PhD thesis

# EXAMINATION OF WOOD CONSTRUCTION SOLUTIONS IN HUNGARIAN VERNACULAR ARCHITECTURE

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**Doctoral school:**

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Examination of wood construction solutions in hungarian vernacular architecture

## Objective

The designers of Hungarian organic architecture have created wood-based solutions that have not only made the world aware of the greatness of building close to nature (think of the Hungarian pavilion at the 1992 Seville World Expo, or the Hungarian wood-based building at the 2020 Dubai World Expo), but also their solutions are geared towards forward-looking architecture that can mitigate global resource scarcity, economic crises and the destructive human presence.

It is not the purpose of this thesis to define Hungarian organic architecture as a movement/style precisely, given its indefinability or very imprecise definition (precise beginning and ongoing approach) and its perceived unnecessity for the purposes of this thesis. Consequently, the presentation and analysis of the widespread and recognised (well-known and accepted) Hungarian vernacular building structures (wall and slab) is done through the presentation of the individual structures with the aim of drawing conclusions from different approaches that can further develop and move the timber construction designs of today's time - optimising them and providing opportunities for further development of certain solutions.

The research and its results will address the issue of a more easily, successfully and simply mappable/demarcatable HUNGARIAN vernacular architecture and the resulting Hungarian organic architecture. Research in a foreign, global context would - due to its scope - produce results that are too superficial and too generalised, which would not yield real research results. *The main thesis of the dissertation is that by studying Hungarian vernacular wooden architecture (through the study of the outstanding figures and designs of Hungarian vernacular architecture and organic architecture), conclusions*

*can be drawn from which the design of wooden architecture can be optimised, improved and perfected.*

In order to achieve this, it is necessary to narrow down the broader spectrum of Hungarian folk culture to folk architecture, including the study of wall and slab structures by comparing individual works of Hungarian organic architecture (searching for parallels).

Clear formulations (architectural, wooden architecture, etc.), a transparent system (organicism, approach, etc.), the basic concepts should be defined at the beginning of the thesis. An understanding and knowledge of these terms, materials, structures, etc. is essential to present consistent results.

The aim of the doctoral thesis is to create a suitable, uniform comparability system for the (re)analysis of Hungarian folk architecture in order to propose new, improved and modern solutions, primarily in the field of architectural timber construction, by analysing the experience gained. The final outcome and aim of the research is to propose structural solutions that can be used in practical architectural design and promote the wider use of wood structures for sustainability.

In essence, the study of Hungarian vernacular architecture (as it influences, among other things, the Hungarian organic architecture that is still in use today) aims to draw conclusions that can be used to achieve modern building construction solutions (wall structures, slab structures).The degree of modernity and adequacy is determined on the basis of the current building energy regulation (7/2006 (V.24.) TNM tightened (5/2018.(III.23.) MvM decree).

## The method of the research

Today's Hungarian organic architecture is as much based on Károly Kós's architecture as it is on Rudolf Steiner's philosophy or the study of Hungarian folk art. These well-articulated

factors (persons, works of art) can be interpreted in themselves - but the perception, conception and formulation of the architectural/artistic effects they produce in individual persons is the result of the work of human character and person.
To be able to treat the individual Hungarian organic architectural (wood-architectural) solutions as objectively as possible, it is necessary to know the determining and separable factors (Hungarian folk architecture, Hungarian folk art, Imre Makovecz, etc.) that influence the said architecture. The influence of these on each other and the resulting physical manifestations (architectural) of the results - narrowed down to the wood-architectural sense - are the solutions that the dissertation tries to study in a narrowed scope. This study requires - basic knowledge. With the basic knowledge (organic architecture, Hungarian folk architecture) and a targeted presentation of the works/structures created, we can move on. The further step means comparability: the objective is to present objectively the selected Hungarian folk architecture solutions and the Hungarian organic works based on them in order to create a unified system of comparison. In order to make the improvements achieved measurable and comparable, a computer-generated simulation was carried out, generating (temperature and humidity) diagrams. The technical (layer level) drawings were created using the CAD software ArchiCAD 26 (build 4019, in Hungarian, full version (educational license), Win64 platform), the latest version available at the time of writing this thesis (November-December 2022), developed by the Hungarian company Graphisoft. The vapour simulation studies were analysed with WUFI (Wärme Und Feuchte Instationär) 2D version 4.5.0.192.DB.27.5.0.86 under an exclusive 6-month vendor license, and the thermographic simulations were analysed with THERM Finite Element Simulator software version 7.8.57.0

(University of California Regents. (U.S. Department of Energy)) (09/21/22).

As far as standards are concerned, the nationalised standard MSZ EN 15026:2007 was used for the assessment of the thermal and moisture performance of building structures and building elements. The estimation of moisture migration follows the principle of numerical simulation. For the assessment of the thermal and moisture behaviour of building structures and building elements, the nationalised standard MSZ EN ISO 13788:2013 was also taken into account. The critical surface moisture and internal surface temperature conditions prior to condensation within the structure were also taken into account by considering the aforementioned nationalised standard. The calculation methods have been considered according to ISO 13788:2001.

In the comparison, concrete advantages and disadvantages (feasibility, thermal insulation properties) must be formulated in order to weigh up the solution(s) (recommended for improvement, solution to be improved or not suitable).

An objective and definable result of the research can be obtained if objective conclusions can be drawn from the analysis of the individual architectural/construction solutions.

The structure of the dissertation should therefore start with a clarification of the basic concepts. It is necessary to establish the basic concepts and thus the framework (wood-oriented research of Hungarian folk architecture). The aim of the research is to propose new solutions, based on the knowledge of the advantages and disadvantages of previous systems.

The basic concepts (timber structure, load-bearing structure, stress, mechanical/biological damage, drainage, etc.) are explained using the generally known and accepted teaching material, mainly printed, in architectural education. For concepts that are less technically formulated (organicity,

organic approach, etc.), they are based on the formulations of architectural history teaching materials and architectural historians, also used in architectural education.
In order to choose the most appropriate solutions to be examined in the light of these concepts, it is necessary to know the main aspects of the careers and approaches of the various authors (architects, structuralists) in order to compare and 'weigh' them. This knowledge comes primarily from personal accounts, life histories, reviews and reminiscences, and descriptions by architectural historians.

## The aim of the research

**The intended outcome of the research is the presentation of new architectural insights, proposals and concrete (architectural) building construction solutions resulting from the analysis of the established structures and building materials related to the selected Hungarian folk architecture (and Hungarian organic approach).** It is therefore necessary, first of all, to get to know Hungarian folk architecture itself, and secondly, the organic architectural trend; and then to be able to objectively weigh and compare all of these in the narrowing down of the use of wood. The rational, economical design of our folk structures has influenced Hungarian organic architecture - which is still prevalent today. Through the study of our ancient structures and the materials used in them, solutions can be found that provide usable solutions for today's architecture - in a time of global raw material (wood, metal) shortages and energy crisis. **With this in mind, the research aims to create sustainable, resource-minimising, recycled (by-products) supporting and auxiliary elements and systems that reduce the demand for major construction raw materials by favouring invasive**

**wood species, thereby optimising and reducing the scarcity of raw materials and energy.** An important consideration was to create modern solutions that avoided or minimised the use of artificial materials. With this in mind, the main focus of the studies was on earth, earthenware, clay and, of course, timber architecture. Established, upgraded wood construction solutions (RRFA, LVL, backbone sheet supports, DSB, etc.) were deliberately not used because of their known and applied properties. Based on the specifications of these structures, they can be well and successfully combined (based on appropriate structural, fire, wood material protection dimensioning) with the structures investigated and presented in the thesis (lath-laminated straw moulded liner body and thermal insulation infill specifically favourable to the RRFA profile height).
Hungarian organic architecture, which is strongly inspired by Hungarian folk architecture, nowadays uses modern building materials, including artificially produced ones, in accordance with the energy requirements of our time, which cannot fully serve the aforementioned main objective by analysing them. **Consequently, the early solutions of the Hungarian organic architecture, which were established in this approach and design attitude, are relevant in the research.**

To achieve the research objective, the aim is to answer the following main questions and to support the research findings:

1.) Can the relationship between Hungarian folk architecture and Hungarian organic architecture be objectively proven? Can it be proven that Hungarian organic architecture is based on Hungarian folk architecture?
2.) If Hungarian organic architecture is based on Hungarian folk architecture - are there any folk

architectural (mainly) wood-frame solutions that can be used today?

3.) Which Hungarian folk architecture (wall and slab construction) and timber construction solutions have been developed?
4.) What are the characteristics (advantages, disadvantages) of wood construction solutions? Which structural solutions deserve further development and how?
5.) Can surplus wood and waste wood from forestry and forestry by-products be used for construction purposes? If yes, how?
6.) What other possibilities (depending on material properties) can be offered by the use of surplus or waste materials?
7.) Based on the results obtained, what are the possibilities for further development?
8.) The use of building materials and the design of structures (traditional timber structures, earth-based structures, etc.) in today's organic architecture is only slightly influenced by the direct application of Hungarian folk architecture - in contrast to the formal world of Hungarian folk architecture. The use of earth-based structures (hedge walls, vert walls, etc.) and simple slab structures (pólyásfödém, sárlécfödém, etc.) is marginalised. It is therefore necessary to examine the basic Hungarian vernacular architectural structures (wall structures, slab structures) in order to ensure that they are still applicable today.

## Theses

1. The foundations of Hungarian organic architecture can be found in Hungarian folk architecture, thus by studying Hungarian folk architecture we can arrive at architectural solutions that are relevant to Hungarian organic architecture.
2. The use of building materials and the design of structures (traditional timber structures, earth-based structures, etc.) in today's organic architecture is only slightly influenced by the direct application of Hungarian folk architecture - in contrast to the formal world of Hungarian folk architecture. The use of earth-based structures (hedge walls, vert walls, etc.) and simple slab structures (pólyásfödém, sárlécfödém, etc.) has been marginalised. It is therefore necessary to examine the basic Hungarian vernacular architectural structures (wall structures, slab structures) in order to ensure that they are still applicable today.
3. By examining certain building structures of Hungarian folk architecture, solutions can be created that can be applied today.
4. Hungarian vernacular architecture, thus Hungarian organic architecture, can alleviate the crisis of today's building materials (mainly wood) and promote sustainable architecture.
5. Construction materials/raw materials generated as by-products and wastes from wood and forestry can be used and further transformed into wood construction solutions for today's building industry.

## The results of the research

In the simulations, 8 different basic slab structures, 13 modified slab structures, 6 basic wall structures, 9 modified wall structures and 4 new slab structures were tested. In total, 40 technical drawings and corresponding simulations were carried

out. It is also worthwhile to investigate the use of wood and forestry by-products in new buildings - the use of tree branches, due to their low self-weight and their geometry, air-tightness and relatively good thermal insulation properties, can be used in the construction industry for structural applications (slabs, facade cladding, etc.). Further tests (structural, building physics, fire protection) should be carried out on the use of tree branches. Knowing the density, diameter and type of material of the twigs can help to draw important conclusions about their usefulness (distributed in a stack in an orderly or disorderly fashion, compacted alone or supported by an auxiliary support, etc.) and their application. Just such remarkable research, with further potential, can also be derived from the development of new layering systems in the recovery of waste materials (construction materials) based on the principle of the sheet pile (textile cotton material wound on small-element timber from wood waste with interlayer cellulose filling, with stabilisation of clayey water, etc.).

Wall structures and modified wall structures

After analysing the conventional structures (F1, F2, F3, F4, F5, F6), I tried to combine them with building materials designed in a similar way to the building systems used at the time, in order to modify and improve their physical properties (heat transfer coefficient). These modified structures are marked with "*, **" and the resulting heat transmission values are compared. These showed that for some structures (F1 (pine wall), F4 (hedge wall), F6 (reed wall)) there was a large improvement. For the F4** structure, there is a large reduction in heat transfer values when tested, mainly due to the additional insulation applied. It is recommended to reduce the thickness of the insulation for economic reasons. Three modified designs (F1**,

F4**, F6**) meet today's requirements (Umax wall = 0.24 W/m2K).

Slab structures, modified slab structures

After analysing the conventional slab structures (A1, CS1, D1, P1, S1, T1, V1), I tried to combine them with building materials designed in a similar way to the building systems used at the time, in order to modify and improve their physical properties (heat transfer coefficient). These modified structures are marked with "*, **" and the resulting heat transmission values are compared. On the basis of these results, it can be said that the modification of the slab structures resulted in solutions that can be applied today in two cases (A1**, CS1**). In the case of the covered beam slab (A1), the most favourable of the modified structures (A1**) is almost five times more favourable in terms of heat transfer coefficient compared to the original structure. The improved A1** (UA1**= 0.1624 W/m2K) and CS1** (UCS1**= 0.1624 W/m2K) structures meet the energy requirements for attic slabs today (Attic slab max= 0.17 W/m2K). The D1** structure is four times more favourable in terms of heat transfer coefficient than the original lined covered beam slab structure. The largest changes are observed for the P1 and S1 structures. The large change is due to the high level of additional thermal insulation.

A common phenomenon observed in some simulation evaluations was the thermal bridging of the timber frame and the increased heat and energy transfer properties of the (wood) surfaces in direct contact. An important and substantial improvement was achieved by the complete replacement of the individual layers (e.g. slag filling).

New slab structures

The principles of the modified slab structures (Xa, Xb, Xc, Xd, Y) are based on the basic slab structures of our folk architecture. In order to improve their thermotechnical properties, mainly by replacing or modifying their stratigraphic components, I have carried out thermographic and vapour simulation studies of several possible solutions. An important aspect has been the use of materials from wood and forestry by-products and waste products from the construction industry, both as building materials to increase the thermal insulation properties and as load-bearing structures (aerated concrete, branches, etc.)

Four of the modified slab structures (Xa (UXa= 0.1664 W/m2K), Xb (UXb= 0.1585 W/m2K), Xc (UXc= 0.1697 W/m2K), Xd (UXd= 0.1653 W/m2K)) have been designed to meet the energy requirements for modern (attic) slab structures (attic slab max= 0.17 W/m2K).

There are a number of further possibilities for further studies to be carried out for the implementation (structural checks, fire ratings, wood material protection procedures). The existence of these studies is a fundamental condition for the proposed structural solutions to become today's building structures - and further economic and resource (raw material) analyses are necessary for their rational use and constructability.

## Publications related to the topic of the dissertation

Tóth Bence Péter: **Népi faszerkezeti megoldások**
In: *Firgi Tibor (Firgi Tibor építőmérnök) ÓE/YMÉK/Építőmérnöki Intézet ; Szűcs László (Szűcs László Földtudományok) ÓE/YMÉK/Építőmérnöki Intézet (szerk.) XVI. Építőmérnöki Tudományos Tanácskozás közleményei*

*Konferencia helye, ideje: Budapest, Magyarország 2021.11.16. (Óbudai Egyetem Ybl Miklós Építéstudományi Kar)*
*Budapest: Óbudai Egyetem Ybl Miklós Építéstudományi Kar, pp 69-75 (2022)*
*Nyelv: Magyar | Befoglaló link(ek): ISBN: 9789634492924*
*Közlemény: 33615542 | Nyilvános Befoglaló: 33610847*
*Forrás | Könyvrészlet (Konferenciaközlemény) | Tudományos*

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Tóth Bence Péter: **A magyar népi építészet és a magyar organikus építészet kapcsolata**
*webcikk*
*Megjelenés: (2022)*
*Nyelv: Magyar | Egyéb URL*
*Közlemény: 33364648 | Nyilvános Forrás | Folyóiratcikk (Szakcikk) | Tudományos*

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Tóth Bence Péter: **Deciduous trees in architecture**
*In: Németh Róbert (Németh Róbert Faanyagtudományok) SOE/SKK/Faanyagtudományi Intézet; Rademacher Peter (Rademacher Peter Erdészet, faipar); Hansmann Christian; Bak Miklós (Bak Miklós Faanyagtudomány) SOE/SKK/Faanyagtudományi Intézet; Báder Mátyás (Báder Mátyás Faanyagtudomány) SOE/SKK/Faanyagtudományi Intézet (szerk.)*
*9th Hardwood Proceedings : Part I. With Special Focus on "An Underutilized Resource: Hardwood Oriented Research" Konferencia helye, ideje: Sopron, Magyarország 2021.06.24. - 2021.06.25.*
*Sopron: Soproni Egyetemi Kiadó, pp 279-286 (2020) ( Hardwood conference proceedings 2631-004X; 9 Pt. I.)*
*Nyelv: Angol | WoS Befoglaló link(ek): ISBN: 9789633343777*
*Teljes dokumentum*

*Közlemény: 31928222 | Nyilvános Befoglaló: 31784953*
*Forrás | Könyvrészlet ( Szaktanulmány ) | Tudományos*

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Tóth Bence Péter: **Properties of joists build by branches and twigs**
*In: Németh Róbert (Németh Róbert Faanyagtudományok) SOE/SKK/Faanyagtudományi Intézet; Rademacher Peter (Rademacher Peter Erdészet, faipar); Hansmann Christian; Bak Miklós (Bak Miklós Faanyagtudomány) SOE/SKK/Faanyagtudományi Intézet ; Báder Mátyás (Báder Mátyás Faanyagtudomány) SOE/SKK/Faanyagtudományi Intézet (szerk.)*
*9th Hardwood Proceedings : Part I. With Special Focus on "An Underutilized Resource: Hardwood Oriented Research" Konferencia helye, ideje: Sopron, Magyarország 2021.06.24. - 2021.06.25.*
*Sopron: Soproni Egyetemi Kiadó, pp 287-290 (2020) ( Hardwood conference proceedings 2631-004X ; 9 Pt. I.)*
*Nyelv: Angol | WoS Teljes dokumentum Befoglaló link(ek): ISBN: 9789633343777 Teljes dokumentum*
*Közlemény: 31928224 | Nyilvános Befoglaló: 31784953*
*Forrás | Könyvrészlet ( Szaktanulmány ) | Tudományos*

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Tóth Bence Péter: **Designing in Context – Nemzetközi Építészeti Konferencia a Goetheanumban**
*Online cikk - Országépítő*
*Megjelenés: (2022)*
*Nyelv: Magyar | Egyéb URL*
*Közlemény: 33334411 | Nyilvános Forrás | Folyóiratcikk (Ismertetés) | Ismeretterjesztő*

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Tóth Bence Péter: **A mai magyar organikus építészet – Kérdések és válaszok Rüll Tamással, Makovecz Imre irodájának vezetőjével**
*Építészfórum online interjú*
*Megjelenés: (2022)*
*Nyelv: Magyar | Egyéb URL*
*Közlemény: 33334406 | Nyilvános Forrás | Folyóiratcikk (Ismertetés) | Tudományos*

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Tóth Bence Péter: **Fecskelátogató Központ. Diplomaterv**
*SZIE Ybl Miklós Építésztudományi Kar, Msc, 2019*
*RÉGI-ÚJ MAGYAR ÉPÍTŐMŰVÉSZET (1785-282X ): 19 4 pp 81-82 (2019)*
*Nyelv: Magyar | Matarka*
*Művészettörténeti Tudományos Bizottság II. FTO MTB [1901- ]*
*Közlemény: 31971100 | Nyilvános Forrás | Folyóiratcikk (Szakcikk ) | Tudományos | Matarka*

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Tóth Bence Péter: **A fecskeház - mesterdiploma**
*ORSZÁGÉPÍTŐ (0866-0069 ): 2019 3 pp 78-79 (2019)*
*Nyelv: Magyar | Matarka*
*Közlemény: 31971099 | Nyilvános Forrás | Folyóiratcikk (Szakcikk ) | Tudományos | Matarka*

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Befogadás alatt álló publikációk:

1.) Tóth Bence Péter: **Az Ybl Miklós Építéstudományi Karán működő NTDK felmérő-, és építőtáborok tapasztalatai**

*ICOMOS Magyar Nemzeti Bizottság Egyesület – Fiatal Műemlékvédők Fóruma 2022 tanulmánykötet – befogadás alatt*

2.) Tóth Bence Péter: **Imre Makovecz – Pura architettura organica ungherese** /Makovecz Imre – organikus tisztaság/ **-** *olasz nyelven megjelenő folyóiratcikk (szakcikk) Bioarchitettura (Instituto Nazionale BIOARCHITETTURA)* https://www.bioarchitettura.it/

3.) Tóth Bence Péter: **Népi födémszerkezeteink és tovább fejlesztési lehetőségeik**
*Magyar Építőipar, magyar nyelvű lektorált folyóiratcikk (szakcikk)*