Parametric wooden installations in urban architecture

K.Kasulu[1], O.V. Volichenko[2]

[1]Peoples' friendship university of Russia
[2]Moscow state university of civil engineering
(National research university)

Abstract: The article explores parametric wooden installations to reimagine public architecture by combining the natural properties of wood with computational strategies. It explores how iterative modelling, digital fabrication and user-centric awareness reveal aesthetic and structural possibilities in open or semi-public spaces. A qualitative approach that combines experimental design, prototypes, and field feedback shows that it effectively creates interactive forms, optimises material use, and promotes community participation. While environmental factors and cultural ideas influence longevity, the results highlighted by the ZCB bamboo pavilion are an example of how digital workflows are adapted to sustainability, craft traditions and changing needs, ultimately confirming the promise of these structures to architects, policymakers and communities.

Key words: parametric design, urban architecture, wooden installations, prototypes, digital fabrication, zcb bamboo pavilion, sustainability, digital form, lightweight, innovation.

Introduction

Parametric design has garnered attention in contemporary architectural discourse due to its ability to produce complex geometric shapes and its flexibility in different materials and contexts. Over the past decade, architects and researchers have begun to apply parametric approaches to wood, a resource that has long been celebrated for its sustainability, renewability and inherent aesthetic qualities [1, 287-300, 2]. This growing scientific interest is associated with a broader transition to digital fabrication and computing methods, as developers use data-driven algorithms and methods to improve hardware efficiency, structural efficiency and user interaction [3]. In urban architecture, wooden installations designed through parametric approaches are an attractive component because they represent both artistic sculptures and functional solutions that promote public participation.

Wooden installations in public spaces, from public squares to building lobbies, have gained popularity for their aesthetic appeal, interactive capabilities and environmentally friendly underpinnings [5]. From an aesthetic point of view, parametric wooden structures contribute to a harmonious combination of light and form, creating a creative atmosphere that can attract viewers. In addition, such compositions often contribute to public participation, in which people can lean on them, walk under them or simply appreciate their organic complexity. These tactile and visual characteristics contributed to public participation and forced architects to overcome difficulties associated with fabrication restrictions and design prospects. Numerous discussions in regard to wood's flexibility and the visual warmth it provides to reinterpret traditional pavilion designs into interactive, community-oriented installations foster dialogue between the natural landscape and digital design.

Despite the excitement of these projects, systematic research on how parametric wooden installations form a general perception of the atmospheric environment is still insufficient. Therefore, this article looks at the interactions between form, features and user responses. Drawing on a case study of the ZCB Bamboo Pavilion in Hong Kong, designed initially through collaborative efforts between the Chinese University of Hong Kong and the Zero Carbon Building (ZCB) program, the discussion sheds light on how parametric principles can be adapted to wood, bamboo, or hybrid timber materials in public contexts [5, p.15]. The pavilion's open-air design demonstrates how computational design, detailed structural analysis, and construction techniques can be combined with environmental information to provide an amazing but beautiful installation that attracts visitors and addresses sustainability goals.

This article examines how simple parametric wooden prototypes positioned in open or semi-public domains perform in terms of structural integrity, user interaction, and aesthetic expression. By referencing the ZCB Bamboo Pavilion as a benchmark, the research evaluates how digital workflows translate into physical outcomes [8], investigates public engagement and perception, and pinpoints key observations that can refine future parametric applications in timber and bamboo [2]. Through these lenses, research highlights how environmental performance, ease of construction and maintenance focus on iterative feedback loop information and integrate computational design with practical ideas derived from real-world prototypes.

The article underscores parametric wooden structures' community and civic engagement potential by narrowing its scope to public pavilions, park installations, and lobby sculptures. Installations face challenges related to weather resistance and safety which designers address by placing them in locations with changing environmental conditions and frequent public use [5]. Through evaluation of prototypes in authentic environments, architects strengthen the connection between building innovation and material choices alongside community interactions. The combination of computational methods with real-world design elements enables the creation of public spaces that are both meaningful and dynamic.

A selection of built projects and experimental prototypes underscores the feasibility and impact of parametric wooden installations. From large-scale cultural pavilions (e.g., the ZCB Bamboo Pavilion and ICD/ITKE Research Pavilions) to more minor sculptural explorations, these examples illuminate how designers address structural integrity, user interaction, and environmental performance [8]. Some have leveraged intricate joinery systems to achieve lightweight, self-supporting forms, while others opt for robust lattice configurations capable of supporting higher loads. In such projects, there is a consensus that the computational design stage is as important as on-site assembly and requires extreme tolerances, frequent prototyping and interdisciplinary cooperation between architects, engineers and fabricators.

However, previous studies focus on parameter design innovations and technical triumphs, often ignoring questions about user perspective, and socio-cultural significance [3]. This article emphasises further systematic investigations: studies of user behaviour and observation of strict patterns. By capturing these data, architects can refine parametric wooden installations to better align with public needs, ecological considerations, and communal aspirations.

The discussion strives to enrich the academic dialogue and explores a simple but representative prototype, presents results from the ZCB Bamboo Pavilion, and presents computational approaches in urban architecture by relying on parallel examples. More specifically, it argues that thoughtful integration of computational logic, environmental performance strategies, and community engagement can stimulate a new wave of sustainable, interactive, and context-sensitive installations in wood.

Methodology

This study took a qualitative systematic approach, emphasising the observational data and user feedback to examine the structure and performance of parametric wooden installations in public spaces. The aim of the study was to explore how and what people perceived and experienced of such structures in their everyday lives, by first observing peoples activity after they visited such as social media engagement and then collecting data from people who experienced these installations. Throughout the study, a series of design experiments gathered insights into how computationally generated wooden structures functioned aesthetically through their visual impact and spatial presence and structurally through their stability, material behaviour, and interaction with environmental factors within open or semi-public environments.

Case Study Results: ZCB Bamboo Pavilion (Hong Kong)

The ZCB Bamboo Pavilion [Fig.1], designed and constructed through a multidisciplinary collaboration by the Chinese University of Hong Kong's School of Architecture is a exemplary for how bamboo can be incorporated into a parametric design paradigm along with encouraging sustainable construction practices. As pointed out by Crolla [6, p.15, 7, p.14-23], The ZCB Bamboo Pavilion exemplifies the integration between digital form finding techniques and traditional materials, resulting in the low-carbon structure having great cultural significance. This groundbreaking initiative highlights a number of key topics that emphasise the growing popularity of bamboo in the world of contemporary architecture.

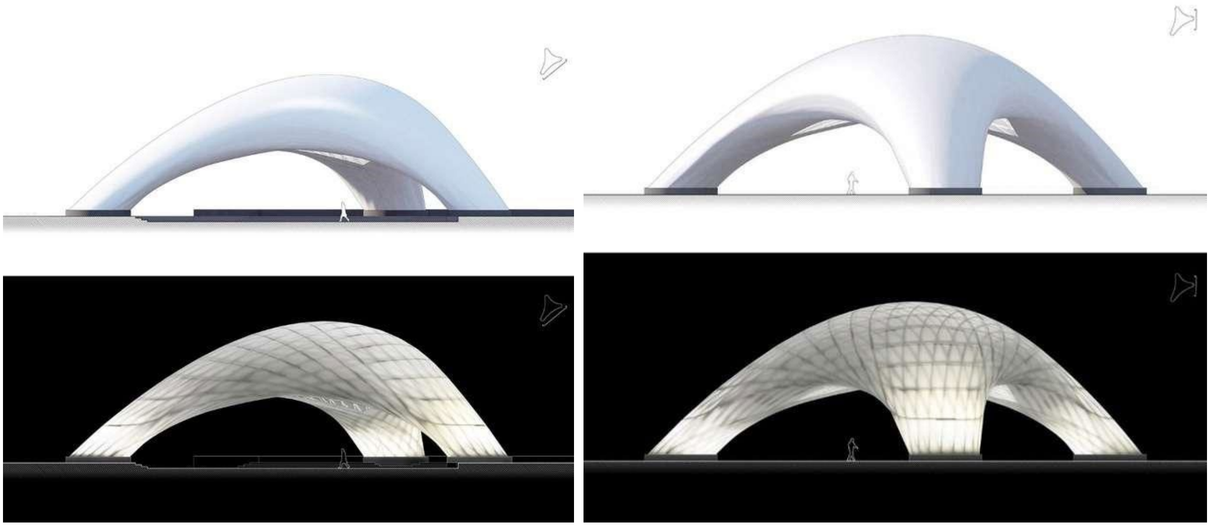

Fig.1 shows the iterative design of the Bamboo Pavilion located at the Zero Carbon Building (ZCB) in Hong Kong.

The objective of the ZCB bamboo pavilion was to demonstrate bamboo's lightweight and adaptable nature and its sustainable advantages [Fig.2]. Adier et al [8, p.2449] argue that bamboo has exceptional tensile strength and accelerated growth rates, which makes it a suitable alternative to traditional wood or steel in lowrise and pavilion structures. Using the natural flexibility of bamboo and the optimal power-to-weight ratio, the design team maintained the structural integrity required for public utilisation. Ramage et al. [5] further argue that integrating locally sourced, fast-growing materials into parametric workflows can help architects respond to escalating environmental concerns without sacrificing design quality or complexity.

Fig.2 shows the self-supporting bamboo structure from locally sourced poles bent together to form a lightweight durable framework.

A distinguishing feature of the pavilion lies in its free-form geometry, generated through computational models [Fig.3] that carefully balance structural requirements and aesthetic intent. Carpo [4] points out that parametric design processes help architects to find multiple forms of the object while staying close to the real world constraints, which is something that the team of the pavilion has also used – by accurately modelling the curvature and spacing of the bamboo members using algorithmic simulations.

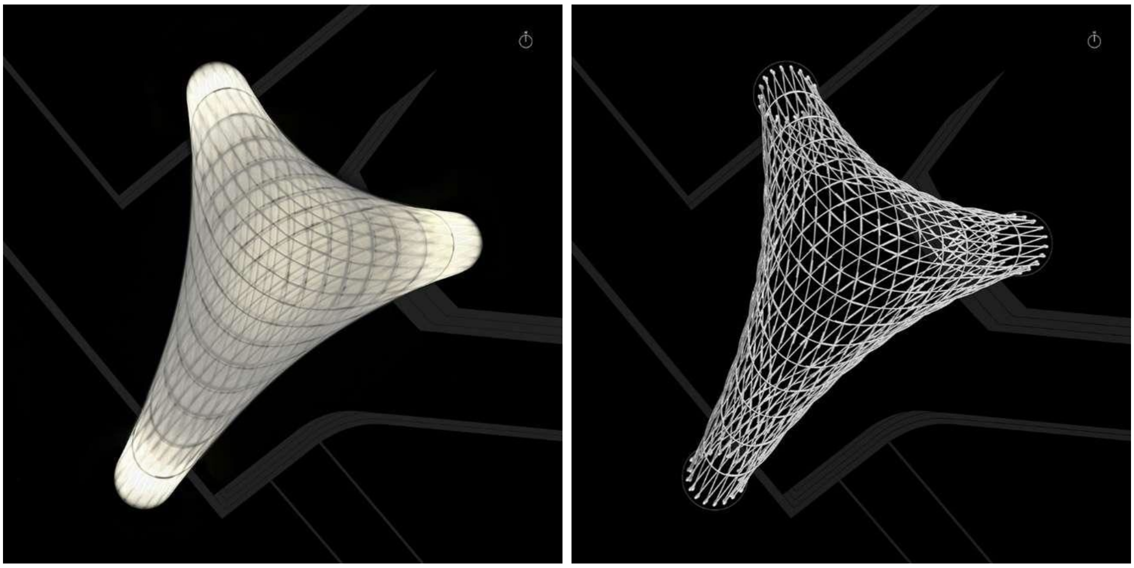

Fig.3 shows the parametric approach digitally simulating the shell structure to optimise form, stability and load distribution.

This computional approach not only facilitated the creation of an interesting visual design, but also ensured the cohesive functioning to handle loads, wind forces and human interaction characteristic of public installation. Simultaneously with the parametric design, the design utilised digital simulation to examine the bending properties of bamboo culms and examine the complexity of ideal relationships [Fig.4]. Menges [3] emphasises the importance of simulating material properties at the initial design phase as they provide a predictive understanding of how materials deform and bend under specific conditions which was critical to the pavilion's success as the design team systematically evaluated several connection strategies, such as overlapping fittings and metal brackets, evaluating the respective components prior to assembly, enhancing the shape of the pavilion and ensuring an impeccable combination of computational accuracy and handcrafted artistry.

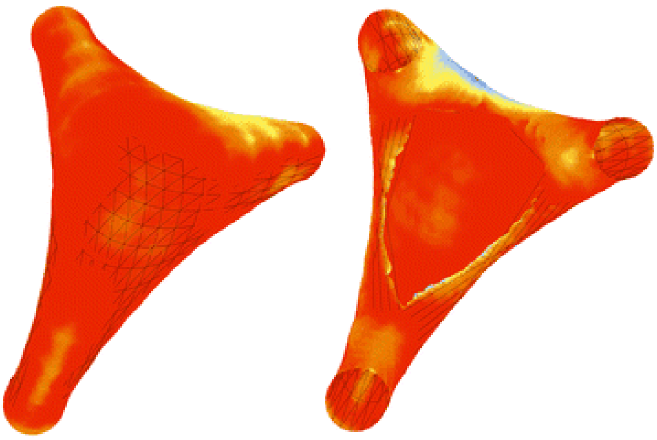

Fig.4 shows the simulation of the bamboo shell to ensure structural integrity and stress concentrations evenly spread.

The pavilion is a publicly accessible exhibition project [Fig.5], which is located prominently in the zero carbon building zone of Hong Kong and thus tries to seduce the visitors to sustainable building methods with their intuition. According to Crolla [6, p.15], the pavilion is an important platform for enhancing the perception of bamboo as a building material for architectural design. Through tours, information presentations, and constant interaction with the public, the structure has inspired discussions that merely surpass aesthetic considerations regarding the broad implications of sustainable design and renewable materials.

The pavilion contains not only aesthetic ideas, but also a social status associated with the growing interest in public engagement in architectural design. In addition, the Bamboo Pavilion at ZCB highlights the deep cultural significance of bamboo in the Asian architectural tradition since this material has been used for centuries in residential buildings, scaffolding and temporary structures [10, p.429-42].

Fig.5 shows the pavilion in its public setting as a striking example drawing attention with its organic flowing form and natural materiality.

Through the integration of bamboo into a contemporary, digitally driven design context, the effectiveness of this material in fulfilling both classic and new requirements is demonstrated. Sun [11, p.223-232, 12] points out that the traditional meaning of bamboo as humble and adaptable is in perfect harmony with the emergent parametric design philosophies that focus on the context-sensitive solutions. The success of the pavilion testifies to the ability of heritage materials such as bamboo to integrate seamlessly into cutting-edge digital practices [Fig.6]. The last outstanding aspect of the ZCB bamboo pavilion demonstrates bamboo's adaptability within a parametric workflow, especially in assembly logistics and standardisation of components.

While digital design tools provided the geometric and structural framework [Fig. 7], much of the final construction relied on traditional craftsmanship, particularly in the bending and binding of bamboo culms. As Menges [3] identifies that blending computational design intelligence with locally developed craft techniques leads to outstanding architectural results that enhance both material performance and cultural identity. In the case of the pavilion, it demonstrates that contemporary fabrication methods can seamlessly merge with traditional construction practices through the collaboration between digital advances and practical expertise seen in every bamboo piece.

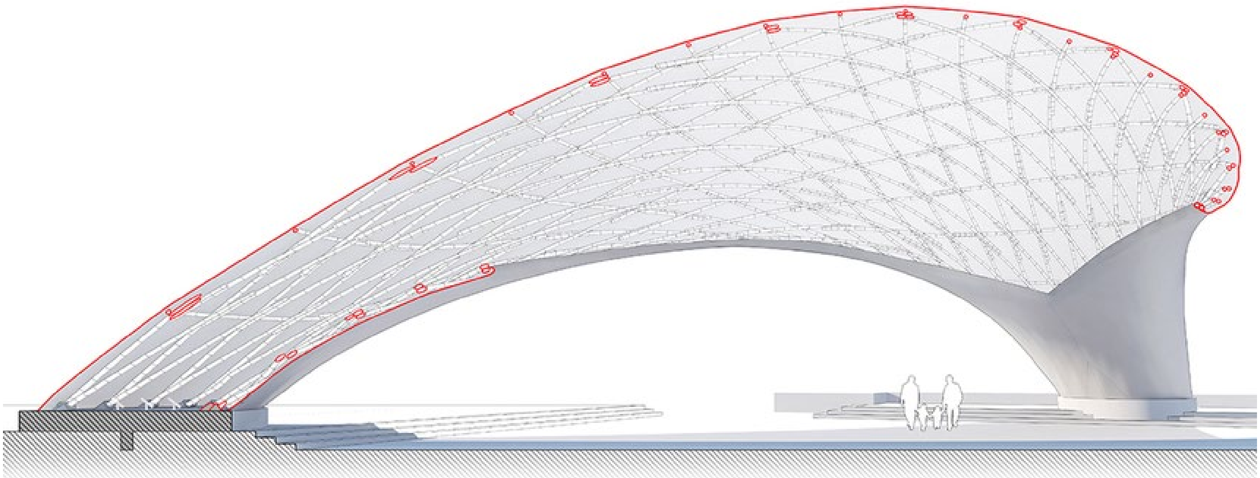

Fig.6 shows the integration of bamboo into cutting edge digital and bridge the gap between historical wisdom and contemporary innovation.

Fig.7 shows the versatility and sustainability embodying traditional craftmanship and significance across many societies.

Discussion

Parametric wooden and bamboo structures use precise geometric planning to distribute weight effectively and create attractive designs. Designers can detect stress points and improve structural connections for enhanced durability through computational modelling even in structures made from lightweight materials. In many of the prototypes examined, the precision of parametric geometry helped direct forces through carefully placed joints and bracing components, reducing the likelihood of deformation.

The delicate nature of bamboo and thin timber components demands supplementary support through methods like internal metal connections and specialized joinery to maintain long-term durability. Although not very accurate, handmade joints sometimes can show excellent resistance to unexpected structural movements, which highlights the need to balance accuracy of digital calculations and methods of practical assembly. Comparative analysis of wood and bamboo prototypes illuminate significant differences in material properties. Glued beams and wood boards part of engineered wood products deliver both enhanced balance and consistent load-bearing abilities. The design process benefits from this prediction because the parametric tool relies on the material's uniform properties. Bamboo's natural organic structure and irregular cross-section present challenges in both design and fabrication processes. Bamboo's inherent flexibility, rapid growth rate, and lightweight characteristics present opportunities for efficient form-finding, especially when parametric methods can adapt to material irregularities. Both materials have proven effective in similar installation scenarios, though design teams often adopt bamboo to emphasise sustainability and a distinct cultural or aesthetic narrative.

The observation of the interaction of passers-by with such installations shows a combination of curiosity, playfulness and aesthetic appreciation. Many visitors look at the form differently, walking through arches and canopies [Fig.1]. In addition, some people use the installation for temporary seating or a sculptural object as a social centre or recreation area. Structures made of wood or bamboo often serve as interesting backdrops for photographic works, where users capture photos and distribute them through social networks. These behavioural patterns emphasise the importance of these pavilions and installations in stimulating public spaces while at the same time serving as artistic centres and catalysts for informal social interactions.

Wood and bamboo installations require regular maintenance with protective coatings like non-toxic sealants and oils to protect against weathering when exposed to environments with high humidity, intense UV exposure, and frequent rainfalls. Steel substructures or carbon fibre wrapping around essential connection points serve as reinforcement options for major or extended duration projects. These techniques increase design complexity and disrupt the lightweight minimalistic appearance that parametric installations usually have. Routine inspections guide maintenance protocols that focus on quick identification and repair of damaged components and strategic replacement of worn parts. Through the use of preventive measures combined with meticulous attention to detail both structural integrity and visual appearance remain intact. Timber and bamboo structures typically perform in alignment with their design objectives which focus on structural efficiency and the development of visually pleasing urban areas. However, unexpected situations can develop when unexpected user behaviour and site conditions occur.

For example, prototypes envisioned as purely sculptural elements may evolve into impromptu seating areas, exposing connections or surfaces to loads beyond the initially intended design parameters. In other cases, microclimates or shadow patterns around the site alter the comfort and usability of the space. Re-examining case studies like the ZCB Bamboo Pavilion shows that, while the overall structural and aesthetic objectives often succeed, ongoing adjustments in detailing, materials, and use scenarios can further refine the outcome and align real-world performance with the designer's aspirations.

Numerous challenges persist despite the promise of parametric design for wood and bamboo. The structural complexity of geometric shapes requires careful geometric analysis and makes it challenging both for tight budgets and strict building regulations. Creating multifunctional profiles and non-standard custom joints requires unique skills that combine mathematical understanding and practical application. In certain cultures there exists doubt regarding the longevity of wood and bamboo when used in major long-term constructions. Without proper educational efforts and transparent communication, misunderstandings about fire hazards and threats from insects or rot may restrict how widely these materials are used.

Looking forward, parametric wooden and bamboo structures have great potential to redefine public spaces. Using computational techniques to optimise the model, designers can increase the likelihood of designing installations that achieve aesthetic, design and sustainability goals at the same time. Future endeavours can combine the flexibility of bamboo with the strength of engineered wood products to explore permanent structures and hybrid systems with cultural resonance. In large installations, advanced digital fabrication tools can be integrated, and more accurate assembly can be done while still engaging with local artisanal skills.

In community and civic development these installations function as entry points to comprehensive urban spaces where people can stay longer and engage with others while contemplating the relationship between nature, design and technology.

Conclusion

Parametric wooden installations can enhance public architecture by uniting computational modelling with thoughtful material strategies, balancing visual ambition and structural viability. Projects such as the ZCB Bamboo Pavilion demonstrate the diversity of wood and bamboo in the formulation of temporary, semi-permanent and large-scale urban structures while involving the community and enhancing the shared space. These structures require interdisciplinary teamwork together with incremental prototyping and regular performance tracking to improve their design and reach widespread acceptance. As wooden structures evolve by integrating traditional handicraft techniques with modern technological innovations as digital fabrication technologies advance to shape future urban architectural design.

References

1. Caetano, Inês, et al. “Computational design in architecture: defining parametric, generative, and algorithmic design.” Frontiers of Architectural Research, vol. 9, no. 2, June 2020, pp. 287–300.
2. Oxman, R., & Oxman, R. (Eds.). (2014). Theories of the Digital in Architecture. Routledge. URL: academia.edu/4402003/Oxman_Rivka_and_Oxman_Robert_2014_Theories_of_the_Digital_in_Architecture_Routlideg_Talylor_and_Francis
3. Menges, Achim. Material synthesis: fusing the physical and the computational. John Wiley and Sons, Inc, 2015. URL: wiley.com/en-gb/Material+Synthesis%3A+Fusing+the+Physical+and+the+Computational-p-9781118878866
4. Carpo, M. (2017). The second digital turn: design beyond intelligence. MIT Press. URL: mitpress.mit.edu/9780262534024/the-second-digital-turn/
5. Ramage, M. H., et al. The wood from the trees: the use of timber in construction. Feb. 2017. URL: repository.cam.ac.uk, doi.org/10.1016/j.rser.2016.09.107.
6. Crolla, Kristof. “Building indeterminacy modelling – the ‘zcb bamboo pavilion’ as a case study on nonstandard construction from natural materials.” visualization in engineering, vol. 5, no. 1, July 2017, p. 15.

7. Schumacher, P. (2009). "Parametricism: A New Global Style for Architecture and Urban Design." Architectural Design, 79(4), pp.14–23.
8. Kolarevic, branko, and kevin klinger, editors. manufacturing material effects. 0 ed., routledge, 2013. URL: doi.org/10.4324/9781315881171
9. Adier, Maria Fe V., et al. "Bamboo as sustainable building materials: a systematic review of properties, treatment methods, and standards." buildings, vol. 13, no. 10, sept. 2023, pp. 2449.
10. Chung, K. F., and W. K. Yu. "Mechanical properties of structural bamboo for bamboo scaffoldings." engineering structures, vol. 24, no. 4, Apr. 2002, pp. 429–42.
11. 11. Sun, Ke Nan. "Digital construction of bamboo architecture based on multi-technology cooperation: constructing a new parameterized digital construction workflow of bamboo architecture from traditional bamboo construction technology." jeroen van ameijde, nicole gardner, kyung hoon hyun, dan luo, urvi sheth (eds.), post-carbon - proceedings of the 27th caadria conference, sydney, 9-15 april 2022, pp. 223-232. URL: papers.cumincad.org/cgi-bin/works/paper/caadria2022_431.
12. Hensel, M., & Menges, A. (2008). Versatility and Vicissitude: Performance in Morpho-Ecological Design. Wiley Academy. URL: doi.org/10.1002/ad.635

Дата поступления: 20.02.2025
Дата публикации: 25.04 2025