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2 INTEGRATION OF INCLUSIVE ENGINEERING PRINCIPLES AND CRAFT TECHNOLOGIES IN THE DESIGN OF FOOD SERVICE FACILITIES IN THE CONTEXT OF POST-WAR RECONSTRUCTION OF UKRAINE: BUILDING MATERIALS, ARCHITECTURAL SOLUTIONS, QUALITY, SAFETY

ABSTRACT

The study is devoted to the integration of inclusive engineering principles and craft technologies in the design of food service facilities within the context of Ukraine's post-war reconstruction. The primary focus is on the environmentally responsible selection of building materials (wood, clay, straw, hemp fiber, arbolite concrete) and architectural solutions that address the needs of vulnerable population groups, including veterans, persons with disabilities, and internally displaced persons. Emphasis is placed on ensuring quality standards, safety (notably HACCP), and hygiene, which are critically important in the food service sector.

In the context of the war in Ukraine, which has caused extensive infrastructure destruction, there is a need to create a new architectural and construction culture oriented toward sustainable development, social inclusivity, and the preservation of local identity. The proposed approach combines circular economy principles (material reuse), craft technologies (hand labor, local resources), and inclusive design (barrier-free access, adaptive furniture, sensory comfort). This contributes to the economic recovery of communities, reduces environmental impact, and creates culturally significant spaces.

The objective is to develop a methodology for integrating inclusive engineering and craft technologies to create accessible, safe, and authentic food service facilities.

The study includes an analysis of the thermophysical characteristics of building materials such as density, heat capacity, thermal conductivity, and vapor permeability, along with a comparison of their technological complexity, environmental friendliness, and economic feasibility. Results demonstrate the advantages of materials with high heat capacity (reed panels, arbolite) for energy efficiency and low thermal conductivity (cellulose insulation, foam glass) for thermal insulation. Architectural solutions encompass ramps, wide corridors, zoning, anti-slip surfaces, and hygienic materials compliant with HACCP standards.

This approach ensures the creation of sustainable, safe, and socially inclusive spaces that support the local economy, reduce ecological footprint, and contribute to the preservation of Ukrainian identity. It is recommended to adapt regulatory frameworks and educational programs to promote these principles.

KEYWORDS

Inclusive engineering, craft technologies, design, architectural solutions, building materials, sustainable development, post-war reconstruction of Ukraine, food service facilities, quality, safety, HACCP.

The war in Ukraine has caused extensive destruction [1] to the housing stock and social infrastructure facilities, demolishing millions of square meters of residential buildings, schools, hospitals, public structures, and cultural heritage sites. In the face of such losses, the task arises not only of physical reconstruction but also of forming a new architectural and construction culture focused on the principles of sustainable development, environmental responsibility, and social sensitivity. Considering resource limitations, rising costs of building materials, and the urgent need for fast and efficient solutions, the reuse of building materials obtained from the demolition of destroyed structures becomes especially important [2–4].

In this context, the restoration of social infrastructure requires the implementation of new approaches to the design of public facilities – primarily food service establishments – that take into account the needs of vulnerable population groups, as well as quality requirements [5–7] and the safety of the food environment [7, 8]. This approach should be based on four strategic directions:

– social inclusivity, which implies the creation of a barrier-free environment accessible to all population categories, including persons with disabilities, elderly people, veterans, and internally displaced persons [9–12];

– environmental responsibility, realized through the use of renewable natural resources, reuse of building materials [2–4], and minimization of the carbon footprint at all stages of construction;

– local identity, expressed in the preservation of cultural characteristics, architectural traditions, and the material heritage [13] of a specific community;

– sanitary and hygienic safety [7, 8, 14], ensured through the implementation of quality management systems [6, 7, 15] and HACCP [7, 8, 15], which regulate spatial, engineering-technological, and operational solutions in food service establishments in accordance with food safety principles and hygiene standards.

2.1 NEW CONSTRUCTION GUIDELINES IN THE PROCESS OF UKRAINE'S RECONSTRUCTION

In the post-war period [16], when resources are limited and the need for prompt, effective, and economically viable solutions is critical, approaches based on the circular economy gain special importance. The reuse of building materials recovered from demolished structures allows not only to reduce the demand for new resources and lower transportation and disposal costs but also significantly decreases environmental impact [2, 3, 17–19]. This becomes particularly relevant in designing social infrastructure facilities, especially food service establishments, which require fast, high-quality, and accessible reconstruction [10–12].

At the same time, physical reconstruction must be accompanied by a paradigm shift: from "technocratic restoration" [2, 4, 13] to "human-centered reconstruction", which takes into account social sensitivity and the needs of vulnerable groups – including persons with limited mobility, veterans, elderly people, children, and internally displaced persons [11, 12, 14, 20, 21]. In this context, inclusive engineering design is regarded as a necessary prerequisite for creating environments that are not only accessible but also adapted to diverse physical, sensory, and cognitive needs [9–12, 14, 20, 21].

Craft technologies [14], based on manual labor, local knowledge, and the use of natural materials, play a special role in this approach. Their advantage lies in high adaptability to local contexts: from small communities and rural areas to temporary facilities, including field kitchens, mobile canteens, and modular cafés. Combined with inclusive engineering, they enable the creation of spatial solutions that are environmentally balanced, technically simple to implement, and socially acceptable. Moreover, this approach encourages community involvement in reconstruction processes, fostering economic recovery at the local level [11, 12, 14].

Another critically important aspect is the preservation and restoration of local identity, which for decades has suffered destruction and homogenization. Local identity includes architectural styles, materials, color schemes, decorative motifs, landscape features, linguistic and cultural codes, and social rituals that form the unique character of each territory, creating a distinct "national style" [22]. In the design of food service establishments, this is expressed, for example, through the use of traditional forms (such as clay facades, wooden elements, ceramic inserts), the introduction of ethnodesign elements in interiors, and the use of local products in menus.

Combined with inclusive and ecological approaches, local identity creates the foundation for culturally significant, socially cohesive, and sustainable gastronomic spaces that reflect the uniqueness of the community while meeting modern technical, ergonomic, and sanitary-hygienic standards. This allows avoiding the stereotypical "standardized design" characteristic of "soviet architecture" and instead promotes a conscious transformation of space through the lens of authenticity, safety, and quality. It imparts a unique character to the community, supports its historical memory, roots social bonds, and contributes to sustainable development.

2.1.1 THE ROLE OF CRAFT APPROACHES IN THE CONTEXT OF THE CIRCULAR ECONOMY

In the process of Ukraine's post-war reconstruction, craft approaches [14] are gradually gaining status as one of the key vectors for implementing the principles of the circular economy [4, 23, 24], especially in the context of architectural and engineering design of social facilities — particularly food service establishments. These approaches imply a shift away from the linear model of "production — consumption — disposal" toward a cyclical model, where materials receive a second life and architectural solutions focus on restoration, reuse, recycling, and prolonged service life [23].

Craft technologies involve the manual or semi-manual production of building materials with maximal use of local resources — natural, renewable, and low-toxicity. This not only reduces dependence on industrial supply chains but also allows flexible adaptation of designs to local conditions and community needs. In the design of food service facilities, this approach offers several advantages:

— enables the creation of aesthetically expressive, individualized interiors featuring elements of regional style (clay, wood, straw, ceramics, linen textiles);

— allows for the reuse of materials (e.g., bricks, wood, stone) for facades, bar areas, furniture, or decorative elements;

— contributes to reducing the carbon footprint and the volume of construction waste, aligning with the ecological goals of reconstruction [4, 23].

At the same time, the material life cycle — from the original source to reintegration into a new structure — becomes a central category in engineering design [9]. Within this approach, not only the primary parameters of the material (strength, thermal insulation, moisture resistance) are planned, but also its potential for further utilization, reclamation, or reassembly.

The application of craft technologies is particularly effective when combined with modular constructions and adaptive architecture, enabling the creation of both permanent and temporary food service facilities — mobile canteens, summer kitchens, social cafés — that account for seasonality, population migration, or fluctuating demand.

Engaging the community — local artisans, small entrepreneurs, and craftsmen — in this process not only supports the local economy but also fosters social responsibility in projects, enhances their cultural rootedness, and stimulates the development of craft food productions closely linked to the food service establishment.

Thus, craft technologies in the architecture of food service facilities in post-war Ukraine represent not only aesthetics and tradition but also a strategic resource for sustainable reconstruction, integrated into the principles of ecological feasibility, economic efficiency, and social inclusion.

2.1.2 THE ROLE OF INCLUSIVITY IN DESIGN

Inclusive engineering in Ukraine's post-war reconstruction acquires particular importance as an interdisciplinary approach that combines technical, architectural, social, and humanitarian dimensions in the design, construction, and operation of the physical environment [9, 11, 12]. Its key goal is to create spaces that are physically, sensorially, and psychologically accessible, functional, safe, and comfortable for all user categories — regardless of age, gender, physical or cognitive characteristics [10, 14, 25].

Inclusivity becomes especially relevant in the design of food service establishments [5, 11, 14], which perform not only service functions but also social, rehabilitative, and integrative roles. In the context of the return to peaceful life of a significant number of veterans [26], persons with disabilities, and internally displaced persons, food service facilities become spaces for meeting, socializing, employment, and support, requiring a particularly sensitive architectural approach.

This approach goes beyond mere formal compliance with technical accessibility standards and includes a profound rethinking of architectural-spatial models [27], engineering systems [9, 27], and technological processes, taking into account the real-life experiences of users. The principle "the environment must adapt to the person, not vice versa" demands the involvement of specialists in ergonomics, psychology, interior design, and medical rehabilitation.

In establishments that combine food service functions with craft production (such as bakeries, mini-workshops, or family cafés), inclusivity acquires an additional dimension — production accessibility. This concerns not only the physical adaptation of work areas (surface heights, safe equipment placement, presence of tactile or visual markers) but also an inclusive work culture that supports the participation of people with functional limitations in production and service processes. This promotes not only economic integration but also reduces labor market discrimination, increases autonomy, and fosters local entrepreneurship.

Thus, inclusive engineering in the design of food service establishments is not only a tool for spatial accessibility [14, 28] but also a powerful mechanism for creating a just, "humane", and sustainable environment where technical solutions meet real user needs and architecture becomes an instrument of social cohesion and dignity.

2.1.3 RELEVANCE OF THE RESEARCH DIRECTION

The full-scale war in Ukraine has caused a profound transformation of the social, engineering, and architectural environment, posing new demands on the spatial design, construction, and operation of public facilities. Today, the task is not only the physical reconstruction of damaged housing and social infrastructure but also the rethinking of approaches to architectural and structural modeling, taking into account the principles of sustainable development, environmental responsibility, social justice, and cultural rootedness.

In conditions of resource scarcity, rapid urbanization, and the need for quick solutions, inclusive engineering practices oriented toward the needs of a wide range of users — especially persons with disabilities, combat veterans, elderly people, children, and internally displaced persons — gain special relevance. The growing share of the population with functional limitations requires fundamentally new approaches to shaping the physical environment, where accessibility, comfort, safety, and adaptability are considered the basic characteristics of spatial quality.

At the same time, the role of craft technologies is increasing — as an alternative to mass industrial construction — that ensures the use of local resources, consideration of the local context, community involvement in reconstruction, and the restoration of local identity. The combination of manual production methods, artisanal practices, and modern materials science approaches creates conditions for forming a more flexible, ecological, and socially sensitive architectural environment.

At the intersection of inclusive engineering and craft technologies, a promising research direction is emerging that allows the design of food service establishments not only as functional objects but also as centers of social integration, cultural renewal, and spatial justice. These facilities must meet criteria of environmental sustainability, technological adaptability, economic feasibility, and regulatory safety, taking into account quality standards and HACCP principles.

In this context, the aim of the research is the integration of inclusive engineering principles and craft technologies into the design process of food service establishments with an emphasis on the selection of building materials, architectural solutions, and spatial organization in the context of Ukraine's post-war reconstruction. Special attention is paid to safety, quality, social sensitivity, environmental responsibility, and cultural appropriateness.

Research objectives:

— to analyze current challenges and trends in the field of inclusive engineering, particularly considering the needs of persons with disabilities, veterans, and internally displaced persons;

— to investigate the potential of craft technologies for implementing circular economy principles and preserving local identity in construction;

— to develop methodological approaches for combining inclusive engineering and craft practices in the production of building materials and the implementation of architectural solutions involving local resources;

– to assess the impact of the proposed approach on the level of social integration, environmental sustainability, and economic efficiency within food service projects;

– to formulate recommendations for adapting regulatory frameworks and educational programs to disseminate principles of inclusive and craft approaches in architectural design and construction practice.

2.2 MATERIALS AND METHODS

2.2.1 MATERIALS

The study analyzed building materials that comply with the principles of the circular economy, inclusive engineering, and craft technologies, taking into account the requirements of DSTU 9191:2022 [29]. Building products were characterized by origin (organic and inorganic) and type (concretes, arbolites, fibrous, bituminous, etc.), as well as suitability for designing food service establishments in the context of Ukraine's post-war reconstruction. The thermophysical properties of the building materials were evaluated:

– density (ρ_0) – from 35 to 1000 kg/m^3;

– specific heat capacity (C) – from 0.84 to 2.3 kJ/(kg·K);

– declared thermal conductivity (λ_0) – from 0.039 to 0.16 W/(m·K);

– calculated moisture content by mass (w), for operating condition A – from 0.1 to 16%; for operating condition B – from 0.2 to 24%;

– calculated thermal conductivity (λ_d) for operating condition A – from 0.045 to 0.24 W/(m·K); for operating condition B – from 0.048 to 0.3 W/(m·K);

– calculated heat absorption coefficient (s) for operating condition A – from 0.41 to 6.75 W/(m^2·K); for operating condition B – from 0.45 to 7.7 W/(m^2·K);

– calculated vapor permeability (δ) for operating conditions A and B – from 0.002 to 0.49 mg/(m·h·Pa).

The selection of materials was based on their environmental friendliness (low carbon footprint, biodegradability), local availability, hygienic compliance (adherence to HACCP principles), as well as suitability for craft production, which promotes community involvement.

2.2.2 METHODS

The research methodology involved a comprehensive approach to assessing materials and architectural solutions for the creation of inclusive, environmentally sustainable, and safe food service establishments. A comparative analysis of the thermophysical characteristics of materials according to DSTU 9191:2022 [29] was applied to determine their effectiveness in energy-efficient structures.

The evaluation criteria included:

1) technological accessibility (ease of production, use of local resources);

2) environmental sustainability (possibility of reuse, low environmental impact);

3) social inclusivity (adaptability to the needs of vulnerable groups, including persons with disabilities and veterans);

4) economic feasibility (optimization of construction costs).

Additionally, the compliance of materials and solutions with safety and hygiene standards (HACCP) was analyzed, as well as their potential to implement local identity through ethno-design. Both quantitative methods (analysis of thermophysical parameters) and qualitative methods (comparison of architectural solutions such as zoning, barrier-free access, non-slip coatings) were used for evaluation.

2.3 RESULTS

2.3.1 PRINCIPLES OF INCLUSIVE ENGINEERING IN THE FIELD OF BUILDING MATERIALS

In the modern competitive environment, craft productions, like food service establishments, face the need to increase business efficiency to maintain their viability and adapt to social changes. Considering factors such as employee health, motivation, inclusivity, and professional skill development becomes not only socially necessary but also economically viable.

Inclusive engineering in the field of building materials involves a systematic integration that combines technical, social, and economic aspects [20] aimed at ensuring a barrier-free environment and improving the quality of working conditions.

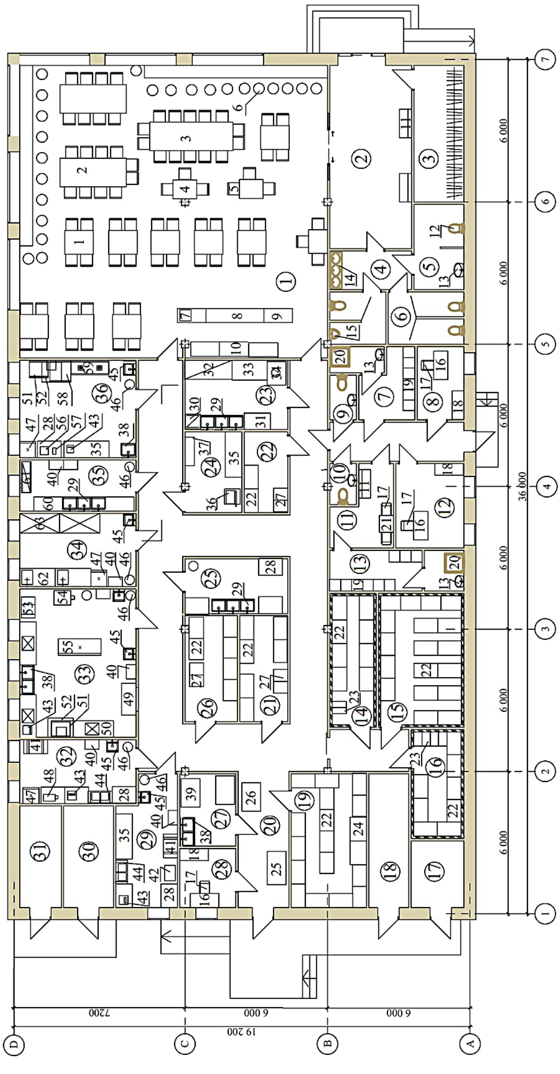
Technical aspects of implementing inclusive solutions in food establishments include architectural and planning measures (ramps with a slope of up to 8%, handrails, non-slip coverings, designated parking spaces), engineering and technical solutions (standardized ventilation and air conditioning systems, energy-efficient heating, alternative energy sources), ergonomic equipment (adjustable furniture, lifts), information tools (Braille, sound systems), and specialized premises (accessible lobbies, restrooms, cloakrooms) [20] (**Fig. 2.1**).

Social aspects include rehabilitation practices, staff motivation, ensuring inclusivity, and developing employee competencies, which together form a comprehensive model of sustainable production [20, 30–32].

Rehabilitation – one of the key aspects of the engineering approach to work organization – involves not only adapting work areas for people with disabilities but also creating conditions for the social reintegration of groups such as war veterans [32]. This includes the accessibility of the architectural environment, specialized equipment, compliance with microclimate parameters [14], and staff training to work in an inclusive environment.

Employee motivation in craft productions is closely related to corporate culture, which takes into account the social significance of work, its contribution to the community, and the personal value of the employee. This is implemented through clearly defined goals, training programs, and opportunities for professional growth [33].

Inclusivity as a strategy covers not only physical accessibility but also the creation of cultural diversity. This requires staff training in cultural and gender sensitivity, which is the basis for forming a safe and supportive environment [33]. Employee competence – another key element of the engineering approach – concerns not only technical skills but also the development of communication, organizational, and adaptive abilities necessary for work in the modern production environment [31, 33].



1 – restaurant hall; 2 – vestibule; 3 – cloakroom; 4 – restroom; 5 – restroom for persons with reduced mobility; 6 – guest restrooms; 7 – male staff cloakroom; 8 – office; 9 – male staff restrooms; 10 – female staff restrooms; 11 – staff room; 12 – director's office; 13 – female staff cloakroom; 14 – refrigerated room for meat and fish; 15 – refrigerated room for vegetables, fruits, and greens; 16 – refrigerated room for dairy, gastronomy, and eggs; 17 – exhaust ventilation room; 18 – heat station; 19 – dry goods storeroom; 20 – loading area; 21 – vegetable and root vegetable storeroom; 22 – janitorial inventory and equipment room; 23 – dishwashing area; 24 – bread slicing room; 25 – egg processing room; 26 – dry products storeroom; 27 – ware and inventory washing and storage area; 28 – storekeeper's office; 29 – vegetable processing room; 30 – electrical room; 31 – supply ventilation room; 32 – meat and fish processing room; 33 – pastry room; 34 – cold kitchen; 35 – kitchenware washing area; 36 – hot kitchen

Fig. 2.1 Floor plan at elevation 0.000 of a foodservice enterprise
Source: [20]

Finally, ensuring team stability, reducing staff turnover, and improving brand image require the implementation of long-term strategies that combine social responsibility and economic efficiency [30, 33].

The economic aspects of inclusive solutions in food service establishments involve reducing staff turnover and lowering recruitment and training costs by creating a comfortable working environment. The requirement to provide at least 5% of seats in dining areas for wheelchair users expands the customer base and increases profitability, while the possibility of receiving state support encourages the implementation of accessible solutions [20].

Thus, the principles of inclusive engineering in the field of building materials are not limited to technical aspects but also cover social, psychological, cultural, and economic parameters that form the foundation of a sustainable, safe, and "human-centered" production environment.

2.3.2 PRINCIPLES OF CRAFT TECHNOLOGIES IN THE FIELD OF BUILDING MATERIALS

In the post-war period of Ukraine's reconstruction, there is an increasing interest in the use of local natural building materials — wood, straw, clay, hemp fiber, and others. Importantly, these materials harmoniously combine environmental friendliness, locality, and the possibility of manual production — key characteristics of the craft approach that align with the ideas of the circular economy. Traditional Ukrainian structures, such as adobe and rammed clay blocks, demonstrate high adaptability and durability. Their potential for reuse, recycling, or complete biodegradation makes them ideal for sustainable construction, especially in socially oriented and rehabilitation projects of post-war recovery.

Modern scientific research highlights the relevance of bio-based composites, in particular hempcrete, which is characterized by a low carbon footprint, high thermal insulation, hygroscopicity, and biodegradability [34].

Another promising direction is wood-concrete (arbolite) — lightweight concrete based on wood chips and plant fibers with gypsum binder [35], which provides excellent thermal insulation properties. Local production based on wood waste makes this technology accessible to small communities and enterprises.

Rammed clay and adobe technologies, deeply rooted in Ukrainian architecture, are being revived today as environmentally friendly and affordable construction methods [36]. Modern developments combine traditional methods with innovative solutions, such as the use of straw blocks, "super-adobe" technology, and other natural materials. There are already modern eco-houses in Ukraine made of adobe, confirming the viability of these approaches.

A distinctive feature of using these materials is their craft nature — local raw materials, small production volumes, involvement of local communities, and the possibility of rapid implementation of innovations [35]. This not only supports the development of crafts and the local economy but also aligns with the principles of inclusive engineering. In particular, the simplicity and accessibility of producing clay or arbolite blocks make it possible to involve different social groups in construction, including people with disabilities.

In the context of post-war reconstruction, this integration of craft technologies and the principles of inclusive design is especially relevant for creating food service establishments that should be not only energy-efficient and environmentally friendly but also maximally accessible. The use of natural materials contributes to a healthy microclimate, reduces the impact of chemicals and temperature fluctuations, which is important for vulnerable population groups.

Fig. 2.2–2.10 present the calculated thermophysical characteristics of building materials – products made from natural organic and inorganic raw materials in accordance with the requirements of DSTU 9191:2022 [29]. The comparative characteristics of the thermal insulation material take into account its density (ρ); heat capacity (C); thermal conductivity (λ); moisture content by mass (w); heat absorption coefficient (s); and vapor permeability (δ) under operating conditions (A, B). According to DBN V.2.6-31:2021 [37], operating conditions A are applied to internal walls and enclosing structures in dry rooms, while B – to external walls and structures operating in normal, humid, or wet environments.

According to thermophysical properties, building products can be classified into three categories:

1) high heat capacity ($C \geq 2.0$ kJ/(kg·K));

2) medium heat capacity ($C \approx 1.0$–2.0 kJ/(kg·K));

3) low heat capacity ($C \leq 1.0$ kJ/(kg·K)).

Products with high heat capacity ($C \geq 2.0$ kJ/(kg·K)):

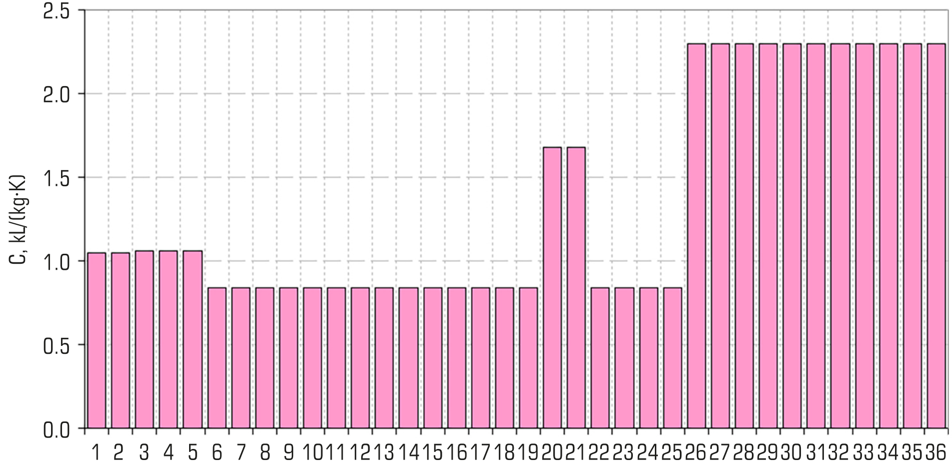
– reed thermal insulation boards – 2.3 kJ/(kg·K), characterized by high heat capacity, which ensures high heat retention ability. They are used as natural thermal insulation materials in walls, floors, and roofs, especially in environmentally oriented construction. Due to their natural composition, they have good vapor permeability, help regulate indoor humidity, and create comfortable microclimatic conditions. In addition to thermal insulation, these boards provide environmental friendliness and biodegradability, although they may require additional protection against moisture and pests. The use of reed boards is advisable in projects focused on sustainable development and natural materials;

– fiberboard and particleboard – 2.3 kJ/(kg·K), characterized by high heat capacity, suitable for interiors and internal partitions where temperature regulation without sharp fluctuations is needed. These materials have high vapor permeability, which helps maintain optimal humidity levels. Thanks to their natural composition, the boards are environmentally friendly, have good sound insulation properties, but require protection from moisture and pests. Ideal for projects emphasizing a healthy environment and energy efficiency;

– wood concrete (arbolite) products on Portland cement – 2.3 kJ/(kg·K), used for load-bearing and self-supporting walls of low-rise buildings; enclosing structures where a combination of thermal insulation and strength is important; ecological facilities (housing, public buildings, inclusive spaces) – due to natural fillers and vapor permeability; structures where smooth leveling of temperature fluctuations is needed – arbolite accumulates heat during the day and releases it at night. Arbolite works well in external walls, especially in regions with sharp daily temperature fluctuations, and in passive heating systems.

Products with high heat capacity (C ≥ 2.0 kJ/(kg·K)) effectively accumulate and release heat, ensuring a stable microclimate and comfort indoors even under significant daily temperature fluctuations, making them optimal for energy-efficient and environmentally friendly constructions.

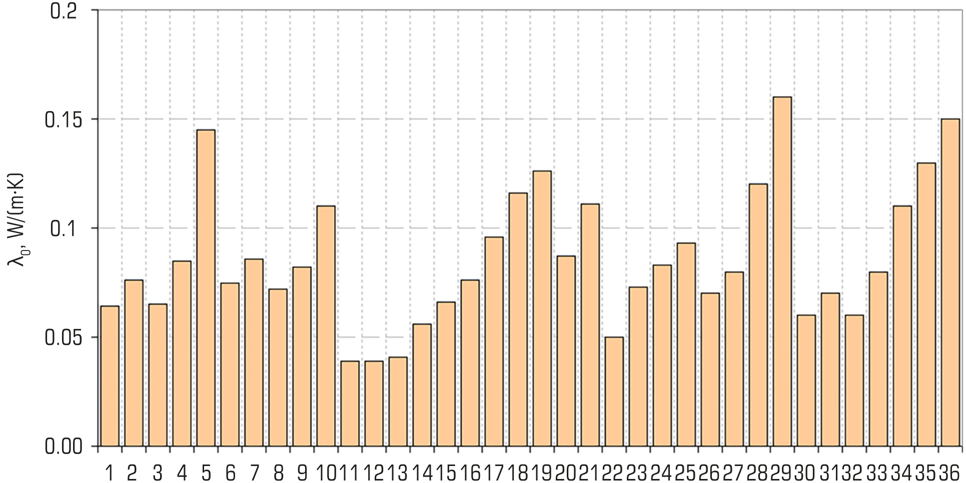
Materials with high heat capacity are especially effective in passive heating systems and in regions with a continental climate.



1 – perlite-phosphogel products (200)*; 2 – perlite-phosphogel products (300); 3 – wall polystyrene concrete blocks (200); 4 – wall polystyrene concrete blocks (300); 5 – wall polystyrene concrete blocks (600); 6 – perlite-cement and perlite-gypsum thermal insulation products (300); 7 – perlite-cement and perlite-gypsum thermal insulation products (450); 8 – perlite-bentonite thermal insulation products (250); 9 – perlite-bentonite thermal insulation products (300); 10 – perlite-bentonite thermal insulation products (400); 11 – cellulose insulation (35); 12 – cellulose insulation (50); 13 – cellulose insulation (65); 14 – cellulose insulation (100); 15 – cement-polystyrene products (250); 16 – cement-polystyrene products (300); 17 – cement-polystyrene products (400); 18 – cement-polystyrene products (500); 19 – cement-polystyrene products (550); 20 – perlite-bitumen thermal insulation products (300); 21 – perlite-bitumen thermal insulation products (400); 22 – foam glass products (120); 23 – silicate-cement blocks (300); 24 – silicate-cement blocks (400); 25 – silicate-cement blocks (500); 26 – wood concrete (arbolite) products on Portland cement (300); 27 – wood concrete (arbolite) products on Portland cement (400); 28 – wood concrete (arbolite) products on Portland cement (600); 29 – wood concrete (arbolite) products on Portland cement (800); 30 – reed thermal insulation boards (200); 31 – reed thermal insulation boards (300); 32 – fiberboard and particleboard (200); 33 – fiberboard and particleboard (400); 34 – fiberboard and particleboard (600); 35 – fiberboard and particleboard (800); 36 – fiberboard and particleboard (1000)

(material density, ρ_0, kg/m^3)

Fig. 2.2 Comparison of the heat capacity of products made from natural organic and inorganic raw materials (C, kJ/(kg•K)) depending on the density of materials (ρ_0, kg/m^3) in the dry state



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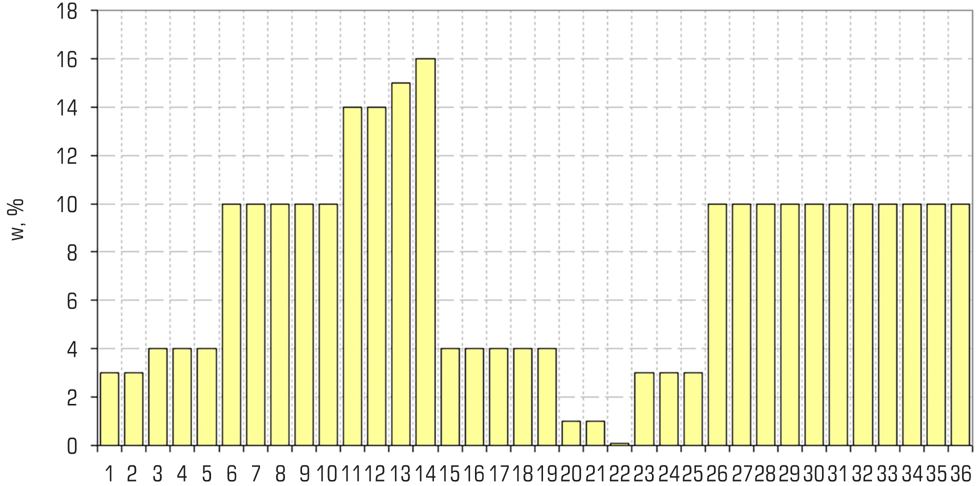
*(*material density*, ρ_0, *kg/m*^{3})

Fig. 2.3 Comparison of the declared thermal conductivity of products made from natural organic and inorganic raw materials (λ_0, W/(m•K)) depending on the density of materials (ρ_0, kg/m^3) in the dry state



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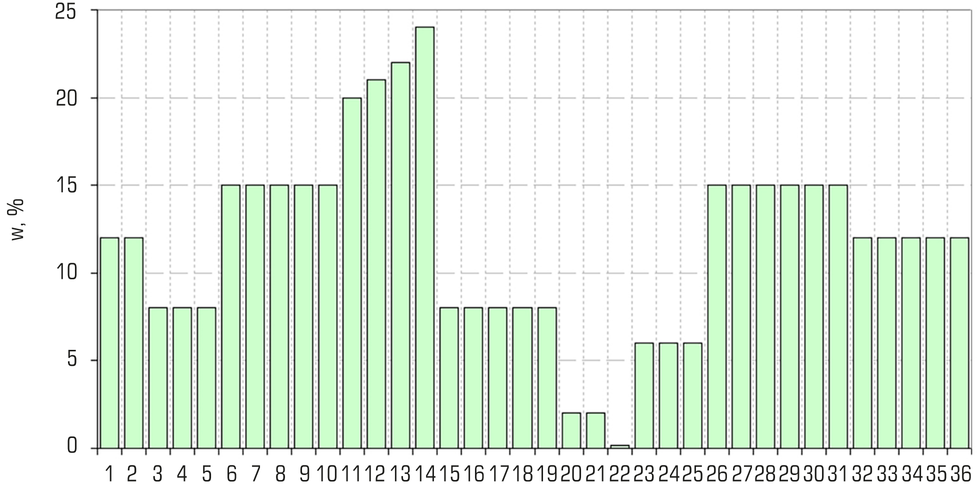
(material density, ρ_0, kg/m^3)

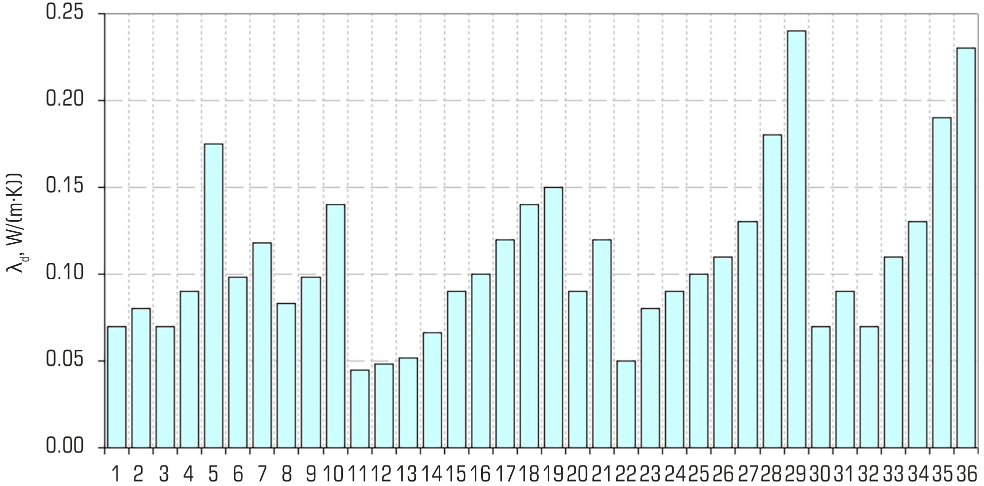
Fig. 2.4 Comparison of the calculated mass moisture content of products made from natural organic and inorganic raw materials (w, %) under service conditions (A), depending on the density of materials (ρ_0, kg/m^3)



1 – perlite-phosphogel products (200)*; 2 – perlite-phosphogel products (300); 3 – wall polystyrene concrete blocks (200); 4 – wall polystyrene concrete blocks (300); 5 – wall polystyrene concrete blocks (600); 6 – perlite-cement and perlite-gypsum thermal insulation products (300); 7 – perlite-cement and perlite-gypsum thermal insulation products (450); 8 – perlite-bentonite thermal insulation products (250); 9 – perlite-bentonite thermal insulation products (300); 10 – perlite-bentonite thermal insulation products (400); 11 – cellulose insulation (35); 12 – cellulose insulation (50); 13 – cellulose insulation (65); 14 – cellulose insulation (100); 15 – cement-polystyrene products (250); 16 – cement-polystyrene products (300); 17 – cement-polystyrene products (400); 18 – cement-polystyrene products (500); 19 – cement-polystyrene products (550); 20 – perlite-bitumen thermal insulation products (300); 21 – perlite-bitumen thermal insulation products (400); 22 – foam glass products (120); 23 – silicate-cement blocks (300); 24 – silicate-cement blocks (400); 25 – silicate-cement blocks (500); 26 – wood concrete (arbolite) products on Portland cement (300); 27 – wood concrete (arbolite) products on Portland cement (400); 28 – wood concrete (arbolite) products on Portland cement (600); 29 – wood concrete (arbolite) products on Portland cement (800); 30 – reed thermal insulation boards (200); 31 – reed thermal insulation boards (300); 32 – fiberboard and particleboard (200); 33 – fiberboard and particleboard (400); 34 – fiberboard and particleboard (600); 35 – fiberboard and particleboard (800); 36 – fiberboard and particleboard (1000)

*(*material density*, ρ_0, *kg/m*^{3})

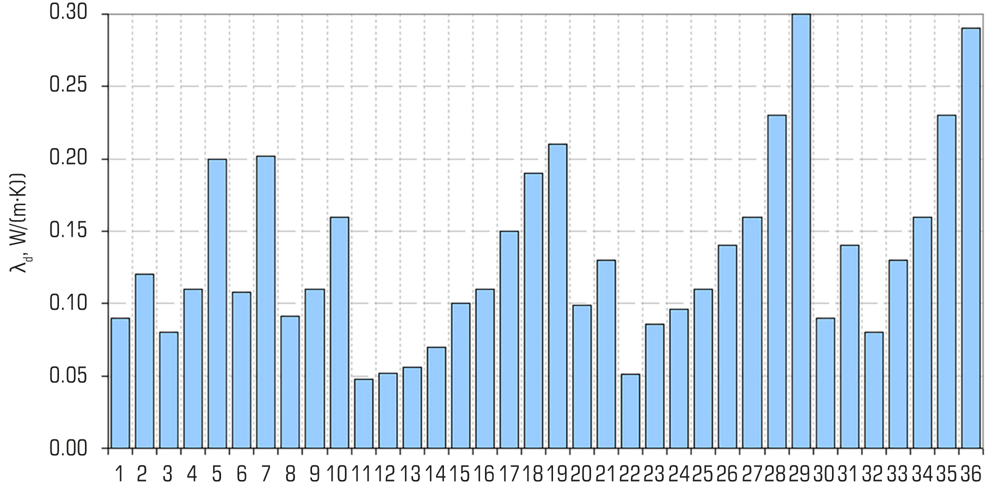
Fig. 2.5 Comparison of the calculated mass moisture content of products made from natural organic and inorganic raw materials (*w*, %) under service conditions (*B*), depending on the density of materials (ρ_0, kg/m^3)



1 – perlite-phosphogel products (200)*; 2 – perlite-phosphogel products (300); 3 – wall polystyrene concrete blocks (200); 4 – wall polystyrene concrete blocks (300); 5 – wall polystyrene concrete blocks (600); 6 – perlite-cement and perlite-gypsum thermal insulation products (300); 7 – perlite-cement and perlite-gypsum thermal insulation products (450); 8 – perlite-bentonite thermal insulation products (250); 9 – perlite-bentonite thermal insulation products (300); 10 – perlite-bentonite thermal insulation products (400); 11 – cellulose insulation (35); 12 – cellulose insulation (50); 13 – cellulose insulation (65); 14 – cellulose insulation (100); 15 – cement-polystyrene products (250); 16 – cement-polystyrene products (300); 17 – cement-polystyrene products (400); 18 – cement-polystyrene products (500); 19 – cement-polystyrene products (550); 20 – perlite-bitumen thermal insulation products (300); 21 – perlite-bitumen thermal insulation products (400); 22 – foam glass products (120); 23 – silicate-cement blocks (300); 24 – silicate-cement blocks (400); 25 – silicate-cement blocks (500); 26 – wood concrete (arbolite) products on Portland cement (300); 27 – wood concrete (arbolite) products on Portland cement (400); 28 – wood concrete (arbolite) products on Portland cement (600); 29 – wood concrete (arbolite) products on Portland cement (800); 30 – reed thermal insulation boards (200); 31 – reed thermal insulation boards (300); 32 – fiberboard and particleboard (200); 33 – fiberboard and particleboard (400); 34 – fiberboard and particleboard (600); 35 – fiberboard and particleboard (800); 36 – fiberboard and particleboard (1000)

(material density, ρ_0, kg/m³)

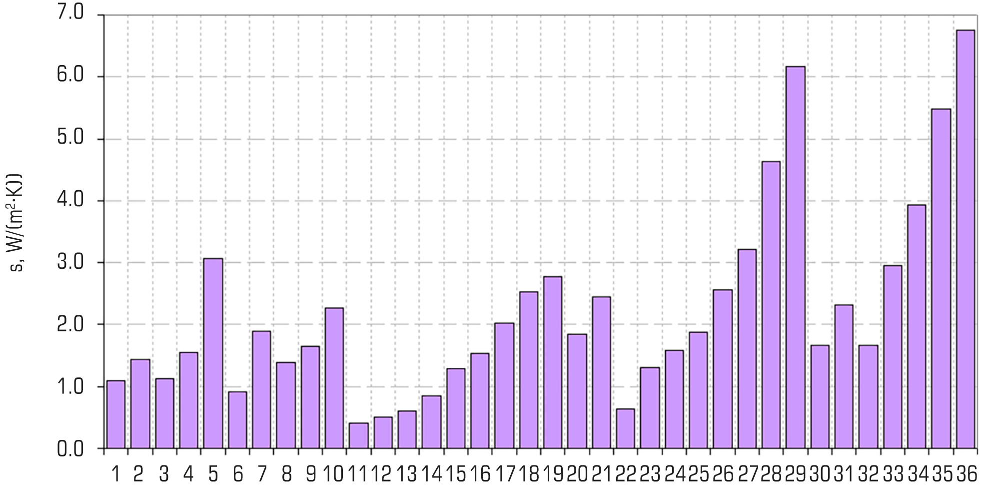
Fig. 2.6 Comparison of the calculated thermal conductivity characteristics of products made from natural organic and inorganic raw materials (λ_d, W/(m•K)) under service conditions (*A*), depending on the density of materials (ρ_0, kg/m^3)



1 – perlite-phosphogel products (200)*; 2 – perlite-phosphogel products (300); 3 – wall polystyrene concrete blocks (200); 4 – wall polystyrene concrete blocks (300); 5 – wall polystyrene concrete blocks (600); 6 – perlite-cement and perlite-gypsum thermal insulation products (300); 7 – perlite-cement and perlite-gypsum thermal insulation products (450); 8 – perlite-bentonite thermal insulation products (250); 9 – perlite-bentonite thermal insulation products (300); 10 – perlite-bentonite thermal insulation products (400); 11 – cellulose insulation (35); 12 – cellulose insulation (50); 13 – cellulose insulation (65); 14 – cellulose insulation (100); 15 – cement-polystyrene products (250); 16 – cement-polystyrene products (300); 17 – cement-polystyrene products (400); 18 – cement-polystyrene products (500); 19 – cement-polystyrene products (550); 20 – perlite-bitumen thermal insulation products (300); 21 – perlite-bitumen thermal insulation products (400); 22 – foam glass products (120); 23 – silicate-cement blocks (300); 24 – silicate-cement blocks (400); 25 – silicate-cement blocks (500); 26 – wood concrete (arbolite) products on Portland cement (300); 27 – wood concrete (arbolite) products on Portland cement (400); 28 – wood concrete (arbolite) products on Portland cement (600); 29 – wood concrete (arbolite) products on Portland cement (800); 30 – reed thermal insulation boards (200); 31 – reed thermal insulation boards (300); 32 – fiberboard and particleboard (200); 33 – fiberboard and particleboard (400); 34 – fiberboard and particleboard (600); 35 – fiberboard and particleboard (800); 36 – fiberboard and particleboard (1000)

*(*material density*, ρ_0, *kg/m*^{3})

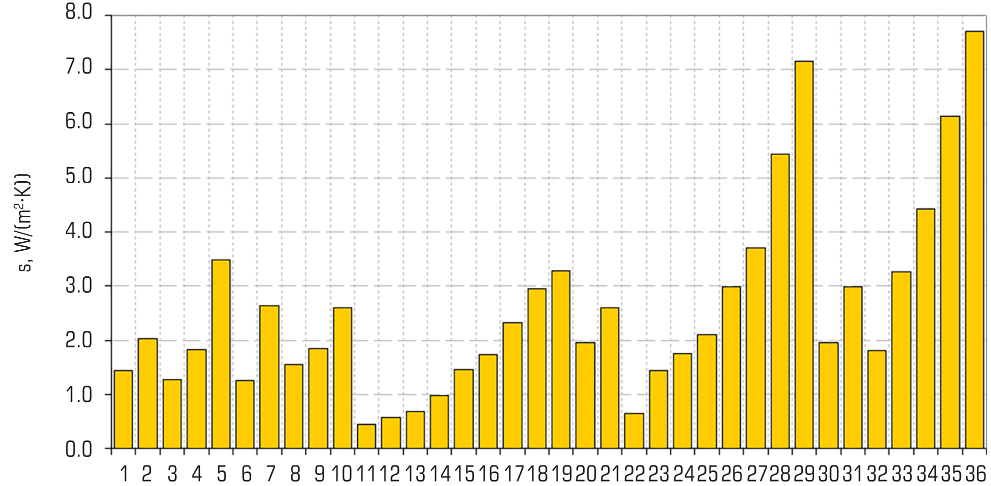
Fig. 2.7 Comparison of the calculated thermal conductivity characteristics of products made from natural organic and inorganic raw materials (λ_d, W/(m•K)) under service conditions (*B*), depending on the density of materials (ρ_0, kg/m^3)



1 – perlite-phosphogel products (200)*; 2 – perlite-phosphogel products (300); 3 – wall polystyrene concrete blocks (200); 4 – wall polystyrene concrete blocks (300); 5 – wall polystyrene concrete blocks (600); 6 – perlite-cement and perlite-gypsum thermal insulation products (300); 7 – perlite-cement and perlite-gypsum thermal insulation products (450); 8 – perlite-bentonite thermal insulation products (250); 9 – perlite-bentonite thermal insulation products (300); 10 – perlite-bentonite thermal insulation products (400); 11 – cellulose insulation (35); 12 – cellulose insulation (50); 13 – cellulose insulation (65); 14 – cellulose insulation (100); 15 – cement-polystyrene products (250); 16 – cement-polystyrene products (300); 17 – cement-polystyrene products (400); 18 – cement-polystyrene products (500); 19 – cement-polystyrene products (550); 20 – perlite-bitumen thermal insulation products (300); 21 – perlite-bitumen thermal insulation products (400); 22 – foam glass products (120); 23 – silicate-cement blocks (300); 24 – silicate-cement blocks (400); 25 – silicate-cement blocks (500); 26 – wood concrete (arbolite) products on Portland cement (300); 27 – wood concrete (arbolite) products on Portland cement (400); 28 – wood concrete (arbolite) products on Portland cement (600); 29 – wood concrete (arbolite) products on Portland cement (800); 30 – reed thermal insulation boards (200); 31 – reed thermal insulation boards (300); 32 – fiberboard and particleboard (200); 33 – fiberboard and particleboard (400); 34 – fiberboard and particleboard (600); 35 – fiberboard and particleboard (800); 36 – fiberboard and particleboard (1000)

(material density, ρ_0, kg/m^3)

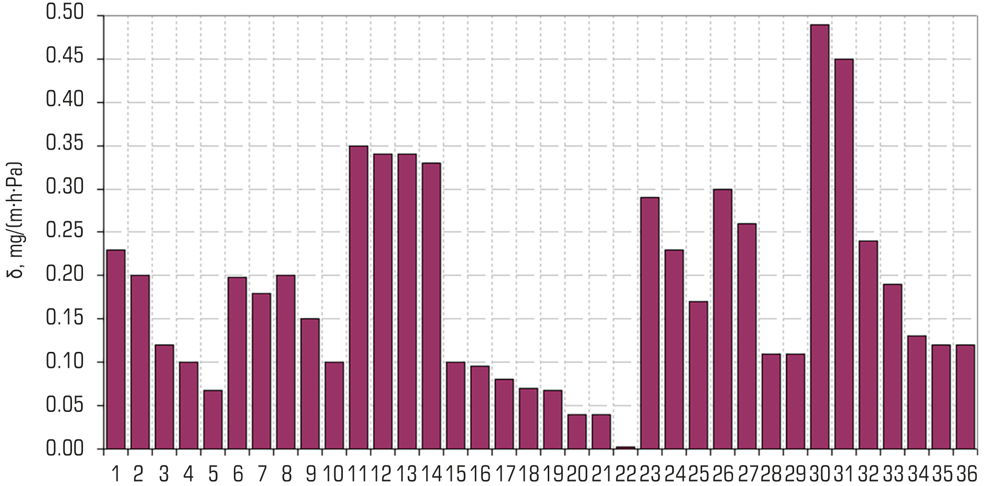
Fig. 2.8 Comparison of the calculated heat absorption coefficient characteristics of products made from natural organic and inorganic raw materials (*s*, W/(m^2•K)) under service conditions (*A*), depending on the density of materials (ρ_0, kg/m^3)



1 – perlite-phosphogel products (200)*; 2 – perlite-phosphogel products (300); 3 – wall polystyrene concrete blocks (200); 4 – wall polystyrene concrete blocks (300); 5 – wall polystyrene concrete blocks (600); 6 – perlite-cement and perlite-gypsum thermal insulation products (300); 7 – perlite-cement and perlite-gypsum thermal insulation products (450); 8 – perlite-bentonite thermal insulation products (250); 9 – perlite-bentonite thermal insulation products (300); 10 – perlite-bentonite thermal insulation products (400); 11 – cellulose insulation (35); 12 – cellulose insulation (50); 13 – cellulose insulation (65); 14 – cellulose insulation (100); 15 – cement-polystyrene products (250); 16 – cement-polystyrene products (300); 17 – cement-polystyrene products (400); 18 – cement-polystyrene products (500); 19 – cement-polystyrene products (550); 20 – perlite-bitumen thermal insulation products (300); 21 – perlite-bitumen thermal insulation products (400); 22 – foam glass products (120); 23 – silicate-cement blocks (300); 24 – silicate-cement blocks (400); 25 – silicate-cement blocks (500); 26 – wood concrete (arbolite) products on Portland cement (300); 27 – wood concrete (arbolite) products on Portland cement (400); 28 – wood concrete (arbolite) products on Portland cement (600); 29 – wood concrete (arbolite) products on Portland cement (800); 30 – reed thermal insulation boards (200); 31 – reed thermal insulation boards (300); 32 – fiberboard and particleboard (200); 33 – fiberboard and particleboard (400); 34 – fiberboard and particleboard (600); 35 – fiberboard and particleboard (800); 36 – fiberboard and particleboard (1000)

(material density, ρ_0, kg/m³)

Fig. 2.9 Comparison of the calculated heat absorption coefficient characteristics of products made from natural organic and inorganic raw materials (*s*, W/(m²•K)) under service conditions (*B*), depending on the density of materials (ρ_0, kg/m³)



1 – perlite-phosphogel products (200)*; 2 – perlite-phosphogel products (300); 3 – wall polystyrene concrete blocks (200); 4 – wall polystyrene concrete blocks (300); 5 – wall polystyrene concrete blocks (600); 6 – perlite-cement and perlite-gypsum thermal insulation products (300); 7 – perlite-cement and perlite-gypsum thermal insulation products (450); 8 – perlite-bentonite thermal insulation products (250); 9 – perlite-bentonite thermal insulation products (300); 10 – perlite-bentonite thermal insulation products (400); 11 – cellulose insulation (35); 12 – cellulose insulation (50); 13 – cellulose insulation (65); 14 – cellulose insulation (100); 15 – cement-polystyrene products (250); 16 – cement-polystyrene products (300); 17 – cement-polystyrene products (400); 18 – cement-polystyrene products (500); 19 – cement-polystyrene products (550); 20 – perlite-bitumen thermal insulation products (300); 21 – perlite-bitumen thermal insulation products (400); 22 – foam glass products (120); 23 – silicate-cement blocks (300); 24 – silicate-cement blocks (400); 25 – silicate-cement blocks (500); 26 – wood concrete (arbolite) products on Portland cement (300); 27 – wood concrete (arbolite) products on Portland cement (400); 28 – wood concrete (arbolite) products on Portland cement (600); 29 – wood concrete (arbolite) products on Portland cement (800); 30 – reed thermal insulation boards (200); 31 – reed thermal insulation boards (300); 32 – fiberboard and particleboard (200); 33 – fiberboard and particleboard (400); 34 – fiberboard and particleboard (600); 35 – fiberboard and particleboard (800); 36 – fiberboard and particleboard (1000)

**(material density, ρ_0, kg/m^3)*

Fig. 2.10 Comparison of the calculated vapor permeability characteristics of products made from natural organic and inorganic raw materials (δ, mg/(m•h•Pa)) under service conditions (*A*, *B*), depending on the density of materials (ρ_0, kg/m^3)

Products with medium heat capacity ($C \approx 1.0–2.0$ kJ/(kg·K)):

– perlite-bitumen insulation products – 1.68 kJ/(kg·K), characterized by medium thermal inertia. They are used as lightweight insulation layers in roofs, floors, and walls; in constructions where minimal weight with sufficient insulation is required; in systems that do not demand significant heat accumulation, such as for rapid heating and cooling of rooms; and in combination with more massive materials to balance insulation and inertia. They are moisture-resistant and biologically durable, but due to bitumen content, they are less eco-friendly and vapor-impermeable, which limits their use in inclusive spaces with higher microclimate demands;

– polystyrene concrete wall blocks – 1.06 kJ/(kg·K), have moderate heat accumulation ability. Thanks to this combined with low density and thermal conductivity, they effectively reduce heat loss but respond quickly to temperature changes. Such blocks are applied in quick-assembly and lightweight wall constructions, especially in post-war recovery conditions, combined with materials of higher thermal inertia to ensure stable indoor microclimate;

– perlite-phosphogel products – 1.05 kJ/(kg·K), possess moderate heat storage capacity. This, combined with low density and thermal conductivity, makes them effective insulation materials that significantly reduce heat loss in enclosing structures. They are typically used for insulating walls, roofs, and floors, particularly in buildings where structural lightness and good energy-saving properties are important.

Products with medium heat capacity ($C \approx 1.0–2.0$ kJ/(kg·K)) provide a balance between insulation properties and rapid response to temperature changes, making them suitable for lightweight and fast-assembly constructions, but requiring combination with more massive layers for stable microclimate.

Products with low heat capacity ($C \leq 1.0$ kJ/(kg·K)):

– perlite-cement and perlite-gypsum insulation products (0.84 kJ/(kg·K)) – have low heat capacity, indicating a limited ability to accumulate heat. They are used as effective lightweight thermal insulation materials in walls, floors, and roofs of buildings. They combine well with other more massive structural elements, reducing heat loss. They are characterized by vapor permeability, which contributes to humidity regulation and maintaining microclimatic conditions indoors. They are more environmentally friendly due to their natural components;

– perlite-bentonite thermal insulation products (0.84 kJ/(kg·K)) – characterized by low heat capacity and increased strength due to the inclusion of bentonite. They are used as lightweight thermal insulation layers in wall and roof structures where thermal insulation and shape stability are important. They provide adequate vapor permeability and moisture resistance. They contribute to creating a comfortable microclimate by regulating humidity;

– cellulose insulation (0.84 kJ/(kg·K)) – an eco-friendly insulation material made from recycled cellulose with low heat capacity, providing minimal heat accumulation and rapid temperature changes. They are widely used for insulating walls, roofs, and floors. They have high vapor permeability and "breathability", making it optimal for inclusive and ecological projects and requires additional treatment for moisture and pest protection;

– cement-polystyrene products (0.84 kJ/(kg·K)) – lightweight thermal insulation materials combining the insulating properties of expanded polystyrene with the strength of cement binder. Low heat capacity causes rapid temperature changes in the material, suitable for constructions with minimal thermal inertia.

They are used in external walls, floors, and facades. They have relatively low vapor permeability, which may require additional measures to maintain microclimate;

— foam glass products (0.84 kJ/(kg·K)) — thermal insulation materials based on foamed glass with low heat capacity, providing lightness and low thermal inertia. They are used in roofs, foundation insulation, and external walls and characterized by high moisture resistance and chemical inertness, making them durable. Relatively high cost and brittleness limit their widespread use;

— silica-cement blocks (0.84 kJ/(kg·K)) — building materials with reduced heat capacity, providing low thermal inertia. They are used in load-bearing and self-supporting wall structures with additional insulation. They maintain shape well and resist moisture exposure. Vapor permeability is moderate, allowing use in various climatic conditions.

Materials with heat capacity ≤ 1.0 kJ/(kg·K) are typically characterized by low thermal storage capacity, making them effective lightweight thermal insulators for rapid temperature regulation of indoor spaces. They are widely used in external enclosing structures, roofs, and floors, providing reduction of heat losses. At the same time, they vary in vapor permeability, strength, and environmental properties, which influences the choice of material depending on the specific project requirements, especially in the context of inclusive and sustainable construction.

Craft technologies allow the production of materials from natural, local components, ensuring not only ecological compatibility but also optimal thermophysical properties. Materials with high heat capacity, produced using craft methods, are used in heavy external structures for heat accumulation and stabilization of indoor microclimate. Medium heat capacity products serve as intermediate layers where a balance between heat storage and rapid heat release is required, contributing to a comfortable temperature regime. Lightweight materials with low heat capacity, made from natural components by craft technologies, are used in internal insulation layers for quick response to temperature changes, providing dynamic thermal regulation.

Thus, the integration of craft production principles with consideration of materials' heat capacity enables the creation of adaptive, ecological, and energy-efficient building structures that meet the requirements of inclusivity and sustainable development in the post-war reconstruction of Ukraine.

The lowest declared thermal conductivity values (λ_0) are observed for: cellulose insulation (ρ_0 35–100 kg/m^3) — λ_0 = 0.039–0.056 W/(m·K); foam glass products (ρ_0 120 kg/m^3) — λ_0 = 0.05 W/(m·K); reed insulation boards (ρ_0 200 kg/m^3) and wood fiber and wood chip boards (ρ_0 200 kg/m^3) — λ_0 = 0.060 W/(m·K). These materials best retain heat, making them effective thermal insulators at relatively small thicknesses.

The highest vapor permeability is found in reed insulation boards (ρ_0 200 kg/m^3) — δ = 0.49 mg/(m·h·Pa). In contrast, foam glass products (ρ_0 120 kg/m^3) have extremely low vapor permeability (δ = 0.002 mg/(m·h·Pa)), acting as a vapor barrier. Materials with a low heat absorption coefficient, such as cellulose insulation (ρ_0 35–100 kg/m^3) — s = 0.41–0.97 W/(m^2·K) — are suitable for interior partitions. A high heat absorption coefficient is characteristic of wood fiber and wood chip boards (ρ_0 1000 kg/m^3) — s = 7.7 W/(m^2·K) (under service condition B) — used for external or massive structures.

Craft thermal insulation materials based on arbolite, reed, cellulose, and wood are suitable for ecological construction and have: low thermal conductivity, good vapor permeability, moderate density, and comply with sustainable building principles:

– provide natural thermoregulation, reducing the need for heating and air conditioning;

– possess hygienic properties if properly treated (vacuum impregnation, natural antiseptics based on essential oils);

– have a low carbon footprint and promote biodegradation after the end of their life cycle;

– allow significant construction cost reduction due to local availability and ease of use.

The Ukrainian experience closely aligns with international trends in sustainable construction and is widely applied in Europe and North America in accordance with ecological standards and other decarbonization programs [34]. Although Ukrainian developments are still at early stages of commercialization, they have high potential and can significantly influence the formation of a new building culture that combines ecology, social justice, and local identity.

2.3.3 COMPREHENSIVE ASSESSMENT OF BUILDING MATERIALS QUALITY

The comprehensive assessment of building materials quality (K_0, points) was determined according to four key criteria (**Table 2.1**):

– thermal protection – based on the calculated thermal conductivity of materials λ_d (W/m·K);

– inclusiveness – evaluated through the vapor permeability of materials δ (mg/m·h·Pa);

– environmental performance – assessed by the natural origin, biodegradability, and chemical safety of materials;

– local availability – defined by the possibility of producing the material locally without the need for import.

Thermal protection of materials was assessed using a five-point scale according to the following values of thermal conductivity λ_d (W/m·K):

5 points – $\lambda_d < 0.08$, very good (excellent) thermal protection;

4 points – λ_d 0.08–0.15, good thermal protection;

3 points – λ_d 0.15–0.20, moderate thermal protection;

2 points – λ_d 0.20–0.25, poor thermal protection;

1 point – $\lambda_d > 0.25$, very poor thermal protection.

Thermal protection of materials makes it possible to evaluate their ability to retain heat and reduce energy consumption for building heating.

Inclusiveness of materials was assessed using a five-point scale according to the following values of vapor permeability δ (mg/m·h·Pa):

5 points – $\delta \geq 0.20$, very good (excellent) inclusiveness;

4 points – δ 0.15–0.20, good inclusiveness;

3 points – δ 0.10–0.15, moderate inclusiveness;

2 points – δ 0.05–0.10, poor inclusiveness;

1 point – $\delta < 0.05$, very poor inclusiveness.

The inclusiveness of materials directly influences indoor comfort and safety by regulating the microclimate and preventing condensation.

Table 2.1 Comprehensive assessment of the quality of building materials based on the criteria of thermal protection, inclusivity, environmental sustainability, and local availability

No.	Material name	Thermal protection, points	Inclusivity, points	Environmental sustainability, points	Local availability, points	Comprehensive quality assessment of building materials, points	Comprehensive ranking
1	2	3	4	5	6	7	8
1	Perlite – phosphogel products (200)	5	5	3	3	4.00	12
2	Perlite – phosphogel products (300)	4	4	3	3	3.50	18
3	Polystyrene concrete wall blocks (200)	5	3	2	2	3.00	25
4	Polystyrene concrete wall blocks (300)	4	3	2	2	2.75	27
5	Polystyrene concrete wall blocks (600)	3	2	2	2	2.25	36
6	Perlite – cement and perlite – gypsum thermal insulation products (300)	4	4	3	3	3.50	19
7	Perlite – cement and perlite – gypsum thermal insulation products (450)	4	4	3	3	3.50	20
8	Perlite – bentonite thermal insulation products (250)	4	4	3	3	3.50	21
9	Perlite – bentonite thermal insulation products (300)	4	3	3	3	3.25	24
10	Perlite-bentonite thermal insulation products (400)	4	2	3	3	3.00	26
11	Cellulose insulation (35)	5	5	5	5	5.00	1
12	Cellulose insulation (50)	5	5	5	5	5.00	2
13	Cellulose insulation (65)	5	5	5	5	5.00	3
14	Cellulose insulation (100)	5	5	5	5	5.00	4
15	Cement – polystyrene products (250)	4	2	2	2	2.50	32
16	Cement – polystyrene products (300)	4	3	2	2	2.75	28
17	Cement – polystyrene products (400)	4	2	2	2	2.50	33
18	Cement – polystyrene products (500)	4	2	2	2	2.50	34
19	Cement – polystyrene products (550)	4	2	2	2	2.50	35
20	Perlite – bitumen thermal insulation products (300)	4	1	3	3	2.75	29
21	Perlite – bitumen thermal insulation products (400)	4	1	3	3	2.75	30

Continuation of Table 1

1	2	3	4	5	6	7	8
22	Foam glass products (120)	5	1	3	2	2.75	31
23	Silicate – cement blocks (300)	4	5	3	3	3.75	14
24	Silicate – cement blocks (400)	4	5	3	3	3.75	15
25	Silicate – cement blocks (500)	4	4	3	3	3.50	22
26	Wood concrete (arbolite) products on Portland cement (300)	4	5	4	5	4.50	8
27	Wood concrete (arbolite) products on Portland cement (400)	4	5	4	5	4.50	9
28	Wood concrete (arbolite) products on Portland cement (600)	3	3	4	5	3.75	16
29	Wood concrete (arbolite) products on Portland cement (800)	2	3	4	5	3.50	23
30	Reed thermal insulation boards (200)	5	5	5	5	5.00	5
31	Reed thermal insulation boards (300)	4	5	5	5	4.75	7
32	Wood fiber and particle boards (200)	5	5	5	5	5.00	6
33	Wood fiber and particle boards (400)	4	4	5	5	4.50	10
34	Wood fiber and particle boards (600)	4	3	5	5	4.25	11
35	Wood fiber and particle boards (800)	3	3	5	5	4.00	13
36	Wood fiber and particle boards (1000)	2	3	5	5	3.75	17

Environmental friendliness of materials was assessed using a five-point scale according to the following criteria:

5 points – natural, biodegradable materials (wood, reed, cellulose);

4 points – natural materials with cement additives or minimally processed (arbolite);

3 points – mineral, conditionally ecological materials (perlite, mineral boards, foam glass);

2 points – synthetic materials with limited recyclability (polystyrene concrete, cement – polystyrene composites);

1 point – chemically treated materials.

Local availability of materials was assessed using a five-point scale according to the following criteria:

5 points – easily manufactured in a craft-based manner from local raw materials;

4 points – local raw materials but requiring factory production;

3 points – requiring industrial-scale production;

2 points — demanding specialized industry;

1 point — imported materials.

For each material, the arithmetic mean score across all four criteria was calculated, providing a comprehensive rating of the material's suitability for use in inclusive and energy-efficient building structures.

The summarized results of the comprehensive material quality assessment (**Fig. 2.11**) demonstrated that the highest scores across all criteria were achieved by cellulose insulation, reed-based thermal insulation boards, and wood-fiber materials. Their overall scores (5.00 and 4.75–5.00) indicate excellent thermal insulation properties, high environmental friendliness and inclusivity, as well as the availability of local raw materials. Such materials exemplify a balanced approach to creating modern building structures that not only reduce energy consumption but also contribute to the formation of barrier-free environments through ecological safety and adaptability to the needs of diverse users. The high ranking of arbolite products based on Portland cement further confirms the potential of combining traditional and natural components to ensure comprehensive sustainability.

At the same time, a number of materials, such as high-density polystyrene concrete blocks, cement-polystyrene products, and foam glass, received significantly lower scores (2.25–2.75). This indicates limited inclusivity and environmental friendliness, despite satisfactory thermal insulation properties.

Perlite-bitumen and perlite-bentonite materials demonstrated average results, highlighting the need for further modernization and adaptation to contemporary requirements. Thus, the analysis confirmed that priority in designing inclusive and sustainable environments should be given to materials derived from natural and renewable resources, whereas traditional synthetic or high-tech solutions require additional improvements to meet the criteria of accessibility and ecological safety.

2.3.4 INCLUSIVE ENGINEERING AND ACCESSIBILITY ARCHITECTURE IN FOOD SERVICE SPACES

Creating accessible, safe, and inclusive environments in food service establishments must consider the diverse needs of consumers, including people with disabilities, veterans, elderly individuals, parents with young children, as well as those with sensory or cognitive differences.

Principles of inclusive engineering involve designing spaces that do not require users to adapt but rather adapt to diverse functional needs. Key solutions include:

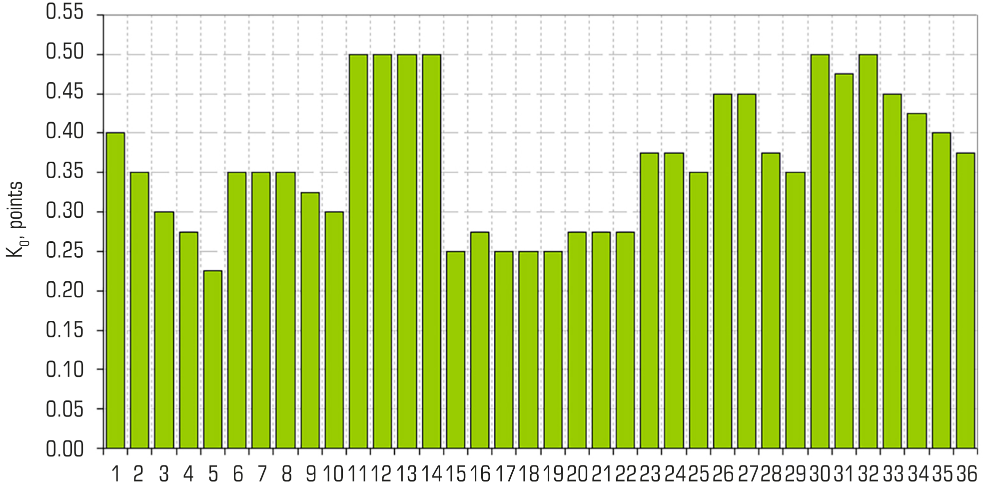
— barrier-free access to the building: ramps with non-slip surfaces, automatic doors, sufficiently wide entrances and corridors;

— navigational orientation within the interior: use of tactile, visual, and auditory landmarks, contrasting zone markings;

— ergonomic functional zones: height-adjustable tables, adapted restrooms, accessible bar counters and reception areas;

— reduction of sensory overload: subdued lighting, natural colors, low-contrast textures, sound insulation, softened acoustic background — essential for people with post-traumatic stress disorder or hypersensitivity.

An important component of inclusive spaces is architectural zoning: avoiding "blind spots", clearly



1 – perlite-phosphogel products (200)*; 2 – perlite-phosphogel products (300); 3 – wall polystyrene concrete blocks (200); 4 – wall polystyrene concrete blocks (300); 5 – wall polystyrene concrete blocks (600); 6 – perlite-cement and perlite-gypsum thermal insulation products (300); 7 – perlite-cement and perlite-gypsum thermal insulation products (450); 8 – perlite-bentonite thermal insulation products (250); 9 – perlite-bentonite thermal insulation products (300); 10 – perlite-bentonite thermal insulation products (400); 11 – cellulose insulation (35); 12 – cellulose insulation (50); 13 – cellulose insulation (65); 14 – cellulose insulation (100); 15 – cement-polystyrene products (250); 16 – cement-polystyrene products (300); 17 – cement-polystyrene products (400); 18 – cement-polystyrene products (500); 19 – cement-polystyrene products (550); 20 – perlite-bitumen thermal insulation products (300); 21 – perlite-bitumen thermal insulation products (400); 22 – foam glass products (120); 23 – silicate-cement blocks (300); 24 – silicate-cement blocks (400); 25 – silicate-cement blocks (500); 26 – wood concrete (arbolite) products on Portland cement (300); 27 – wood concrete (arbolite) products on Portland cement (400); 28 – wood concrete (arbolite) products on Portland cement (600); 29 – wood concrete (arbolite) products on Portland cement (800); 30 – reed thermal insulation boards (200); 31 – reed thermal insulation boards (300); 32 – fiberboard and particleboard (200); 33 – fiberboard and particleboard (400); 34 – fiberboard and particleboard (600); 35 – fiberboard and particleboard (800); 36 – fiberboard and particleboard (1000)

*(*material density*, ρ_0, *kg/m³*)

Fig. 2.11 Comprehensive quality assessment of products made from natural organic and inorganic raw materials (K_0, points) under operating conditions (A, B) depending on material density (ρ_0, kg/m^3)

separating staff and visitor flows, and providing quiet areas that allow for emotional comfort restoration.

Inclusivity must be integrated at all stages of design — from urban planning to interior design.

The interior can serve not only decorative but also navigational functions. Natural finishing materials — wood, textiles, ceramics — can include tactile markers or be visually contrasting to facilitate navigation. For example, embossed wooden panels or patterned clay tiles serve not only as aesthetic but also functional accessibility elements. This also emphasizes the establishment's local identity, combining inclusivity with cultural heritage.

Restrooms, kitchens, and other technical rooms must be hygienically safe and adapted to the needs of all staff and visitors. Surfaces should be non-slip, antibacterial, fire-resistant, and easy to clean. The use of non-toxic paints, varnishes, and sealants ensures compliance with food safety standards and HACCP requirements.

The inclusive approach to designing food service establishments fulfills not only a technical role but also a social integrative function. Facilities that consider the needs of people with limited mobility become spaces for rehabilitation, autonomy, and social interaction. This is especially relevant for veterans, individuals with musculoskeletal disorders, sensory impairments, or psycho-emotional traumas.

Craft technologies are gaining particular importance as a tool for integrating local knowledge, resources, and cultural practices. In the sphere of public catering establishments, they perform a dual function: on one hand — an aesthetic and identificational role (through reflecting regional style), and on the other — an ecological and functional role (thanks to the use of natural materials with a low environmental footprint).

Craft approaches allow architectural and construction solutions to be adapted to the local climate, cultural context, and the needs of specific communities. Such technologies contribute to reducing energy consumption, supporting local production, and restoring the authentic character of the environment.

Craft technologies fit within the logic of the circular economy, where key roles are played by resource renewability, material durability, and closed-loop models. Building materials produced by craft methods possess high reparability and the ability to be reused or recycled with minimal environmental impact.

The use of materials based on arbolite, reed, cellulose, and wood ensures natural regulation of humidity and temperature indoors, which is critically important in food service spaces. These solutions also promote energy saving by reducing the need for technical climate control systems. Wood, handmade clay tiles, reed panels, or textiles made of natural fibers not only serve decorative purposes but also emphasize the ethnocultural uniqueness of the region.

The practice of restoring facades and interiors of cafes and restaurants using natural materials is actively developing in Ukraine. In particular, the use of locally sourced wood species, clay (saman), and straw insulation demonstrates a successful synergy of traditions and modern engineering solutions. These approaches not only reduce construction costs but also support local employment and create opportunities for social entrepreneurship based on artisanal work.

Thus, craft technologies in the architecture of food service establishments act as a tool for socio-ecological transformation, combining sustainability, authenticity, functionality, and community involvement in the restoration process.

2.3.5 QUALITY AND SAFETY: SPATIAL AND TECHNOLOGICAL SOLUTIONS

Ensuring quality and safety are fundamental requirements for the operation of public catering establishments, especially in the context of post-war reconstruction. Increased sanitary and hygienic risks [7, 8, 14], resource shortages, and the need for rapid adaptation of the built environment demand a comprehensive approach to designing engineering and architectural solutions. In this context, the integration of HACCP principles [7, 8, 38–40], quality management systems [6, 7, 15], and inclusive engineering [9–12] forms the foundation for creating a reliable, safe, and sustainable food environment.

The quality of a facility's physical environment is determined not only by comfort and aesthetics but primarily by the conformity of functional zoning and technological processes to safety standards. The main criteria for spatial quality include:

– rational functional zoning, involving clear separation of "clean" and "dirty" zones, sequential arrangement of technological process stages: raw material reception, storage, preparation, thermal processing, serving of finished products, dishwashing, etc.;

– adherence to HACCP principles, particularly avoiding cross-flow of raw materials, finished products, waste, and personnel, reducing the risk of microbiological contamination;

– microclimate control – temperature, humidity, ventilation, and lighting levels according to hygienic norms and food safety standards;

– use of hygienic finishing materials – moisture-resistant, heat-resistant, non-toxic, smooth-textured, easy to clean and disinfect.

Thus, a quality environment in a food service facility is shaped at the intersection of spatial logic, engineering design, and sanitary-hygienic control standards.

Within an inclusive approach, it is important to adapt the food space not only to technological requirements but also to the needs of vulnerable users – persons with disabilities, veterans, elderly people, and workers with limited mobility.

Engineering adaptation not only reduces risks of injury and overload but also creates a space of social support that promotes rehabilitation and employment of vulnerable groups.

In the context of safety regarding building structures and finishes, the choice of materials plays a crucial role, directly affecting hygiene and sanitary safety of premises. Key requirements for materials include:

– biological safety – resistance to mold formation, fungi, and parasite colonization;

– chemical neutrality – absence of volatile toxic substances, formaldehydes, phthalates, hazardous dyes, and sealants;

– heat and moisture resistance – the ability to maintain physico-chemical properties under exposure to high temperatures and moisture, especially critical for kitchens and sanitary facilities;

– compliance with food safety standards set forth in normative legal documents and other industry regulations.

The use of tested, environmentally safe, and certified materials is a prerequisite for forming a sustainable, safe environment that meets HACCP requirements and quality management system principles.

CONCLUSIONS

The conducted analysis demonstrates that post-war reconstruction in Ukraine requires the creation of accessible environments for persons with disabilities, veterans, and internally displaced persons. Inclusive engineering involves adapting public catering spaces through barrier-free access (ramps, wide aisles), ergonomic furniture, contrast lighting, and reducing sensory overload for individuals with post-traumatic stress disorder or sensory impairments. These solutions promote social integration and rehabilitation of vulnerable groups.

Craft technologies based on local materials are effective tools for implementing circular economy principles. They ensure resource reuse, reduce carbon footprint, and support local communities. The use of traditional materials (such as adobe and reed panels) emphasizes local identity, fostering the creation of authentic spaces with ethnodesign elements.

A proposed integration methodology includes the use of eco-friendly materials with high heat capacity (e.g., arbolite, reed panels) for stable microclimate and low thermal conductivity materials (cellulose insulation, foam glass) for thermal insulation. Architectural solutions involve zoning, hygienic coatings, and adaptive elements that comply with HACCP standards and meet the needs of vulnerable groups.

The combination of inclusive engineering and craft technologies enhances social integration through accessible spaces, ecological sustainability by reducing resource consumption, and economic efficiency through local production. This creates a comfortable and safe environment that supports rehabilitation and social cohesion.

To promote the principles of inclusive and craft approaches, it is necessary to consider accessibility and environmental requirements and develop new academic disciplines within bachelor's, master's, and PhD educational programs that address circular economy, craft technologies, and inclusive design.

These conclusions confirm that integrating inclusive engineering and craft technologies shapes sustainable, safe, and culturally significant spaces in public catering establishments, contributing to Ukraine's recovery.

CONFLICT OF INTEREST

There is no conflict of interest. The authors declare that they have no financial, academic, personal or other conflicts of interest that could influence the content, results or interpretation of this study.

USE OF ARTIFICIAL INTELLIGENCE

The authors of this study state that AI tools were not used as a replacement for critical thinking, expertise, and human evaluation.

During the preparation of this work, the authors used Chat GPT (Chat GPT 5.1) for purely mechanical work, editorial assistance: stylistic improvement, grammar, spelling, and translation of sources/references.

The authors carried out a full check of all materials obtained with the participation of AI by: comparing each fragment with primary sources and current scientific literature; manually clarifying terms, definitions, and content in accordance with the research methodology; verifying statistical data, facts, international examples, and regulatory references; ensuring compliance with academic standards, research logic, and the requirements of the target publication. The use of AI tools did not affect the scientific results, empirical conclusions, statistical models, and research position of the authors. All key findings, conceptual models, methodological positions and recommendations of the study are formulated solely by the authors and reflect their own scientific position. After using this tool/service, the authors reviewed and edited the content of the work and bear full responsibility for the content of the published article.

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