic properties.
Keywords: *clay, biopolymer, modification, stabilization, sustainability.*

ПЕРСПЕКТИВЫ МОДИФИКАЦИИ НЕОБОЖЖЕННЫХ ГЛИНИСТЫХ МАТЕРИАЛОВ БИОПОЛИМЕРАМИ

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Растущая роль устойчивого развития в строительстве привлекла внимание к необожжённым глинистым материалам как экологически чистой альтернативе традиционным строительным материалам. Однако их физико-механические, гигроскопические свойства и долговечность часто требуют улучшения, чтобы соответствовать современным стандартам. Внедрение биополимеров стало перспективным решением для модификации и улучшения этих свойств в глинистых материалах. Данный обзор систематизирует результаты исследований о потенциале биополимеров в модификации глинистых материалов, фокусируясь на их физико-механических и гигроскопических свойствах.
Ключевые слова: *глина, биополимер, модификация, стабилизация, устойчивость.*

Introduction. Unfired clay materials are gaining attention as sustainable alternatives to conventional building materials due to their environmental benefits and low energy requirements [1]. However, their widespread application is limited by challenges related to mechanical strength, durability, and hygroscopic properties. Incorporating biopolymers offers a promising solution to these challenges by improving the structural and moisture-regulating characteristics of unfired clay materials. This overview provides a compilation of several studies, showing the potential effect of the biopolymers on the number of properties of clay-based materials. Moreover, it outlines future research directions and applications, emphasizing the role of biopolymers in advancing sustainable construction materials.

Main part. In the last decade, biopolymers have gained popularity for stabilizing clay-based materials, primarily in the construction and geotechnical sectors. Based on the literature review in the doctoral dissertation by Trambitski, 2024 [2], the most commonly used biopolymers for stabilizing and modifying clay-based materials can be identified (Fig. 1).

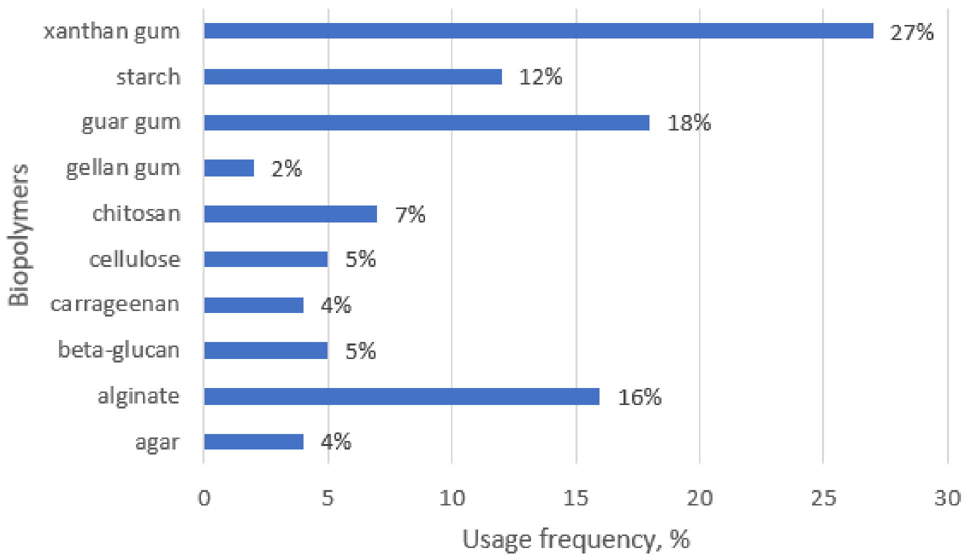

Figure 1. – Popularity of the different biopolymers for clay stabilization

Physical properties such as plasticity, density, and shrinkage are among the most significant characteristics when evaluating clay materials, and the use of biopolymers has a strong impact on them. For example, the addition of biopolymers typically decreases the density of clay materials due to the incorporation of less dense organic matter into the composite (Fig. 2). However, in some studies [3–5], researchers observed the opposite effect—an increase in the density of the clay composite, attributed to the greater compaction of the plastic clay mass during molding with the addition of biopolymers. Most studies also note that the use of biopolymers reduces porosity, as polymeric networks fill voids within the clay matrix, leading to more compact (though not often denser) structures [6].

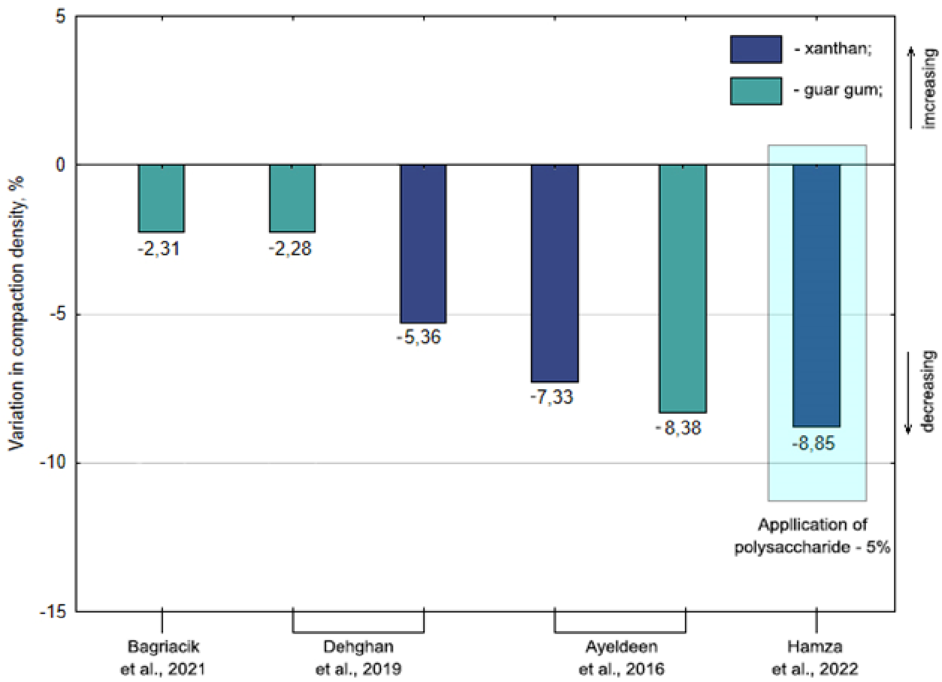

Figure 2. – The impact of most common biopolymers (xanthan and guar gums) on compaction density of the unfired clay materials [7-10]

Plasticity, a critical parameter for processing and shaping, is often improved through the incorporation of polysaccharides like xanthan gum and guar gum, which enhance water retention and create a more cohesive and pliable mixture [11]. However, the type and concentration of the biopolymer significantly affect this property, as excessive amounts may lead to overly sticky mixtures. Shrinkage, a major concern in unfired clay materials, is generally reduced with biopolymer stabilization, as the hydrophilic nature of biopolymers moderates water loss during drying, minimizing cracks and deformation [12]. This combined impact on density, plasticity, and shrinkage underscores the potential of biopolymers to improve the processability and dimensional stability of unfired clay materials.

Modification of the microstructure of clay materials through the formation of polymeric bridges and three-dimensional networks within the clay matrix is critical for enhancing both mechanical strength and durability. Studies [13–16] have demonstrated increases in the compressive strength of clay-based materials stabilized with various types of biopolymers, ranging from 32% to 344%. Depending on their nature, different biopolymers tend to bind clay aggregates either through "direct", or "indirect" contacts, basing on hydrogen bonding, electrostatic interactions, cross-linking mechanisms and etc. [15; 16].

The addition of biopolymers significantly improves the hygroscopic properties of UCBM by increasing their ability to adsorb/retain moisture (Fig. 3). For example, biopolymers such as xanthan gum and guar gum form hydrogel networks within the clay matrix, which absorb and retain water, thereby enhancing moisture buffering capacity [17]. These properties are particularly advantageous for maintaining indoor air quality in unfired clay buildings, as they help stabilize ambient humidity levels.

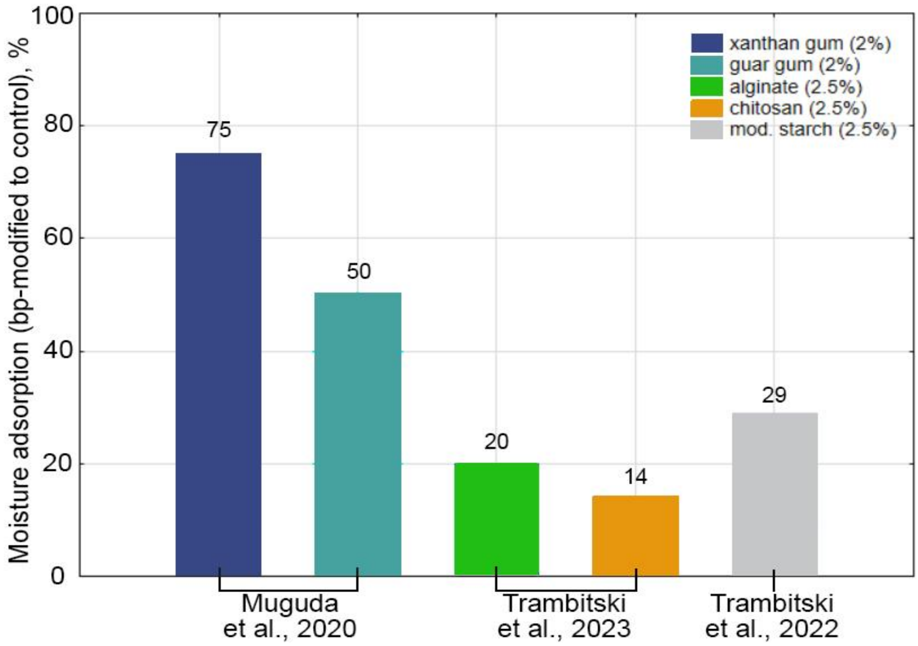

Figure 3. – The impact of biopolymers on moisture buffering capacity of the clay-based materials [4; 5; 18]

The uniform distribution of polysaccharides within the clay matrix contributes to improved interaction with ambient humidity, ensuring better hygroscopic performance [12]. The interaction of polysaccharides with water molecules is mediated by hydrogen bonding, a process critical for stabilization or modification of unfired clay materials. Polysaccharides, rich in hydroxyl groups, readily form hydrogen bonds with water, creating a network that binds moisture within the clay matrix [19; 20].

The use of biopolymers in UCBM aligns with the principles of sustainable construction by reducing reliance on energy-intensive materials and processes. Modified clay materials can be employed in a range of applications, including unfired masonry products, plasters, and insulation panels. Their improved mechanical and hygroscopic properties make them suitable for both structural and non-structural uses.

Conclusions. The capability of biopolymers to modify unfired clay materials represents a transformative step toward sustainable and high-performance building materials. By enhancing physical-mechanical and hygroscopic properties, biopolymers address critical limitations of traditional unfired clay-based materials, such as low durability and susceptibility to water damage. Biopolymers, with their versatility and compatibility with clay, offer immense potential for advancing the field of sustainable construction. Their incorporation into clay-based materials not only improves material properties but also supports the development of eco-friendly, resilient, and cost-effective building solutions for the future.

REFERENCES

1. E. Christoforou, A. Kylili, P.A. Fokaides, I. Ioannou, Cradle to site Life Cycle Assessment (LCA) of adobe bricks, J. Clean. Prod. 112 (2016) 443–452, https://doi.org/10.1016/j.jclepro.2015.09.016.
2. Trambitski, Y. Research of Structure and Durability of Natural Polymer Modified Clays. Doctoral Dissertation, Vilnius Gediminas Technical University, Vilnius, Lithuania, 2024.
3. Dove, C., 2014. The development of unfired earth bricks using seaweed biopolymers. WIT Trans. Built Environ., Eco-architecture. 142, 219-230. Available online: https://www.witpress.com/Secure/elibrary/papers/ARC14/ARC14020FU1.pdf.
4. Trambitski, Y., Kizinievič, O., Kizinievič, O., 2022 a. Modification of clay materials with retrograded starch hydrogel. Constr. Build. Mater. 314, 125619. https://doi.org/10.1016/j.conbuildmat.2021.125619.
5. Trambitski, Y., Kizinievič, O., Gaspar, F., Kizinievič, V., Valente, J., 2023. Eco-friendly unfired clay materials modified by natural polysaccharides. Constr. Build. Mater. 400, 132783. https://doi.org/10.1016/j.conbuildmat.2023.132783.
6. Fatehi, H., Ong, D.E.L., Yu, J., Chang, I., 2023. The Effects of Particle Size Distribution and Moisture Variation on Mechanical Strength of Biopolymer-Treated Soil. Polymers. 15, 1549. https://doi.org/10.3390/polym15061549.
7. Bagriacik, B., Ok, B., Kahiyah, M.T.M.A., 2021. An experimental study on improvement of cohesive soil with eco-friendly guar gum. Soils Rocks. 44, 1–9. https://doi.org/10.28927/SR.2021.060020.
8. Dehghan, H., Tabarsa, A., Latifi, N., Bagheri, Y., 2016. Use of xanthan and guar gums in soil strengthening. Clean Techn. Environ. Policy 21, 155–165. https://doi.org/10.1007/s10098-018-1625-0.
9. Ayeldeen, M.K., Negm, A.M., El Sawwaf, M.A., 2016. Evaluating the physical characteristics of biopolymer/soil mixtures. Arab. J. Geosci. 9 (5), 1–13. https://doi.org/10.1007/s12517-016-2366-1.
10. Hamza, M., Nie, Z., Aziz, M., Ijaz, Z., Rehman, Z., 2022. Strengthening potential of xanthan gum biopolymer in stabilizing weak subgrade soil. Clean Techn. Environ. Policy. 24, 2719–2738. https://doi.org/10.1007/s10098-022-02347-5.
11. Perrot, A., Rangeard, D., Courteille, E., 2018. 3D printing of earth-based materials: Processing aspects. Constr. Build. Mater. 172, 670–676. https://doi.org/10.1016/j.conbuildmat.2018.04.017.
12. Laborel-Préneron, A., Giroudon, M., Aubert, J.E., Magniont, C., Faria, F., 2021. Experimental assessment of bio-based earth bricks durability. IOP Conf. Ser.: Mater. Sci. Eng. 660 (1), 012069. https://doi.org/10.1088/1757-899X/660/1/012069.
13. Tourtelot, J., Bourgès, A., Keita, E., 2021. Influence of biopolymers on the mechanical behavior of Earth-based building materials. Recent Prog. Mater. 3 (3), 1-16. https://doi.org/10.21926/rpm.2103031.
14. Alhaik, G., Ferreira, M., Dubois, V., Wirquin, E., Tilloy, S., Monflier, E., Aouad, G., 2017. Enhance the rheological and mechanical properties of clayey materials by adding starches. Constr. Build. Mater. 139, 602–610. https://doi.org/10.1016/j.conbuildmat.2016.11.130.

15. Soldo, A., Miletić, M., Auad, M.L., 2020. Biopolymers as a sustainable solution for the enhancement of soil mechanical properties. Sci. Rep. 10 (1), 1–13. https://doi.org/10.1038/s41598-019-57135-x.
16. Chang, I., Prasidhi, A.K., Im, J., Cho, G.C., 2015 b. Soil strengthening using thermo-gelation biopolymers. Constr. Build. Mater. 77, 430–438. https://doi.org/10.1016/j.conbuildmat.2014.12.116.
17. Zhou, C., So, P.S., Chen, X.W., 2020. A water retention model considering biopolymer-soil interactions. J. Hydrol. 586, 124874. https://doi.org/10.1016/j.jhydrol.2020.124874.
18. Muguda, S., Lucas, G., Hughes, P.N., Augarde, C.E., Perlot, C., Bruno, A.W., Gallipoli, 2020 a. Durability and hygroscopic behaviour of biopolymer stabilised earthen construction materials. Constr. Build. Mater. 259, 119725. https://doi.org/10.1016/j.conbuildmat.2020.119725.
19. Maji, D., 2019. Introduction to natural polysaccharides, in: S. Maiti, S. Jana (Eds.), Functional Polysaccharides for Biomedical Applications. Woodhead Publishing, Elsevier, pp.1-31. https://doi.org/10.1016/B978-0-08-102555-0.00001-7.
20. Rinaudo, M., 2006. Characterization and Properties of Some Polysaccharides Used as Biomaterials. Macromol. Symp. 245, 549-557. https://doi.org/10.1002/masy.200651379.