University of Sopron Faculty of Wood Engineering and Creative Industries

Doctoral (PhD) dissertation theses

# DEVELOPMENT OF A SPATIAL STRUCTURE DESIGNED FROM NATURAL-BASED COMPOSITES – HUMAN AND ENVIRONMENTAL FACTORS OF SPATIAL DESIGN

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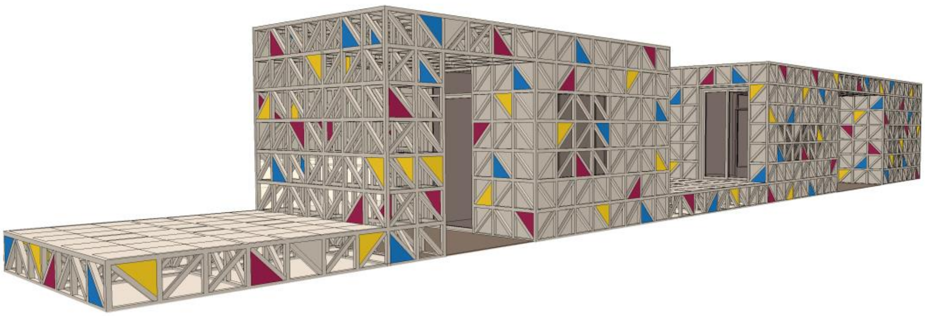

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## Subject and Objectives of the Research_

The adaptation of built spaces to human needs, while ensuring optimal material and energy consumption, represents one of the crucial issues of 21st-century spatial design. Therefore, the aim of this research was to design and develop an autonomous spatial structure that is optimized for human use; constructed in a material- and environmentally-conscious manner from natural and/or nature-based materials; and operates with energy efficiency both in active and passive terms. The designated site is the Botanical Garden of the University of Sopron.

The first section of the thesis presents the design process, which—by studying the physical interactions between humans and their environment—shaped the community micro-space in the spirit of “design for all / universal design.” The planned building, through its form language and flexible spatial configuration, fully accommodates the year-round activities of its users. The transparent articulation of opaque surfaces supports usability; material use, orientation, dimensions, and infrastructural systems enhance energy efficiency; while the natural timber-frame construction contributes to creating a healthy indoor environment.

The second section of the thesis addresses the issue of thermal insulation, following the principles of “healthy building” and “ecological construction.” It investigated the applicability of natural-based composite insulation, produced from reed and coconut fibers in five different base-material ratios, in the presence of two binding agents, cement and polyurethane. The results confirmed the applicability of the reed–coconut composite as a thermal insulating material, with values ranging between $\lambda$ = 0.08–0.15 W/mK, thereby rendering it suitable for use in the thermal regulation systems of the spatial structure.

The third section of the thesis investigated the spatial behavior of the focus group through a questionnaire survey, aiming to enhance the “total experience of perception.” The findings showed that positive personality traits increased the perceived capacity and comfort of the space, while pain, positive states, other sensations, and strong negative impacts acted as stimulants. Conversely, fatigue, negative states, distracting thoughts, and stress reduced spatial engagement. Furthermore, function, temperature, colours, and spatial elements were found to significantly influence spatial usage, whereas the lack of controllability diminished comfort.

In conclusion, it can be stated that the designed spatial structure proves suitable for fulfilling the initial expectations, and its realization would clearly enhance the communal spatial utilization of the University of Sopron and its Botanical Garden.

## Conclusions from the Literature Review_

Existence always takes place within a specific environment, in relation to various spatial elements. Humans adapt to these elements, modify and utilize them, and through this process, create. The full spatial experience is articulated through the interconnected domains of physical (sensory), cognitive, and emotional interfaces. Ultimately, the comfort, convenience, adequacy, and safety of space are determined by subjective perception and use.

The built environment constitutes a planned and artificially created space. While the toolkit of elements required for its formation is virtually limitless, it is governed by rules. Materials, as the most elementary constituents of construction, define space both as autonomous systems and through their temporal performance. They possess mechanical and building-physical characteristics, interact with weather conditions, and simultaneously meet user requirements.

The most essential question of spatial formation is to establish, for a given site, a spatial system that best corresponds to its function and context. The directions, causes, and possibilities of intervention are jointly determined by human and natural factors. During the research, the fundamentals of space, environment, and place, as well as the known and studied interactions between humans and these dimensions, were systematized. The resulting "database" aimed at simplifying the overview of spatial element combinations, thereby supporting the identification of appropriate architectural responses and fostering optimal cooperation during the design process.

| | |
|---|---|
| *Human* | Physique, intellect, emotion, abilities, characteristics, personality, needs and desires, culture, age, health status, social group, attention, perception: visual, kinaesthetic, auditory, olfactory, gustatory, tactile, cognitive, emotional. |
| *Space* | Spatial elements and their system, continuity, order, similarity–difference, dependency relations, localization, spatial division: absolute space, objective space, environment, place, subjective space, society. |
| *Environment* | Perceivable, observable, meaning, ability, characteristics, adaptation, stimulus, behavior, controllability, subjective judgment, preference: coherence, complexity, legibility, mystery. |
| *Locale* | Meaning, characteristic, sense of place, emotion, attachment, personal. |
| *Time* | Moment, past, present, future, duration, frequency, quality. |

Architectural contextual elements between humans and the environment:

*Visual:* light conditions, illumination, orientation, sunlight exposure, shading, mass-space relationship, opaque–transparent, surface, pattern, color, shadow, contrast, rhythm, sequence, repetition, proximity, movement, similarity–difference, communication, harmony, balance, obstruction.

*Kinaesthetic:* space requirement, distance, size, proportion, volume, scale, function, time, mass, obstacle, capacity, spatial system, legibility, orientation, motion, circulation.

*Auditory:* sound, noise, body sound–airborne sound, acoustic phenomena, sound source, experience, perception, sound control (passive – mass, structure; active – loudspeaker), communication, music, distance, quality, intensity, duration, sound mapping, footstep, speech, obstruction.

*Olfactory:* scent, odor, communication, scent source, intensity, distance, spatial elements – material smell, scent memories, olfactory experience, attention capturing, safety technology, obstruction, gustatory effect (synaesthesia), artificial, natural, mixture.

*Tactile:* surface experience, contours, roughness, softness, material, shape, size, proportion, function, hygiene, wear, slipperiness, safety, cleanability, motion – balance, action, air conditions, humidity, temperature conditions, mechanical effects, chemical effects, cooling, heating, ventilation, draft, radiant heat, surface temperature, communication.

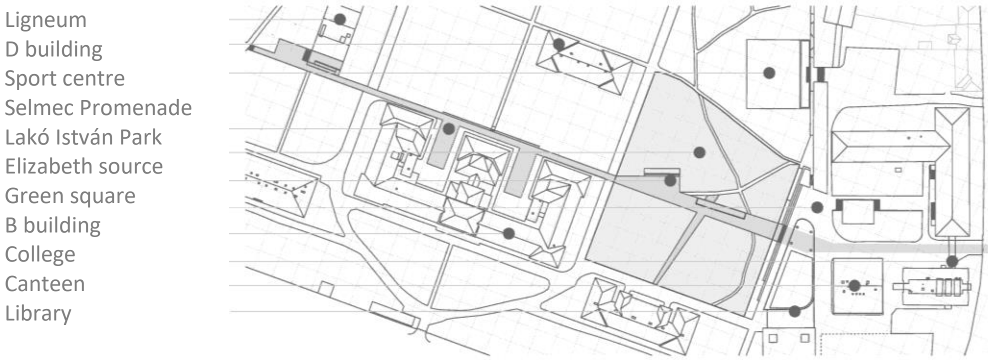
*Cognitive:* meaning – function, short- and long-term memory, semantic network, meaning chain, schemas, similarity–difference, recall – remembrance, attention, conscious and unconscious perception, stimulus threshold, memory of places, past–present–future, cognitive processes (decision-making, consumer, creative), experience, action, information, stimuli, performed action – expected outcome, habituation, overstimulation, wear, inattention, attentional blindness.

*Emotional:* momentary, long-term, basic emotions, cognitive emotions, purely human emotions, emotion patterns, evaluation, general emotional traits, subtle emotions, somatic marker, past–present–future, influences information processing, complex sense of place, psychological performance, behavioural mode, mood.

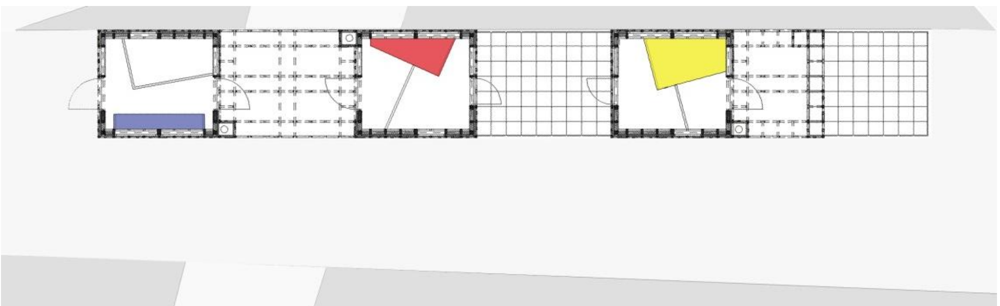
## Presentation of the Design_

The primary focus of the intervention was the reinterpretation of the obstructed visual and physical connection between student and educational spaces. The development site is the area between Building B and the dormitories, which, in homage to the garden's first planner, was named LAKÓ ISTVÁN PARK. The proposed interventions include the creation of a main circulation axis and a connected university route – SELMECI PROMENADE – complemented by enclosable micro-environments. The planned building consists of a system of enclosed, covered-open, and uncovered spaces. The rhythm of delineated volumes and open areas follows the dynamics of year-round use. The volumes not only provide separation but also participate in direct use in a "furniture-like" manner. The enclosable spatial units are linked by a playful wave-like pattern.

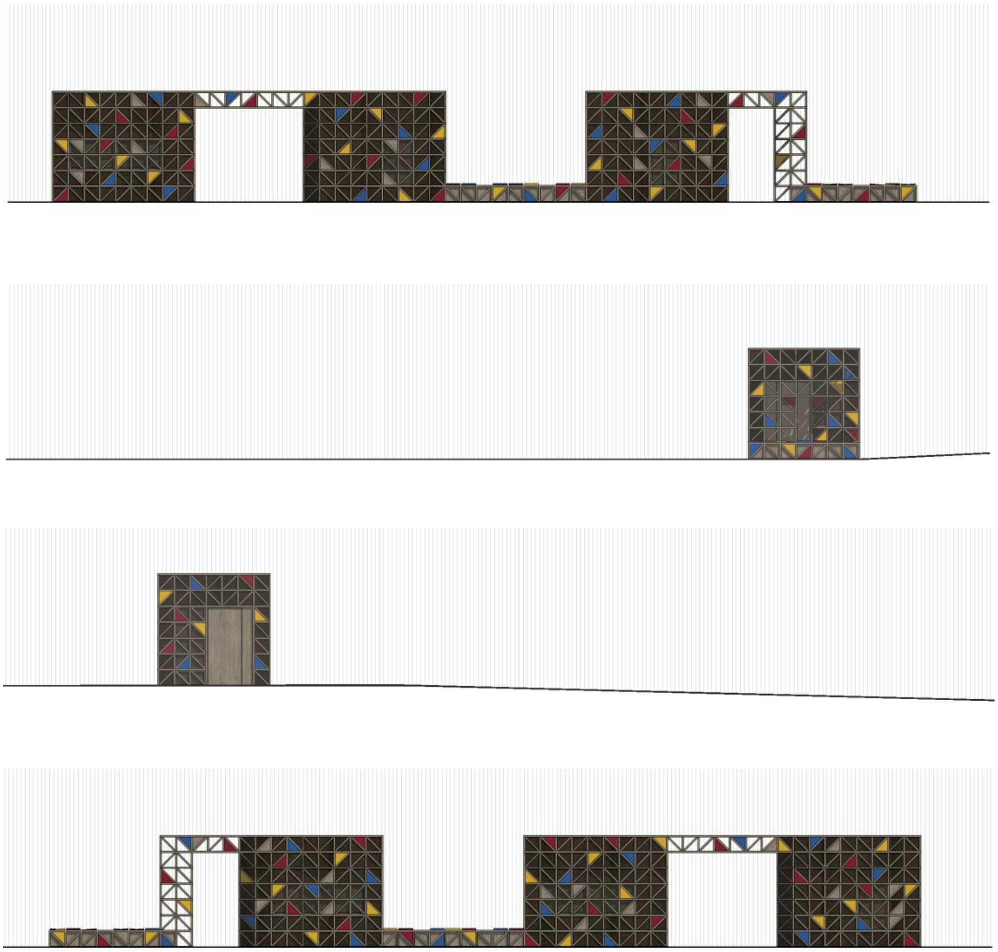
The interior spaces, alluding to Selmec traditions, evoke the atmosphere of mining tunnels. Effects of "concealed presence" and "retreat within the crowd" are perceptible. The covered-open spaces and sun terraces direct attention toward the park's visual highlights, such as the plane trees. Each building unit receives direct sunlight throughout the year and day. The infrastructural systems are automatically controlled. The use of natural materials in the building supports a healthy indoor environment.



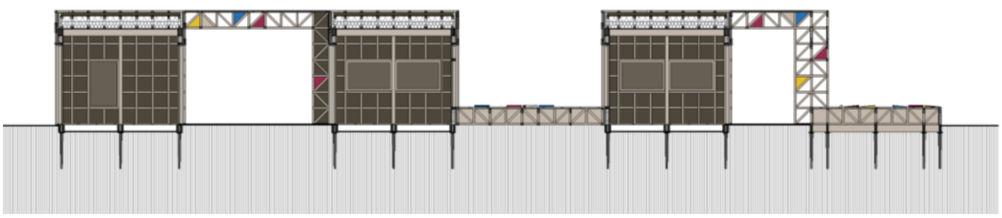

Location



Plan



Elevations



Section

## Summary of the Research and Methods_

One of the primary objectives in the development of the spatial structure was to formulate an enclosing structural system that relies exclusively on renewable, natural-based materials while satisfying the expectations of users and the relevant regulatory requirements. The research focused on two construction materials: reed and coconut fibers. Both materials exhibit excellent thermal and acoustic insulation properties and are highly durable, yet their practical utilization is still being explored even on a global scale. To reinforce these base materials, the study employed ordinary Portland cement (PC) and methylene-diphenyl-diisocyanate (MDI) as binders, applying semi-dry and hot-pressing methods. From each composite type, five panels were produced.

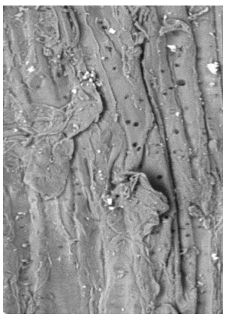
The tests performed included thickness swelling according to MSZ EN 317, water absorption according to MSZ 1336:4–13379, bending properties according to EN 310, tensile strength perpendicular to the plane according to EN 319, and thermal conductivity according to MSZ EN ISO 10456, along with FTIR analysis. In addition, scanning electron microscopy (SEM) images were captured for both intact and fractured specimens.

**Composite Panel Recipe (%)**

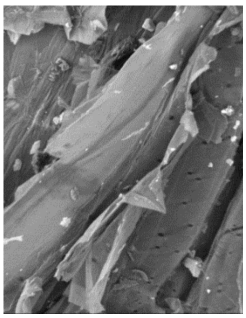
| Materials | CEM_1 | CEM_2 | CEM_3 | CEM_4 | CEM_5 |
|---|---|---|---|---|---|
| Reed | 1.00 | 0.60 | 0.50 | 0.40 | 0.00 |
| Coconut | 0.00 | 0.40 | 0.50 | 0.60 | 1.00 |
| PC | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 |
| $Na_2SiO_3$ | 0.052 | 0.052 | 0.052 | 0.052 | 0.052 |

| Materials | MDI_1 | MDI_2 | MDI_3 | MDI_4 | MDI_5 |
|---|---|---|---|---|---|
| Reed | 1.00 | 0.60 | 0.50 | 0.40 | 0.00 |
| Coconut | 0.00 | 0.40 | 0.50 | 0.60 | 1.00 |
| MDI | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |


Coconut fibre


Coco SEM photo


Reed fibre


Reed SEM photo

The results indicated that increasing the coconut fiber content enhanced the mechanical properties of the panels, while a higher reed content improved their insulation performance. The density of the panels had a significant influence on their physical, mechanical, and thermal properties, and the physical tests of the samples revealed improved resistance to wet conditions. An important finding was that, in the MDI matrix, a substantial portion of water uptake occurred during the second testing period, thereby improving the water resistance of the panels. SEM images demonstrated an adequate interaction between the materials within the composite system at the fracture surfaces, showing strong entanglement between the reed and coconut fibers. FTIR analyses further confirmed the successful bonding between the lignocellulosic materials and the binders.

The study concluded that reinforcement between the reed and coconut fiber materials and the PC/MDI matrix is feasible; however, further investigations are required to enhance the insulating and strength properties of the panels and to determine the optimal reed-to-coconut ratio. Future research directions point towards the pre-treatment of raw materials and the examination of mechanical mixing procedures, where panels containing nearly equal proportions of coconut and reed fibers (MDI3-4 and CEM3-4) appear to be the most indicative.

| | Density (kg/m$^3$) | Water abs. (%) | Thickness swelling (%) | Internal bonding str.(MPa) | Flexural strength (MPA) | Young modulus (GPa) | λ (W/mK) |
|---|---|---|---|---|---|---|---|
| MDI1 | 460 | 64,7 | 24,9 | 0,060 | 2,41 | 1,59 | 0,0831 |
| MD12 | 517 | 38,0 | 13,5 | 0,290 | 4,94 | 1,69 | 0,0836 |
| MDI3 | 557 | 34,6 | 13,2 | 0,300 | 5,67 | 1,82 | 0,0876 |
| MDI4 | 525 | 36,3 | 14,3 | 0,350 | 5,89 | 1,51 | 0,0934 |
| MDI5 | 557 | 41,7 | 14,5 | 0,360 | 6,33 | 1,52 | 0,0970 |
| CEM1 | 1085 | 46,7 | 16,4 | 0,001 | 1,04 | 0.80 | 0,1060 |
| CEM2 | 1147 | 39,8 | 9,2 | 0,020 | 2,09 | 1,96 | 0,1150 |
| CEM3 | 1255 | 33,8 | 5,4 | 0,160 | 3,65 | 3,29 | 0,1290 |
| CEM4 | 1163 | 35,3 | 4,3 | 0,200 | 3,71 | 3,41 | 0,1450 |
| CEM5 | 1037 | 39,5 | 3,7 | 0,310 | 5,13 | 3,82 | 0,1540 |

Reed-coco-MDI panels (MDI1-5)

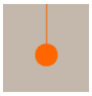
Reed-coco-cement panels (CEM1-5)

## Research Results_

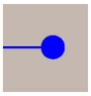
The reed–coconut composite can be applied in multiple locations within the thermal insulation system of the spatial structure. The coconut–cement panels (CEM_5_4_3) appear promising for summer mass insulation of the interior spaces, whereas for winter thermal insulation, the use of reed–MDI composites (MDI_1_2_3) may offer an effective and ecologically sound solution. The straightforward installation of the panels is facilitated by a double timber-frame system, upon which a coconut mat is laid, providing both the exterior cladding and waterproofing. The “soft” exterior cladding is secured by a playful, colourful lattice framework, which simultaneously defines the visual character of the spatial structure. The naturally produced thermal insulation panels, manufactured with minimal processing, can ensure comfortable indoor climate conditions and a healthy environment for users. The interior walls, floors, and ceilings are clad with wood, composite panels, and parquet, while the window and door systems incorporate insulated glazing, wooden frames, and doors with fixed and tilt-opening positions, as well as dimensioned and automated ventilation slots.

The heating system is dual: it combines climate control and electric heating panels, providing both winter heating and summer cooling options. Temperature can also be manually adjusted. Sensors monitor temperature, humidity, opening positions, and $CO_2$ levels. Closely coordinated with the heating system, the ventilation system regulates both natural gravity-driven air exchange and fan-assisted ventilation. The building is compact and energy-efficient.

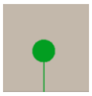
Natural daylight in the interior is supplemented by artificial, dimmable, coloured light sources operating according to a timed program. The program adjusts the lighting in response to information from light sensors to correspond with daily and seasonal variations, while also supporting the perception of thermal comfort. For personal comfort, the intensity and color of the background lighting can be controlled via two user interfaces, while direct, individualized illumination of work surfaces is provided using mobile lighting units.



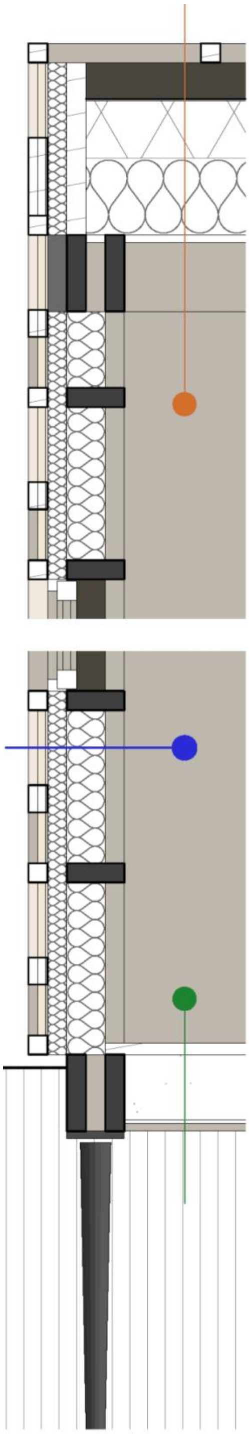
- Lattice frame
- Coconut mat waterproofing
- Reed–coconut thermal ins.
- Coconut–reed thermal ins.
- Wood construction
- Wood panel

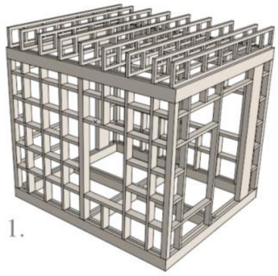


- Lattice frame
- Coconut mat waterproofing
- Reed–coconut thermal ins.
- Coconut–reed thermal ins.
- Wood construction
- Coconut–reed panel

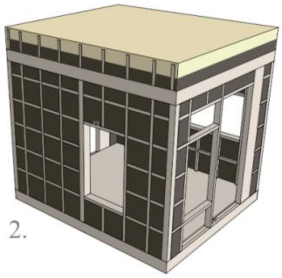


- Wood flooring
- Wood frame construction
- Sand spreading
- Geotextile
- Foam glass ins.
- Soil

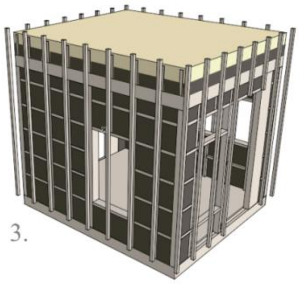




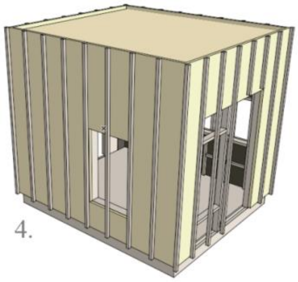

Wood construction




Coconut-reed thermal
insulation panel

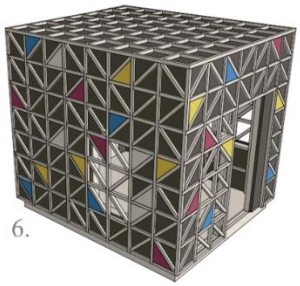



Lattice frame – vertical




Reed-coconut thermal
insulation panel


Coconut mat waterproofing



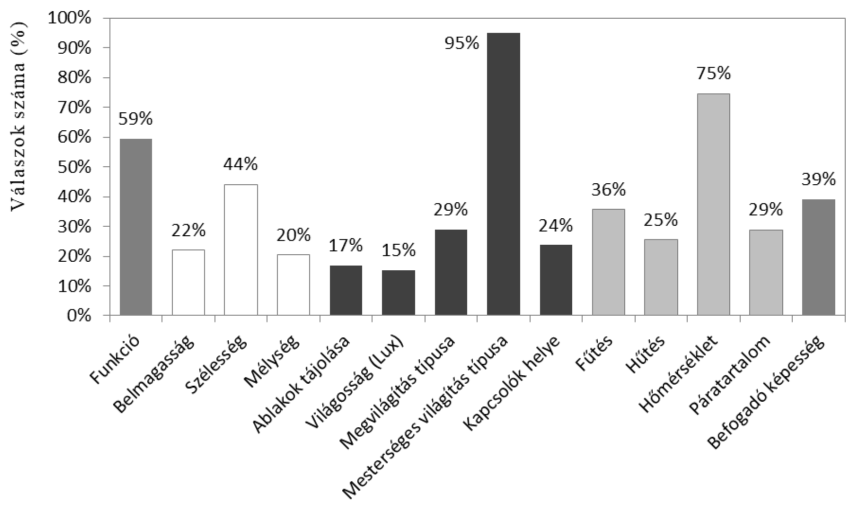

Slat frame –
horizontal, diagonal, colour

Investigation of Spatial Usage and Users_

The primary expected users of the spatial structure are students, typically aged between 18 and 26 years. Despite their active presence, the student population undergoes turnover in four- to five-year cycles, necessitating constant adaptation from the university. Due to their age-specific characteristics, students require both solitude and opportunities to organize into smaller or larger communities and groups, and therefore demand spaces that accommodate both personal and social activities. They exhibit a high degree of desire for freedom, often testing the boundaries of rules and possibilities. Their behavior may be characterized by pronounced emotional extremes, which are further amplified by intensive cognitive demands, particularly during examination periods in January and May.

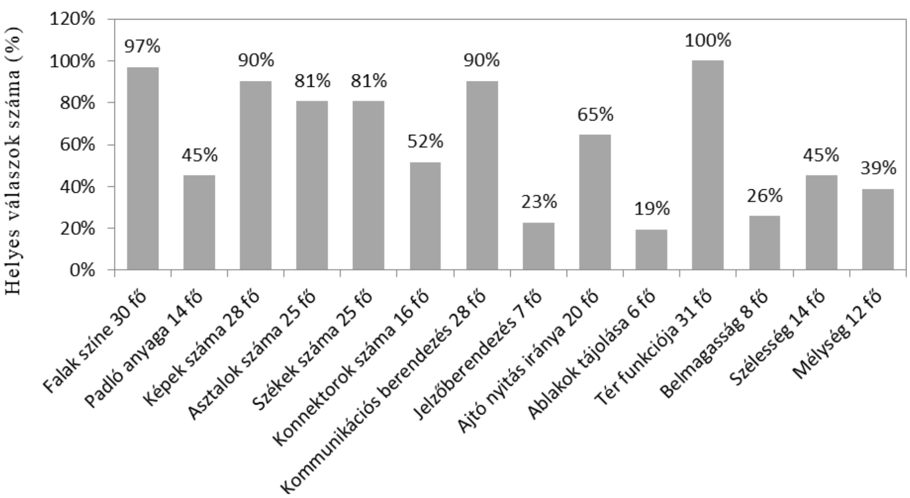
The student body is largely composed of individuals arriving from other regions of Hungary or from abroad, bringing with them diverse customs and cultural backgrounds. The phases of adaptation, acceptance, and habituation exert a strong influence on the students, with the unfamiliar environment often providing an inspiring and attractive force. However, it can also evoke fear, anxiety, and other negative emotions associated with separation.

The development of the spatial structure proceeded with an investigation of student behavior. Two questionnaires assessed participants' knowledge of and impressions about the space, taking into account their personality traits, momentary physical, cognitive, and emotional states, as well as spatial memories. First-year students, regardless of their current states, correctly perceived approximately 37% of the space parameters, and upon recall, perceived adequacy reached about 60%. Overall, the results indicated a notably weak level of spatial perception.



The questionnaires further revealed that the strongest determinants of spatial experience are the perception of function and thermal comfort, as well as the influence of colours and furnishings. At the same time, experiences falling outside the visual field of attention, referred to as “non-conscious perception,” play a significant but “invisible” role in the overall usage experience, despite their relatively weak values observed during the study. As long as these perceptions function subjectively without issue, they remain unnoticed by attention. However, once stimulus thresholds are exceeded, discomfort arises, prompting the user to instinctively seek to modify the conditions and pursue opportunities for control.

In the case of the spatial structure, temperature, light, and visibility conditions can be regulated beyond threshold limits, whereas air quality is largely self-regulating due to its ease of adaptation, rendering adverse effects imperceptible. A sensitive element of usage is the capacity of enclosed units (and its subjective assessment), which underscores the importance of automatic monitoring of environmental conditions. Given the unconventional function of the building, it is expected that users may initially experience uncertainty in interpreting its purpose and in understanding the relationship between its intended function and target audiences. The discovery and comprehension process is supported by the building’s easily legible yet adaptable spatial system, the rhythm of enclosed and open spaces, and varied surface finishes, which may be supplemented with signage and graphic elements. The design of the interior spaces emphasizes simplicity, simultaneously conveying the message of unrestricted usability.

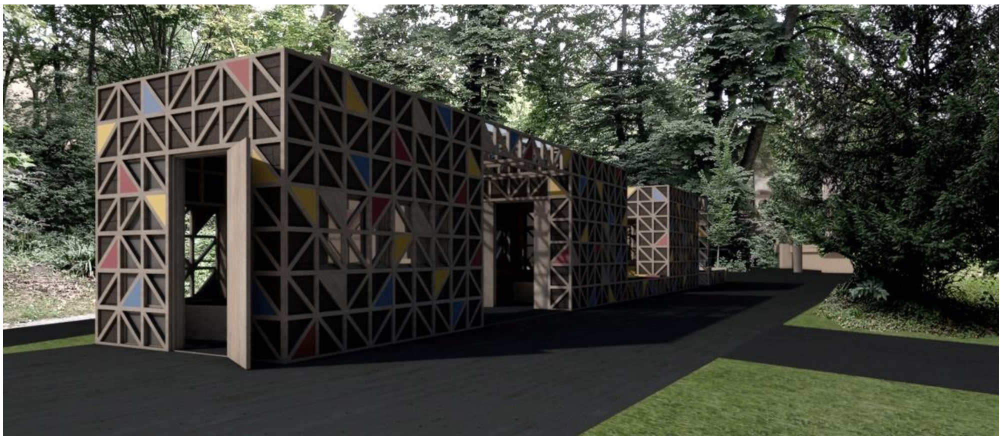


Summary_

Within the framework of the doctoral research, a micro-spatial system was designed in the Botanical Garden of the University of Sopron, specifically within the area designated as Selmec Promenade – Lakó István Park. The system was optimized for human use and environmental factors, and constructed from natural-based, healthy building materials. The initial guiding principles of the design were the "total experience of perception," "design for all," "healthy building," and "ecological construction." These core ideas were structured according to human factors (ergonomics), encompassing physical, cognitive, and emotional interfaces, as well as kinaesthetic, visual, auditory, and haptic surfaces. Guided by these interrelations, the spatial structure was designed, followed by material development and spatial shaping.

The research provided the opportunity to work with natural materials such as wood, reed, and coconut, which have been part of human construction practices since ancient times and have the potential to play a significant role in sustainable development. The physical, mechanical, and thermal results of the reed–coconut composite panels confirmed that the mixture is suitable for creating a healthy indoor environment. Their low cultivation and processing energy requirements, even when accounting for transportation impacts, further establish them as ecological building materials.

Moreover, the investigation of spatial users and usage highlighted the most influential spatial elements, including function, temperature, colours, and furnishings, as well as the "invisible" elements that shape the overall spatial experience. Taking into account the results of the research, it can be concluded that the designed spatial structure meets the initially formulated expectations and, with continued development, can become a valuable element of the University of Sopron and the Selmec traditions.

Theses_

Based on the research, the following architectural and scientific conclusions can be drawn:

**Thesis 1** – Site and Function: The Botanical Garden of the University of Sopron lacks community micro-spaces that can be used year-round and comfortable physical connections between the educational buildings and dormitories. The new spatial structure of the site could clearly enhance the communal usability of the Collection Garden [P4].

**Thesis 2** – Usability and Form-Making: Optimization for human use ("design for all") was carried out along the physical interfaces—kinaesthetic, visual, auditory, and haptic surfaces—as well as cognitive and emotional interfaces. It can be concluded that the designed spatial structure adequately covers the year-round usage requirements across all points of interaction [P1–P5].

**Thesis 3** – Materials and Structure: In order to establish healthy interior conditions and promote environmentally conscious and ecological construction, the applicability of natural-based thermal insulation was investigated. Panels composed of reed–coconut–cement and reed–coconut–methylene-diphenyl-diisocyanate were produced without pre-treatment using semi-dry and hot-pressing methods. The results clearly confirm the potential applicability of reed–coconut composites as sustainable thermal insulation materials, exhibiting thermal conductivity in the range of 0.08–0.15 W/mK [P6–P13].

**Thesis 4** – Spatial Usage and Semantics: The development of the spatial structure continued along the cognitive and emotional interfaces with the aim of facilitating the "total experience of perception," using questionnaire-based research. The results revealed that users correctly perceive approximately 37% of the space parameters and accurately recall around 60%, with the spatial experience being consistently retained. The questionnaires indicated that during spatial use, the role of function, temperature, colours, and spatial elements is significant, whereas the lack of controllability clearly reduces the sense of comfort. It can be concluded that the design and infrastructure of the planned spatial structure adequately respond to these expectations, and its implementation would clearly enhance the communal use and comfort of the University of Sopron and its Botanical Garden [P1–P5].

Publications

| Title – writer – journal |
| --- |
| P1 – Térjátékok – Játék a térben és időben<br>Mucsi Zsuzsanna – Molnár László<br>KGY Neveléstudományi Konferencia, Évf. 20 Szám 3-4, 2022: Képzés és Gyakorlat, 36-42.<br>https://doi.org/10.17165/tp.2022.3-4.36-42 |
| P2 – A térészlelés és térhasználat kognitív működése<br>Mucsi Zsuzsanna – Horváth Péter György<br>In: Márfai, Molnár László; Pásztory, Zoltán (szerk.) Az alkalmazott művészet létmódjai és a kreatív ipar kihívásai napjainkban: Faipari Mérnöki és Kreatívipari Kar tudományos kiadványa, Sopron, Magyarország: Soproni Egyetem Kiadó (2023) 348 p. pp. 145-151., 8 p.<br>https://doi.org/10.35511/978-963-334-453-8.Mucsi_Zs-Horvath_P |
| P3 – A környezet és ember közötti interakció összefüggéseinek vizsgálata<br>Mucsi Zsuzsanna – Horváth Péter György<br>In: Molnár, Dániel; Molnár, Dóra (szerk.) Tavaszi Szél 2024 / Spring Wind 2024. Tanulmánykötet II. Budapest, Magyarország: Doktoranduszok Országos Szövetsége (DOSZ) (2024) pp. 55-68., 14 p.<br>https://dosz.hu/fil/a5ea64c3e36cad90f2465f4f00dd651abf367ec885d7cf22c16ed8ebc6109b0d |
| P4 – Mikrotér mozgásban: Adaptív építészet a Soproni Egyetem Botanikus Kertjében<br>Mucsi Zsuzsanna<br>Tervlap – https://tervlap.hu/cikk-nezet/mikroter-mozgasban-adaptiv-epiteszet-a-soproni-egyetem-botanikus-kertjeben (megjelenés: 2025.09.25) |
| P5 – Épített tér – alkalmazkodás és tér-tárgy összefüggés óvodai környezetben<br>Mucsi Zsuzsanna – Molnár László<br>KÉPZÉS ÉS GYAKORLAT: TRAINING AND PRACTICE 20:3-4 pp. 36-42., 7 p.(2022)<br>Pedagógiai Tudományos Bizottság II. FTO PedTB [1901-] |
| P6 – Ellenállásra tervezve, Kókusz az építőiparban?<br>Magyar Építéstechnika 2022/3-4., 26-27 o. – Mucsi Zsuzsanna |
| P7 – Egységben az erő (Nád)<br>Magyar Építéstechnika 2022/8-9., 48-49 o. – Mucsi Zsuzsanna |
| P8 – Kössük össze! Ívelt és bordás merevítésű héjak és kötött kábelháló erősítésű zsaluzat felhasználási lehetőségei<br>Magyar Építéstechnika 2022/6-7. – Mucsi Zsuzsanna |

| Title – writer – journal |
|---|
| P9 – Semi-dry technology mediated coconut fibre and energy reed straw reinforced cementitious Insulation panels<br>Faridul Hasan – Miklós Bak – Zsófia Kóczán – Zsuzsanna Mucsi – Péter György Horváth – Tibor Alpár<br>Journal of Building Enginiering, Volume 57, 1 October 2022, 104825<br>https://doi.org/10.1016/j.jobe.2022.104825 |
| P10 – Fabrication and characterization of lignocellulosic coconut and energy reed straw-reinforced methylene diphenyl diisocyanate-bonded sustainable insulation panels<br>Faridul Hasan – Miklós Bak – Le Duong Hung Anh – Zsófia Kóczán – László Bejó – Zsuzsanna Mucsi – Péter György Horváth – Tibor Alpár<br>Construction and Building Materials, Volume 414, 2 February 2024, 134992<br>https://doi.org/10.1016/j.conbuildmat.2024.134992 |
| P 11 – Methylene Diphenyl Diisocyanate and Cement-Bonded Insulation Panels Reinforced With Coconut Fiber And Energy Reed Straw Mediated By Semi-Dry Technology<br>Faridul Hasan – Le Duong Hung Anh – Zsuzsanna Mucsi –Péter György Horváth – Tibor Alpár<br>Molnár, Dániel; Molnár, Dóra (szerk.) Tavaszi Szél 2022 / Spring Wind 2022. Tanulmánykötet II. Budapest, Magyarország: Doktoranduszok Országos Szövetsége<br>Conference: XXV. SPRING WIND CONFERENCEA: Pécs, Hungary<br>https://dosz.hu/fil/13de2f285938c0288c59ef46f14b6e4da7682572f00faf0a96ee7de7766229ab |
| P12 – Energy reed fiber reinforce thermosetting polymeric biocomposite<br>Faridul Hasan – Zsuzsanna Mucsi – Péter György Horváth –Tibor Alpár<br>Molnár, Dániel; Molnár, Dóra (szerk.) Tavaszi Szél 2021 / Spring Wind 2021. Tanulmánykötet I. Budapest, Magyarország: Doktoranduszok Országos Szövetsége (DOSZ) (2021) 813 p. pp. 551-555., 5 p.<br>Conference: 10th INTERDISCIPLINARY DOCTORAL CONFERENCE 2021At: Pécs<br>https://dosz.hu/fil/6a891de174fbe1edb6d91acc40ced663638c13d6010b5aa030d21e13131d1260 |
| P13 – Rice straw and energy reed fibres reinforced phenol formaldehyde resin polymeric biocomposites<br>Faridul Hasan – Le Duong Hung Anh – Bak Miklós – Zsuzsanna Mucsi – Péter György Horváth – Tibor Alpár<br>Cellulose, August 2021, 28(12)<br>https://doi.org/10.1007/s10570-021-04029-9 |

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