Nature-friendly building materials in architectural education

Henrich Pifko, Beata Polomová, Gabriela Rolenčíková & Eva Vojteková

Slovak University of Technology in Bratislava
Bratislava, Slovakia

ABSTRACT: The authors of the article endeavour to answer some questions related to nature-friendly building materials (NFBM). The fundamental questions are: What are the NFBM? Why care should be taken when using them in contemporary architecture? How to provide appropriate coverage of them in the teaching process? The article refers to the past, present and future teaching of the NFBM use in the Faculty of Architecture and Design at Slovak University of Technology in Bratislava (FAD-STU), Slovakia. In the article, the authors include also their vision for the future of NFBM and outline their current focus in the research of this topic. The main question though is, will these materials become an integral part of European mainstream architecture or will they remain a deep-green extreme approach to environmental sustainability? The authors view architectural education as crucial in this respect, and conclude that the FAD-STU has fulfilled its educational goals as students' interest in the NFBM has demonstrably increased and their knowledge applied in studio designs is more detailed.

INTRODUCTION

Eco-friendly building materials are still a marginal, but increasingly important topic. Until recently, they were of interest to environmental enthusiasts rather than common builders. However, the vision of a low-carbon Europe also brings to the fore the issue of bound carbon dioxide emissions, and the draft of the latest update of the Energy Performance of Buildings Directive envisages monitoring the bound CO_2 emissions of building materials, in a similar way as the energy efficiency of the building operation is monitored [1].

When assessing the life cycle of buildings, the advantages of nature-friendly building materials (NFBM) are demonstrated, which are minimally processed, easy to recycle, and are from local and renewable sources. Their growing importance is also the reason for the new research and for their appropriate inclusion in architecture teaching.

WHAT ARE THE NFBM?

The traditional and intuitive approach is that nature-friendly building materials are materials *from nature*, minimally processed, ideally local ones from a renewable source (wood, straw, etc) or an abundant source (earth, etc). They utilise local building traditions (wood, earth, stone, etc) and depend on specific craftsmanship, which often disappeared during the period, when there was little interest in the NFBM. On the other hand, this traditional approach to building materials is irreplaceable in the protection and restoration of monuments and in the reconstruction of old buildings.

New approaches see these materials as materials with low embodied energy and bound emissions (CO_2, SO_x, etc), well recyclable or already recycled (*circular economy*). This approach often depends on industrialisation, on new technologies (3D printing) and on exact calculations (life cycle assessment (LCA), environmental product declaration (EPD), etc). The current use of NFBM often combines both approaches and seeks the appropriate expression of the material in architectural design.

Requirements for building materials in general refer first of all to their functional properties: loadbearing ability, insulation capacity, fire resistance, hygiene, durability, and, finally, price. These are traditionally assessed parameters, which must be complied with to the extent required by all building materials. Today, these materials are also evaluated according to their environmental properties: use of non-renewable resources, impact on the quality of the environment: embodied energy, bound CO_2 and SO_2 emissions, and properties at both ends of the life cycle. The third group of requirements can be called *biocompatibility*, including: the impact on human health during the production, use and disposal of building materials and their impact on the interior environment during the operation of buildings. Important is that the environmental and health-connected parameters of NFBM are usually better than those of the common building materials.

NFBM AND THE ENVIRONMENT

The green movement started to care for the environment a few decades ago, and public and government bodies were just a little later [2][3]. This care included the interest in the environmental impacts of the construction industry and of the operation of buildings; visible in the declarations of Habitat conferences [4][5], the changes in legislation (in Europe, Energy Performance of Buildings Directive II was the most important step here [6]) and the interest of architecture professionals, expressed in the manifest Architects Declare [7]. The authors of this article understand that the construction and operation of buildings is responsible for approximately 40% of CO_2 emissions.

Many buildings receive *green building* certificates (Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), WELL Building Standard (WELL), etc). The authors participated in the development of the Common European Sustainable Building Assessment (CESBA) tool [8], and can see that developers, architects and users are interested in the environmental *performance* of their buildings. The European Council and the Parliament are interested in its improvement, and the common vision of a modern Europe is projected into the European Green Deal [9] (Figure 1).

Figure 1: EU Green Deal (European Commission 2020).

Figure 2: FAD-STU student designs using the NFBM (photograph by: R. Špaček).

The NFBM can help achieve the desired improvement in environmental parameters, especially CO_2 emissions, throughout the life cycle of buildings. Wooden buildings have also become more popular due to their better environmental properties [10], and materials, such as hempcrete [11] or papercrete are beginning to be thoroughly verified and tested.

TEACHING THE USE OF NFBM AT THE FAD-STU

At the Faculty of Architecture and Design of Slovak University of Technology in Bratislava, the teaching of NFBM started three decades ago (Figure 2 above). Originally it was one optional subject, Alternative Building Materials. Today, the NFBM is thought (from different perspectives and in varying degrees of detail) in seven optional and two compulsory subjects, including in the design studios. This development is related not only to the current and expected requirements of practice, but also to the interest of students.

At the Institute of Ecological and Experimental Architecture, teaching the properties and use of NFBM is included in the subjects Sustainable Architecture and Architecture and Environment II. In the subject Summer School, workshops on earth architecture are organised (small adobe buildings, such as a bus stop or gazebo) (Figure 3 and Figure 4) and small wooden objects (bird observatory, picnic area). In the design studios, students work on design tasks with the use of NFBM.

Figure 3: Summer school participants.

Figure 4: Summer school students building an earth-brick gazebo (both photographs by R. Špaček).

At the Institute of Structures in Architecture and Engineering Buildings, in the compulsory subject Construction III, lectures cover both traditional, as well as the modern use of wood, and research on hempcrete architecture is being

prepared. At the Institute of History and Theory of Architecture and Monument Restoration, materials in historical buildings, including the NFBM are covered in the subject Traditional and Modern Materials. The cooperation of these institutes is focused on the innovative wooden constructions, the use of new materials (e.g. hempcrete) and new approaches (e.g. 3D printing). The plan is to organise *design and build* workshops (small architecture) and summer schools focused on practical skills in the use of NFBM, first of all earth, straw bales and wood.

Cooperation often involves the Czech counterparts (Association of Earth Building, Universities in Brno and Prague), for example, the organisation of the conferences *Healthy Houses* and the current joint preparation of local standards on earth buildings. Moreover, in a cooperative manner with the non-government organisation (NGO) ArTUR (Architecture for Sustainability), student workshops are being organised that focus on practical skills (earth plasters, earth walls, straw-bale building) [12].

The teaching of NFBM is also based on FAD-STU-specific research. In the field of earth architecture, it is the preparation of common Slovak and Czech standards and testing of 3D printing possibilities [13]. In the use of wood, the focus is on prefabrication and modularity. For the straw bale building, *research by design* is applied in the design studios, for example, in evaluating the potential of EcoCocon prefabs [14]. For the use of hempcrete, research projects were prepared to evaluate the advantages of this material, including student participation and PhD study topics. LCA aspects are also included in architecture teaching.

GOALS AND METHODS

The main educational goal is two-fold, first to teach students how to use the NFBN, and also to convince them to apply this knowledge in their studio designs and later in their practice. To verify the fulfilment of these goals, feedback from students is mainly used. In regard to research, one of the goals is to support the use of NFBM in architectural practice, and the usage of NFBM in vernacular architecture. However, the main research goals are searching for new material and structural solutions, and investigating how these solutions are reflected in the architectural concept and aesthetic expression.

The educational methods used are partly conventional: lectures, analysis of examples in seminars, short design workshops. Reworking of students' own older studio designs for the use of NFBM is also practised, followed by the analysis of the benefits achieved. However, especially in optional subjects, interactivity in emphasised: discussions, role playing, *feeling* samples of materials, excursions to interesting sites being examples of sustainable architecture. *Learning by touching* is recognised as the most efficient method, especially workshops connected to the realisation of small buildings from the NFBM according to students' designs.

In the research, the current use of NFBM in Slovakia and other countries is analysed and their calculated environmental impacts are compared in search for optimal solutions. Field research is used to investigate the application of NFBM in vernacular architecture. In the laboratory, the search for optimal combinations of materials and verification of their properties is paramount. In design studios, the research by design approach is applied in students' studio designs (and *vice versa*, the new knowledge is applied in *design by research*). In the future, the realisation of small full-scale model buildings is proposed to verify the suitability of the proposed material solutions and construction technologies - innovative approaches will be searched for and identified. To support the use of NFBM in practice, a set of standards as a compilation of acquired knowledge is in preparation. The first one, Earth Building Constructions, is ready for assessment by the regulatory authorities.

NFBM AND VERNACULAR ARCHITECTURE

Wood, stone and (unburnt) clay are the most common NFBM used in the traditional vernacular architecture. Today, the ability to maintain and restore these buildings, often listed as monuments, is essential. FAD-STU students often deal with the renovation of such buildings in their studio designs at the Institute of History and Theory of Architecture and Monument Restoration. An interesting contribution to learning about the role of NFBM in vernacular architecture was the workshop in the village of Vavrišovo in the north of Slovakia [15]. The focus was on the documentation of a unique set of historic barns (Figure 5).

Figure 5: Set of historical barns (archive of B. Polomová).

Figure 6 and Figure 7: Documenting the old barns using the NFBM (both photographs by B. Polomová).

Twenty-three students documented floor plans, cross-sections and views of eight buildings (out of about fifty), photographed their interiors and exteriors, and identified the materials used (Figure 6 and Figure 7, above). They received an explanation of the historical constructions and materials for each selected object. The final documentation included the restoration methodology for the new use of buildings [16].

In this field work, students acquired the knowledge and practical skills necessary for the work with the NFBM. They learned that historical constructions are simple, based on long-term observation and on the proven processing of natural materials and resources that have become part of the tradition of vernacular architecture. For example, for the foundations of the oldest buildings, the original builders used boulders from the nearby river, wood from nearby forests, lime plasters and earth floors were also sourced locally.

The results of the workshop served as the basis for the studio designs in the following semesters (Figure 8 to Figure 10). In 2023, based on this preparation and on measurement of four other barns, two diploma theses were worked out. This documentation of the current state of the barns has not only educational, but also scientific significance, the Regional Monuments Office, Slovakia uses it for further research into the cultural-historical values of the vernacular architecture of the region.



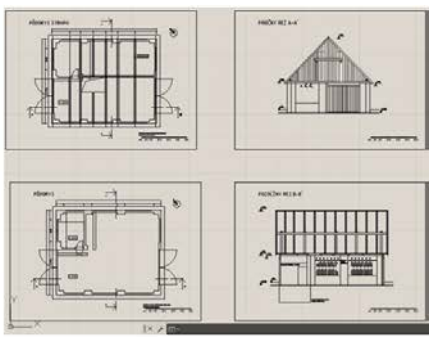

Figure 8, Figure 9 and Figure 10: Student workshop: from measurement to final documentation (photographs by B. Polomová).

HEMPCRETE AS A NEW CHALLENGE

For some builders and educators in Slovakia, hempcrete is a new material, although it has been used marginally for decades in France and Canada. Today, it is also popular in other countries as it has low environmental impact, and acts as a *carbon sink* during its lifetime. It consists of waste hemp shives mixed with a lime-based binder, and is used to produce blocks for masonry construction or to create *rammed* walls in wooden formwork.

Hempcrete is a good thermal and acoustic insulation, but cannot be used as a loadbearing construction. At the FAD-STU, researchers want to enhance its mechanical properties by varying the proportion of ingredients, to improve its environmental impact replacing lime with earth in the binder, and to reduce labour demand using new technologies of prefabrication and 3D printing. In the student design studios, the plan is to apply the research by design approach to analyse the impact of hempcrete use on architecture. This research has just started, with the involvement of PhD students and research grants applications. The goal is to bring hempcrete into the architectural mainstream.

VERBA DOCENT, EXEMPLA TRAHUNT

Or in English: words teach, examples lead/draw (when examples are used, more people will be inclined to follow them). Looking for the most efficient ways of NFBM teaching, the traditional lecture-based approach is still used. Its efficiency is discussed but it is improved with new examples added to involve students in the discussion. Samples of NFBM are demonstrated, which help students to *touch and feel* these materials.



Figure 11, Figure 12 and Figure 13: One-day ArTUR workshop on the NFBM is an example of *teaching by touching*.

A better approach is to teach on the design level, hence the NFBM is used in studio designs. The most efficient way is to use the NFBM on the practical level, in real buildings (at least small ones) and in workshops and summer schools. *Teaching by touching* is the motto here, and this approach is applied both in studying existing buildings and in building new ones. As a less demanding alternative, one-day excursions and design workshops are conducted. In 2023, a mini workshop was prepared in the Eco centre of ArTUR, with 58 STU students participating in it (Figure 11 - Figure 13, above). The students became familiar with the use of NFBM and tried it in practice.

Are the NFBM mainstream or extreme? The authors of this article believe that in the future these materials will be part of the mainstream or at least something *normal*. To prepare architecture students for that, the FAD-STU offers not only theoretical knowledge in lectures, but also practical skills that can be obtained in design studios and specific workshops. The FAD-STU also offers design support (standards [12], handbooks [17][18], software licenses and support [19][20]). This approach, as it stands at the FAD-STU, can prepare students to use the NFBM, so the next step should be an increase in demand among the general public and in the community of design professionals. Short excursions can help encouraging students' interest - an example is a visit to the S-house, an nZEB seminar centre with a wooden structure and straw insulation [21] (Figure 14 and Figure 15).

Figure 14 and Figure 15: S-House seminar centre in Boheimkirchen is a prime example of the use of NFBM (photographs by H. Pifko).

FEEDBACK FROM STUDENTS

After changes in the scope and content of NFBM teaching, it was necessary to check how students perceive and evaluate them. A voluntary questionnaire survey was answered by over 50 students of the second to sixth grade. It was not a representative sample; therefore, a certain bias in the answers was assumed at the start. Nevertheless, the responses indicate that students are accepting these changes positively and that their interest in the NFBM is growing. Two thirds of the respondents already knew about the NFBM, mainly thanks to self-study and information from the Internet. Seventy-five percent of the students involved would welcome more information about the NFBM, 42% have already applied the acquired knowledge in their studio designs and 81% believe that they will use it in practice (Figure 16). The NFBM-related information is most often acquired in compulsory subjects and in design studios. Electives, workshops and summer schools are attended by only a small part of students, so their impact appears to be smaller, although they offer more detailed information and contact with practice. The qualitative contribution of individual educational forms was not covered in the simple questionnaire distributed to students. Also, as this survey was conducted for the first time, an objective comparison of the current situation with the past could not be undertaken.

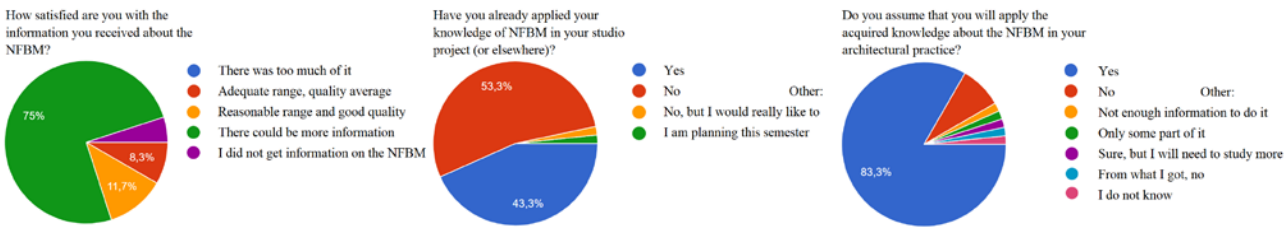

Figure 16: Selected answers from the survey confirm the growing interest of students in the NFBM.

The feedback from this survey is relevant and encouraging, but assessing the fulfilment of the goal of arousing students' interest in the NFBM can be done in another way. In the design studios, there is a significant increase in the number of students who want to design their projects using the NFBM (and they know, how to do it). The number of students in relevant optional subjects is also a good indicator. In the subject Sustainable Architecture (formerly Alternative Materials and Technologies) there was an average of 10 students between 2016 and 2021. In 2022, 49 students chose this subject and in 2023, 58. For comparison, an average of approximately 100 students in compulsory subjects could be

considered. The *vertical* design studios, which are related to the use of NFBM (Green design studio, Wooden studio, Constructions in architecture), have been filled by the maximum number of students in recent years. This proves the interest of students; full capacity is not a matter of chance.

The *teaching by touching* approach can also be used by other teachers and other universities. The ideal form are workshops and summer schools combining design and implementation (e.g. buildings, furniture or machinery). It is advantageous when suitable materials and equipment are available, as well as premises - international cooperation, grants and partners (e.g. ArTUR association) can be actioned (Figure 17 - Figure 21). Various manuals (e.g. Constructions with small carbon footstep) [18]) and e-learning modules available for teaching the NFBM are available and similar ones can be found for other languages and other content too.

Figure 17, Figure 18 and Figure 19: Eco-centre of ArTUR is a workshop site but also a demonstration building for the NFBM (all photographs by H. Pifko).

Figure 20: Workshop: building mini-house (photograph by H. Pifko).

Figure 21: Biomorph architecture using the NFBM (photograph by M. Križo).

CONCLUSIONS

Three decades ago, at the Faculty of Architecture and Design of the STU, the study of materials, such as adobe or straw blocks were introduced. Students had the opportunity to test their practical use during international summer schools. Currently, the NFBM is covered in more subjects and in more institutes, with Faculty support for their use in student designs, especially in *vertical* design studios, where each year more students are interested in this field. Students have direct contact with historical building materials at the *Detached Workplace* in Banská Štiavnica, Slovakia. New subjects and the content of existing ones are constantly being adapted to the current trends, among which is the use of NFBM, especially of wood in its modern forms.

There are strong indications that the educational goals are fulfilled: students' interest in the NFBM has demonstrably increased and their knowledge applied in studio designs is more detailed. Despite the lack of *hard data* on the improvement of the academic results of these students, none of them had problems defending their thesis, even if it was done outside the mainstream of architecture and construction.

Other materials that are *close to nature*, for example, hempcrete are also part of the research. Their properties and specifics in architecture will be investigated in a new research project, which will include new construction methods, e.g. prefabrication and 3D printing. It is expected that the research results will not only be used in theoretical teaching, but also in design studio work, in design workshops, and in the practical handling of these materials in summer schools or in block modules of other subjects managed by various institutes of the FAD. The gained experience in this area will hopefully lead to the preparation of a new teaching methodology for the application of nature-friendly building materials in the architecture of new and renovated buildings. The current focus in on improving the quality and efficiency of architectural education in this field, especially in student design studios.

REFERENCES

1. Energy Performance of Buildings (Recast). Brussels: European Parliament (2023), 24 November 2023, https://bit.ly/epbd4
2. World Commission on Environment and Development. Our Common Future. Oxford: Oxford University Press (1987).
3. Agenda 21. Rio de Janeiro: United Nations (1992), 24 November 2023, https://bit.ly/agnda21
4. Istanbul Declaration on Human Settlements (Habitat II). Istanbul: United Nations (1996), 24 November 2023, https://bit.ly/idhs
5. New Urban Agenda (Habitat III). Quito: United Nations (2017), 24 November 2023, https://bit.ly/nua-en
6. Energy Performance of Buildings Directive II. Brussels: European Parliament (2010), 24 November 2023, https://bit.ly/epbd--ii
7. UK Architects Declare Climate and Biodiversity Emergency. London: BED (2019), 24 November 2023, https://bit.ly/arch-d
8. CESBA Guide. Alberschwende: CEC5 (2012), 24 November 2023, https://bit.ly/cesba-g
9. European Green Deal. Brussels: European Commission (2023), 24 November 2023, https://bit.ly/green--deal
10. Švajlenka, J. and Kozlovská, M., *Efficient and Sustainable Wood-Based Constructions*. Cham: Springer (2023).
11. Stanwix, W. and Sparrow, A., *The Hempcrete Book*. London: Bloomsbury Publishing (2014).
12. Pifko, H., Introducing the 5th draft of technical report Earth Building Constructions. *Healthy Houses 2021 Conf. Proc.*, Bratislava: Spektrum STU, 24-25 (2021).
13. Križo, M., Earth constructions via 3D printing/space potential. *Healthy Houses - Interior 2023 Conf. Proc.*, Bratislava: Spektrum STU, 39 (2023).
14. Build a Sustainable Future with EcoCocon. Bratislava: EcoCocon (2023), 24 November 2023, https://ecococon.eu/gb
15. Baxa, P., Farkašová, M. and Polomová, B., Student Workshop in Vavrišovo. *Spektrum*, 25, **3**, 44 (2019).
16. Implementation of Practical Skills of Pre-project and Implementation Preparation of the Restoration of Historical Buildings into the Education of Architectural Study. Bratislava: FAD-STU (2019).
17. Špaček, R. and Pifko, H. (Eds), Rukoväť Udržateľnej Architektúry (Handbook of Sustainable Architecture). Bratislava: SKA (2013), 24 November 2023, www.bit.ly/rukovat (in Slovak).
18. Konštrukcia s nízkou uhlíkovou stopou (Constructions with small carbon footstep). Hrubý Šúr: ArTUR (2023), 24 November 2023, www.bit.ly/nizka-us (in Slovak).
19. OneClick LCA, Calculate Your Environmental Impacts in Minutes. Helsinki: OCLCA (2023), 24 November 2023, www.oneclicklca.com
20. ISOVER Fragment 5.0, ISOVER (2022), 24 November 2023, www.bit.ly/frag-w (in Slovak).
21. Wimmer, R., Hohensinner, H., Drack, M. and Kunze, C., S-House, Innovative Nutzung von Nachwachsenden Rohstoffen am Beispiel eines Büro- und Ausstellungsgebäudes. Wien: BMVIT (2005), 24 November 2023, www.bit.ly/shouse-eb (in German).