Development of hemp-lime bricks based on hemp grown in Switzerland

Background

The construction industry in Switzerland, like in many other countries, is a major contributor to greenhouse gas emissions. Traditional building materials, particularly concrete and steel, have significant environmental impacts due to their high energy and carbon costs. The Swiss Federal Office for the Environment reports that the construction industry accounts for approximately 35% of the nation's CO_2 emissions, emphasizing the need for alternative, low-carbon products.

One promising solution are Hemp-lime bricks, a bio-composite material made from hemp hurds (the woody core of the hemp plant), lime, and water. Known for its insulation capabilities, and moisture regulation, bricks made of hemp have already gained traction in other countries. However, its application in Switzerland has been limited, partly due to reliance on imported materials, and lack of machinery and production lines. However, Switzerland's unique climate, government policy, and dedication to sustainability make it an ideal location to explore locally sourced hemp for construction, aligning with the national goal of achieving carbon neutrality by 2050.

This project, a collaborative research effort by two departments at Bern University of Applied Sciences (BFH), assessed the viability of using Swiss-grown hemp as a sustainable construction material. The School of Architecture, Wood, and Civil Engineering (AHB) team evaluated the physical and mechanical properties of Swiss hemp and Hemp-lime bricks to understand its potential as a construction material. The physical and mechanical properties of Swiss hemp hurds and the hemp-lime bricks produced from them, such as bulk density, moisture content, particle size distribution, and compressive strength, were assessed and compared with Kanabat, sourced from La Chanvrière. Additionally, the thermal conductivity of the hemp-lime bricks was analysed to determine their effectiveness for insulation and energy efficiency in building applications. Comparisons with imported hemp (Kanabat) provided insight into whether Swiss hemp could match or exceed the quality of imported alternatives.

The School of Agricultural, Forest, and Food Sciences (HAFL) conducted a preliminary Life Cycle Assessment (LCA), to measure the environmental impact of hemp-lime bricks production. The LCA analysed various variants of plant-based construction materials (NawaRo Kalksteine), including different types of hemp hurds each evaluated in terms of global warming potential (GWP), non-renewable energy consumption, and overall ecological impact.

This research project was made possible by funding from the BFH Office for Sustainable Development and several pioneering companies committed to sustainable construction in Switzerland. Glarnisch Textil, the only Swiss company equipped with a decortication machine, contributed with material from locally sourced hemp and its expertise in hemp fiber processing, enabling the team to explore the use of locally produced hemp hurds for construction. Hanfhandwerk, dedicated to preserving and revitalizing traditional building practices, provided material, valuable hands-on experience, and insight into working with hemp in construction. In addition, and part of this project, Katernia Valova (BFH-AHB) also prepared her master's [1] thesis on the feasibility study for the production of hemp-lime bricks and the economic viability of winter hemp cultivation in Switzerland.

Material Characterisation

In this study, three types of hemp hurds, Kanabat, Winter (variety grown for fibre), and Landi (variety grown for seeds), as shown in Figure 1, were tested to evaluate their suitability as materials in hemp-lime bricks. Kanabat hurds were specifically processed for uniform size and minimal dust content, making them well-suited for construction applications. Hanfhandwerk supplied these hurds, which were carefully packaged and standardized, ensuring consistent quality. The Winter hurds, provided by HAFL, were derived as a by-product of a winter hemp cultivation project focused on textile applications. After a natural retting process that loosened fibers from the woody core, the plants were decorticated at Glarnisch Textil, resulting in hurds that contained residual fibers and were not fully dust-free. Lastly, the Landi hurds, acquired through Landi Schweiz, came from hemp grown primarily for seed production. Following decortication at Glarnisch Textil, these hurds were observed to contain finer dust and fibers, suggesting variability in either the processing method or the plant's intrinsic properties.

Figure 1: Kanabat, Winter and Landi hurds (from left) [1]

Particle size Distribution (PSD): Kanabat hurds, with a more uniform particle size, exhibit a steeper slope on the gradation curve as shown in Figure 2, indicating a consistent distribution and fewer fine particles. This uniformity may reduce porosity, slowing CO_2 diffusion and hardening but potentially contributing to homogenous compactness in the final product. In contrast, the Winter and Landi hurds display a more gradual slope, indicating greater variability in particle size. Winter hurds, with a broad range of particle sizes, are more porous, allowing faster CO_2 diffusion and quicker hardening, though the uneven binder coating on finer particles may affect mechanical performance. Landi hurds, containing the finest particles, exhibit the highest porosity, promoting rapid CO_2 diffusion initially, though higher water and binder requirements may extend the overall hardening process.

Figure 2: Gradation curves of Kanabat, Winter and Landi hurds.

Bricks Characterisation

Density of bricks: The density measurements and testing of bricks made by Kanabat, Winter, and Landi hurds reveal valuable differences that influence their suitability for use in construction. Initial density measurements, conducted after a 28-day drying period, showed that Winter hurds produced the highest density at 453 kg/m³, followed by Landi at 416 kg/m³, and Kanabat at 381 kg/m³. Notably, the fibrous Winter and Landi hurds required approximately 10% more water in the mix than the non-fibrous Kanabat hurds. To explore the impact of compressive force during manufacturing, a separate batch of Kanabat specimens was produced under higher pressing force, yielding an increased density of 400 kg/m³, compared to the initial 381 kg/m³. This density increase highlights the role of consistent compressive force in producing denser, potentially more robust hemp-lime bricks. Extended drying (60 days) for thermal conductivity testing provided further insight, showing a significant reduction of approximately 16.5% in density, indicating that much of the initial mass in the specimens was due to water content. Final densities after this extended drying period were 321 kg/m³ for Kanabat, 385 kg/m³ for Winter, and 340 kg/m³ for Landi. This reduction underscores the importance of sufficient drying time to achieve accurate density measurements, which are essential for reliably assessing the thermal and mechanical properties of hemp-lime bricks.

Compressive Strength: Compression tests on bricks made by Kanabat, Winter, and Landi hurds underscore the impact of particle structure and fiber content on the mechanical performance of hemp-lime bricks. As shown in Figure 3, Kanabat bricks, specifically those processed under higher compressive force (Kanabat 2, showed the highest compressive strength at 0.49 MPa, with a high specific strength relative to density, highlighting the benefits of compacted manufacturing. Regular Kanabat samples followed at 0.44 MPa, with slightly more variability, potentially due to less controlled manufacturing conditions. Bricks made of Winter hurds, influenced by residual fiber content and particle size variability, demonstrated a compressive strength of 0.39 MPa, showing greater standard deviation and highlighting the effect of fiber presence on mechanical consistency. Bricks made of Landi hurds showed the lowest compressive strength at 0.36 MPa but displayed consistent performance across samples, likely due to their more homogenous particle and fiber composition.

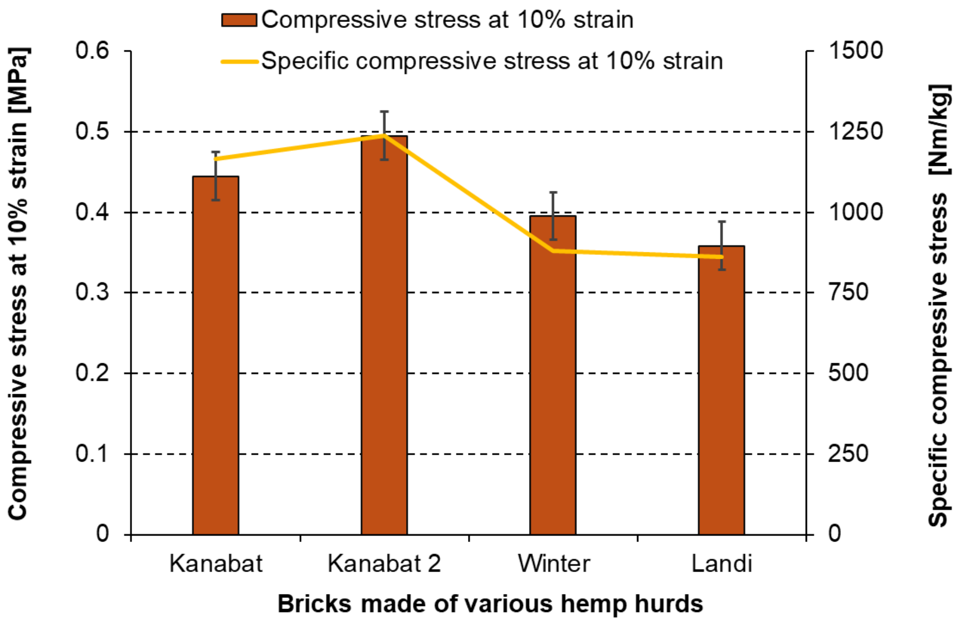

Figure 3: Compressive strength at 10% strain [MPa] of all hemp species, Kanabat, Winter and Landi with addition of Kanabat 1 to compare the importance of compactness force during manufacturing.

Thermal Conductivity: Thermal conductivity tests on specimens dried for 60 days further differentiate the insulation capabilities of bricks made of Kanabat, Winter, and Landi hurds. Kanabat bricks, with the lowest density of 321 kg/m³ after drying, showed the highest thermal conductivity at 0.0746 W/(m·K), indicating lower insulation effectiveness. In contrast, Landi bricks, with a post-drying density of 340 kg/m³, demonstrated the best insulating properties with the lowest thermal conductivity at 0.0674 W/(m·K). The Winter bricks, with the highest post-drying density of 385 kg/m³, showed a moderate thermal conductivity value of 0.0685 W/(m·K). When specific lambda values (thermal conductivity relative to density) were examined, bricks made of Winter and Landi hurds exhibited relatively similar insulating capacities despite density differences. This suggests that both Winter and Landi bricks offer effective insulation potential when considering their density-to-thermal conductivity ratios.

These findings highlight the unique characteristics of each hurd type, impacting the thermal and mechanical properties of hemp-lime bricks and suggesting potential for tailored applications in sustainable construction. To fully explore the feasibility of using Swiss-grown hemp in construction, further research is needed. Such research could deepen understanding of local hemp varieties and optimize material properties, particularly by refining production processes and evaluating the effects of Swiss climate and soil conditions on hemp growth and quality. A dedicated product development phase would also be valuable to adapt manufacturing methods and formulations specifically for Swiss-grown hemp, ultimately supporting the advancement of sustainable, locally sourced building materials in Switzerland.

Life cycle assessment (LCA)

The system boundaries of the LCA include the cultivation or mining of the raw materials, their processing into hurds, and the subsequent mixing with lime, cement, and water to produce 1m³ of the starting mass used to form the building bricks. The LCA does not consider the processes of forming and pressing the bricks or any further steps in the production process. Additionally, transport processes from the field, sawmill, or crushing plant to the industrial facility where the 1m³ mass of bricks is produced are excluded.

For this LCA, allocations were consistently based on economic value. This approach was chosen because hemp hurds are a by-product of fiber extraction, and hemp stalks are a by-product of grain hemp cultivation. Allocation based on mass was deemed inappropriate, as it would lead to significant differences due to the stalk yield per hectare being considerably higher than the grain yield per hectare.

Figure 4 shows that the bricks made from different hemp hurds have similar emissions overall. However, materials with hurds from summer hemp grain production (Landi) show the lowest emissions, with no visible emissions of nitrous oxide due to the minimal use of fertilizers. Carbon dioxide emissions are similar across all bricks, largely resulting from clinker and lime production, with some contributions from fertilizer use.

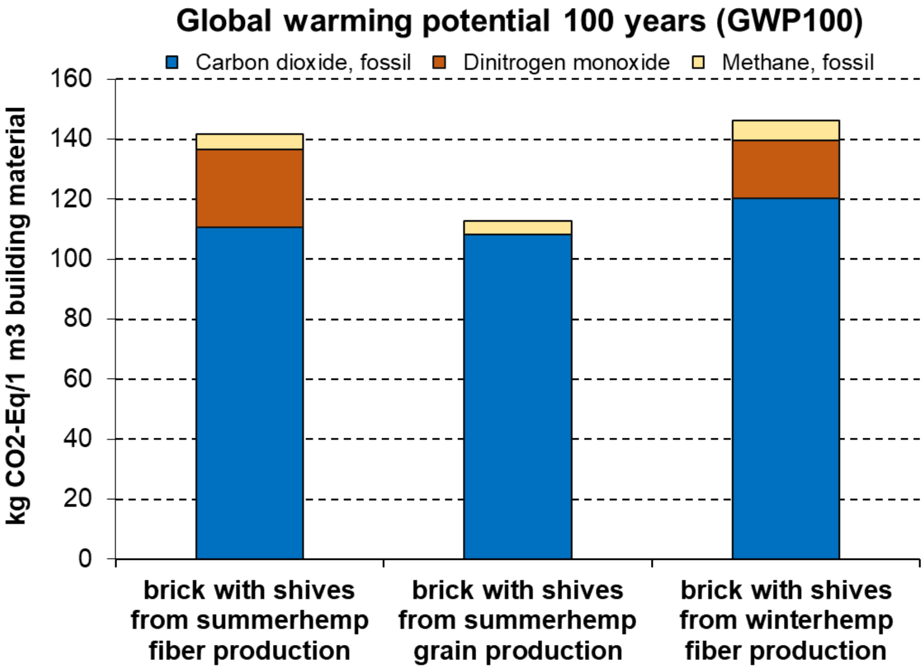

Figure 4: Global warming potential (GWP) of the three bricks, divided into three subcategories. Calculated using the IPCC's GWP100 impact category.

illustrates the environmental impact of the three bricks made of various hemp hurds in eco-points, Figure 5, highlighting the top five impact categories. There is minimal difference in climate change impact across materials. However, emissions to air and water vary significantly, with materials from summer hemp grain (Landi) due to less fertilizer use. Energy resource impact is low across all materials, though winter hemp has higher values due to lower yield. Winter hemp also has a high land use impact due to lower crop yield per hectare and longer tree growth cycles.

The energy consumption of non-renewable resources per m³ of bricks as building materials, as shown in Figure 6, reveals that bricks with hurds from winter hemp have the highest energy use. Most fossil energy is consumed in cement and lime production, primarily sourced from oil and coal, with diesel also used in machinery. Nuclear energy use is comparable across all bricks.

Comparing the three models, bricks with summer hemp hurds are generally the most environmentally friendly. Bricks with hurds from winter hemp perform poorly due to lower yield compared to summer hemp, particularly impacting land use scores (UBP). Collaboration with agricultural experts could help optimize resource use and improve land efficiency for winter hemp, aligning its mechanical benefits with reduced environmental impact for a more sustainable outcome [2]. Summer hemp for grain production outperforms fiber production due to lower inputs (seed and fertilizer) and economic allocation to valuable grain by-products. Most energy consumption comes from lime (60.51%) and cement (29.5%) used in brick production. Hemp cultivation has advantages, with shorter growth cycles and lower resource needs compared to other crops, supporting sustainable cultivation practices. However, high CO_2-eq values in these building materials stem from cement and lime. In the future, the focus should also be on alternative mineral binders with the lowest ecological CO_2 footprint compared to lime and Portland cement.

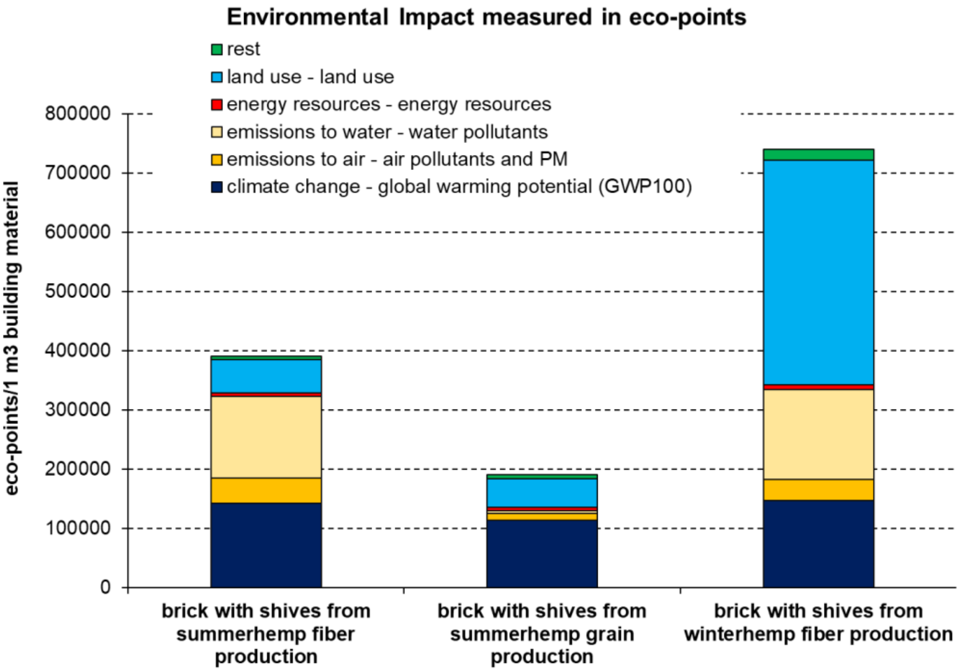

Figure 5: Environmental impact of the five building materials expressed in UBP.

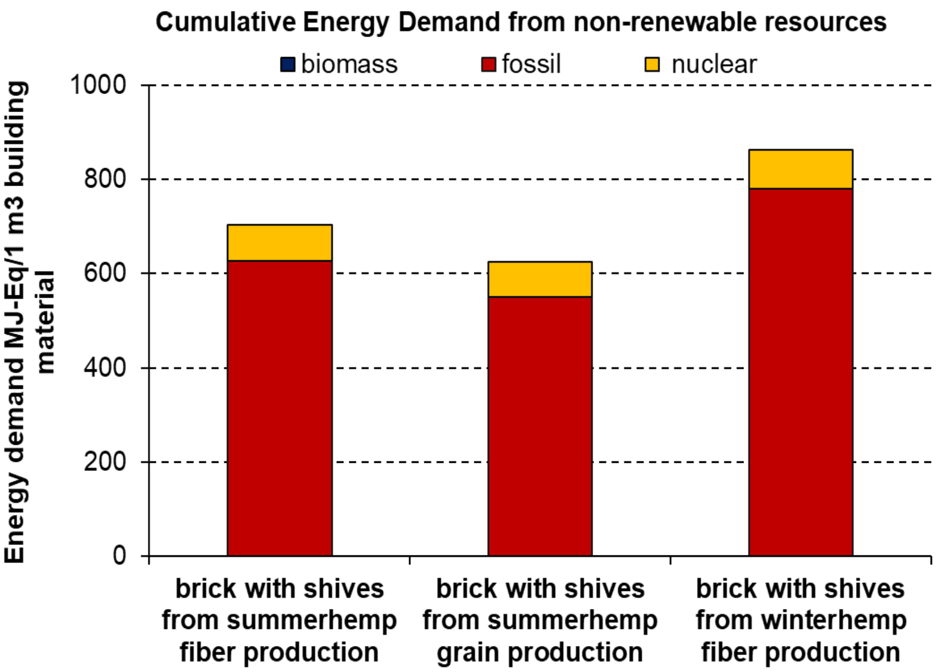

Figure 6: Cumulative energy demand non-renewable resources of the five building materials broken down by category.

Conclusion

By examining the physical and mechanical properties of three types of hemp hurds - Kanabat, Winter, and Landi - it became evident that each type offers distinct advantages and challenges for hemp-lime bricks applications. Bricks made of Kanabat hurds demonstrated higher compressive strength, making them suitable for applications where structural compactness is essential. In contrast, bricks made of Winter and Landi hurds, with higher porosity, provided better insulation properties, aligning with the thermal demands of energy-efficient buildings. The Life Cycle Assessment further showed that summer hemp species offer the lowest environmental impacts due to reduced fertilizer needs and efficient land use.

However, challenges remain, particularly in refining production processes to optimize density and moisture content, which are crucial for achieving consistent mechanical and thermal performance. Given these findings, further research into Swiss-grown hemp varieties, production methods, and product development is recommended. Such efforts would not only deepen the understanding of Swiss hemp's suitability for construction but also contribute to developing a sustainable, locally sourced hemp-lime brick industry, supporting Switzerland's carbon neutrality goals and reducing reliance on imported materials.

References

[1]. Valova K (2025). From Agricultural By-Product to Construction Resource: An Opportunity Study on Employment of Swiss Hemp Shives in Hempcrete Production. Thesis was submitted for the fulfilment of the Master's degree. School of Architecture, Wood, and Civil Engineering (AHB), Bern University of Applied Sciences.

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