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SVEUČILIŠTE JOSIPA JURJA STROSSMAYERA U OSIJEKU

dabar
DIGITALNI AKADEMSKI ARHIVI I REPOZITORIJI

SELF-SUSTAINING MULTIPURPOSE KIOSK FOR UNIVERSITY CAMPUS IN OSIJEK

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Abstract: Sustainable building is growing in importance globally including in Croatia. As green design is gaining rapid recognition in the built environment, the University of Josip Juraj Strossmayer in Osijek decided to contribute to this ongoing process: the University decided that all new building projects and renovations of existing buildings should be carried out in accordance with the principles of sustainable architectural and structural design. One such project was the result of a contest to design a self-sustained module for a kiosk to be located in the university campus. Employees and students of the faculties of civil and electrical engineering created this winning project. From an architectural point of view, their design placed great importance on the simplicity of shapes, materials, and workmanship, with a special emphasis on a transformable interior. Utilization of aluminium for the structure complemented the architectural ideas through the simplicity of constructional solutions that it enabled. Sustainable design, including the harvesting of solar energy, an autonomous water supply, wastewater disposal systems, and the use of recyclable materials, enabled reduction of its environmental impact. The result is a unique structural and architectural design that incorporates many green building elements.

Key words: competition; energy efficiency; module; environment; simplicity

SAMOODRŽIVI VIŠENAMJENSKI KIOSK ZA SVEUČILIŠNI KAMPUS U OSIJEKU

Sažetak: Održiva gradnja na svjetskoj razini svaki dan dobiva na važnosti, a Hrvatska nije izuzetak. Kako zelena gradnja biva sve više prepoznata u kontekstu izgrađenog okoliša, Sveučilište Josipa Jurja Strossmayera u Osijeku odlučilo je dati svoj obol u tom razvitku. Naime, Sveučilište je odlučilo da svi novi građevinski projekti i rekonstrukcije postojećih zgrada trebaju biti u skladu s načelima održive arhitekture i građevinarstva. Jedan takav projekt proizašao je iz natječaja za samoodržive module – kioske za sveučilišni kampus. Pobjednički rad osmislili su zaposlenici i studenti fakulteta građevinarstva i elektrotehnike. Projekt, s arhitektonskog stajališta, veliku važnost pridaje jednostavnosti oblika, materijala i izrade, s posebnim naglaskom na transformabilnom interijeru. Uporaba aluminija u izradi konstrukcije nadopunjuje arhitektonske zamisli kroz jednostavnost primijenjenih konstrukcijskih rješenja koje on omogućuje. Uporaba solarne energije, primjena samodostatnih sustava za opskrbu vodom i odvodnju otpadnih voda, te materijala koji se mogu reciklirati, omogućila je smanjenje njegovog ugljičnog otiska. Ukupni rezultat je jedinstven konstrukcijski i arhitektonski projekt koji ispunjava mnoge zahtjeve zelene gradnje.

Ključne riječi: natječaj; energetska učinkovitost; modul; okoliš; jednostavnost

1 INTRODUCTION

The most significant environmental challenges in history and probably some of the greatest problems ever having confronted humanity are currently being faced, induced by excessive fossil fuel dependency and the growing demand by cities for energy. One possible solution for this is the sustainability concept, including sustainable building design. Globally, buildings account for approximately one third of energy use and are responsible for over 40% of total greenhouse gas emissions [1].

In accordance with global trends in the built environment, the University of Josip Juraj Strossmayer in Osijek decided that the design of all new buildings and the renovation of existing buildings owned by the university would have to incorporate the principles of green building design. The decision was formalized in the University's Environmental Action Plan, which states that special attention should be focused on the building envelope, the low consumption of energy and water, and improvements regarding energy efficiency and sustainability in existing technical systems (HVAC and lighting) [2]. These requirements had to be followed for an anonymous in-house[1] competition, held from November 25, 2014 to February 16, 2015, for the design of a typical self-sustaining module to house a kiosk. The kiosks were intended to enrich the environment of the university campus and the city of Osijek in general.

The presentation of existing projects enables the approval and expansion of certain ideas or concepts, primarily through the sharing of successfully implemented solutions and approaches. With that in mind, the goal of this paper is to provide a review of the winning project of the multi-purpose kiosk contest, which was designed by employees and students of the Faculty of Civil Engineering[2], Osijek, and the Faculty of Electrical Engineering[3]. The project offers insight into the implementation of sustainability requirements and shows collaboration between different fields that resulted in an encompassing approach and a green, practical, and cost-effective solution to the problem at hand.

2 COMPETITION REQUIREMENTS

The main goal of the competition was to generate high-quality and expertly created custom-fit project ideas to create a distinguishing and characteristic urban element for the City of Osijek. These should integrate design and constructional solutions and all aspects of sustainability standards to come up with uniquely shaped economical and sustainable modules. An additional goal was to foster cooperation among educational staff and students. Ideas were evaluated using the following criteria: originality (architectural and structural concept); spatial and visual compatibility of the kiosk with existing environments of the City of Osijek; low building costs; functionality and rationality in the erection and utilization stages; and energy and environmental sustainability. In addition, it was highlighted that the kiosk with the lowest consumption of primary energy would have an advantage [3].

3 ARCHITECTURAL CONCEPT

To allow the possibility of a large number of installation locations and purposes, the winning kiosk took the form of a simple box. With that in mind, great importance was placed on the simplicity of shapes, materials, and workmanship, with a special emphasis on a transformable interior. This minimalistic design and transformable interior (Figure 1) can enable a large variety of possible kiosk functions, including: souvenir shop (for the university and/or the city), internet space, exhibition and presentation space, copy center, tourist information office, ice-cream shop, takeout coffee and snack shop, self-service shop, and classic newspaper kiosk.

The kiosk has a rectangular layout with outer dimensions of 4.64 m x 3.04 m and a flat roof, thus comprising a simple box shape. This structure encompasses a total volume of 41.98 m^3 and provides a gross area of 13.64 m^2, with a total usable area of 10.78 m^2. Sliding and folding glass doors and an area anticipated for advertisements occupy most of the principal facade. An aluminium structure overhang covered with laminated glass additionally

[1] Since it was an in-house competition, all students and employees of the University of J.J. Strossmayer in Osijek could apply. Six entries were submitted, from a total of 50 applicants who were students and employees in the Faculties of Civil Engineering, Electrical Engineering, and Mechanical Engineering.

[2] Ivana Barišić, Josip Bartulić, Ivana Brkanić, Tamara Dadić, Tihomir Dokšanović, Mario Galić, Ivan Radić.

[3] Zvonimir Klaić, Mario Primorac, Danijel Topić.

accents and provides shelter to this communication area. The facade is designed to be ventilated, with flat aluminium panels that are perforated to show the famous panoramas of Osijek. Visibility of the perforated design is ensured by a background contrast during the day and by lights located vertically in the facade air cavity during the night.

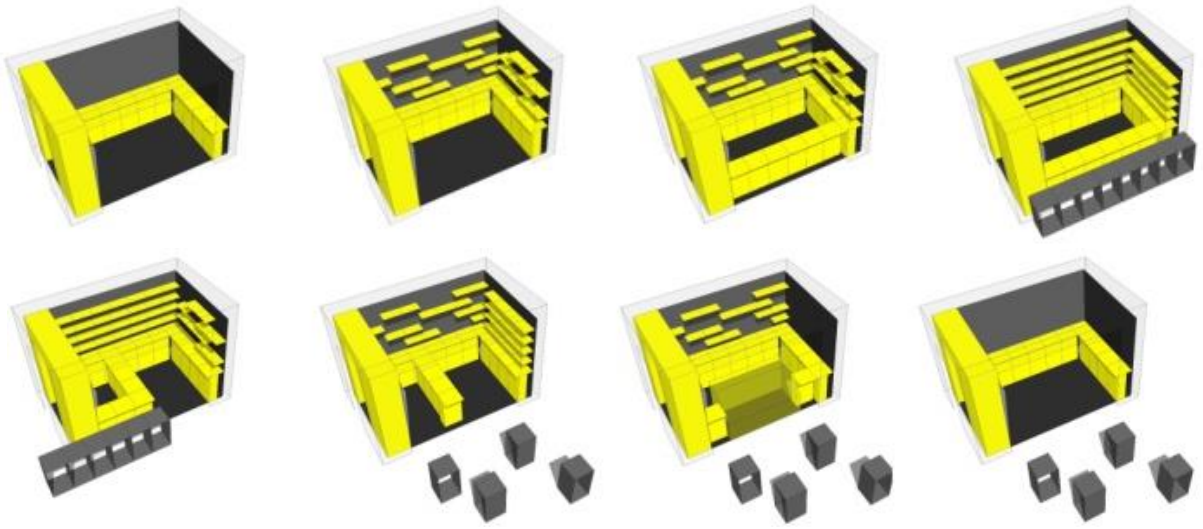


Figure 1 Interior possibilities

Transformable and mobile furniture are the main features of the interior space (Figures 1 and 2). Shelves and cabinets are designed to be modular, so that a large number of different combinations are possible for the presentation of different items. Wall shelves are designed to allow (by opening and closing) various positions of individual shelves or even a large clear surface (all closed). A full-height cabinet located at the side entrance of the kiosk is fixed to accommodate electrical installations and appliances. The sidewall inner lining is comprised of plasterboards painted in dark gray, and the ceiling is also made of plasterboard with built-in lighting fixtures but is painted in white. Black linoleum covers the floor surface and OSB (Oriented Strand Board) wood structural panels make up all the furniture.



Figure 2 Detailed visualization of one possible interior layout

The kiosk design was expanded with additional elements that can be used outside the structure. These kiosk “attachments” comprise a simply shaped bike rack and counters (Figure 3). When the counters are used separately, they assume the role of tables depending on the kiosk purpose—they can serve as counters where customers can consume their takeout coffee, snacks, or ice cream or can serve as exhibit stands. Joining the counters together to form a larger surface can transform them into a market stand. Such modularity and ease of relocation of the stands

is a result of their simple geometry and lightweight material consisting of aluminium alloys. Since these stands are positioned outside the kiosk, their integration to the surroundings is achieved by designing them with Osijek characteristic jargon words on their sides. These elements therefore provide a channel for the interaction of the kiosk with its environment.



Figure 3 Detailed visualization of the exterior with additional elements (counters)

4 STRUCTURE SOLUTION

In the course of the structural system design, two basic principles were taken into consideration. The first principle was ease of assembly and disassembly, in order to provide easier transportation and handling. An energy-efficient structure and utilization of a large degree of the gross area was the second principle. Additionally considered aspects included the integration of structural elements into the kiosk functions, minimization of maintenance costs, and durability. In order to achieve these principles, the structure itself required a low weight, the elements required connection by bolting, and the structure needed to allow transportation to the erection site in the form of subassemblies and assemblies. In addition, slender elements needed to make up the primary structure so that the thermal insulation could occupy a larger share of the wall thickness.

With the given principles and additional demands in mind, aluminium alloys were selected as the primary material of the structure (structural alloys EN AW 6082-T6 and EN AW 6063-T6 [4]). Namely, with its low weight and high strength, aluminium provides the most favorable strength-to-weight ratio. Furthermore, using extrusion as a production method, it is possible to design cross sections that include various practical functions. All connections can be bolted, and owing to the easy oxidation of the surface layer, durability is guaranteed without the application of any additional protection.

The structure itself was designed as a spatial construction that can be divided into two basic frames. The transfer of vertical forces is assumed through the secondary beams within the roof plane, and then via the main frame elements. Horizontal forces are transferred via the facades to the frame system and then to the bracing system. Such a layout of structural elements (Figure 4) fulfills the requirements of a braced structure, which reduces the complexity of connections. It can be said that the structure is of mixed type aluminium-steel, in which vertical forces are conveyed by aluminium alloys and horizontal forces by steel. The total weight of the structure, including the floor system, is 1000 kg.

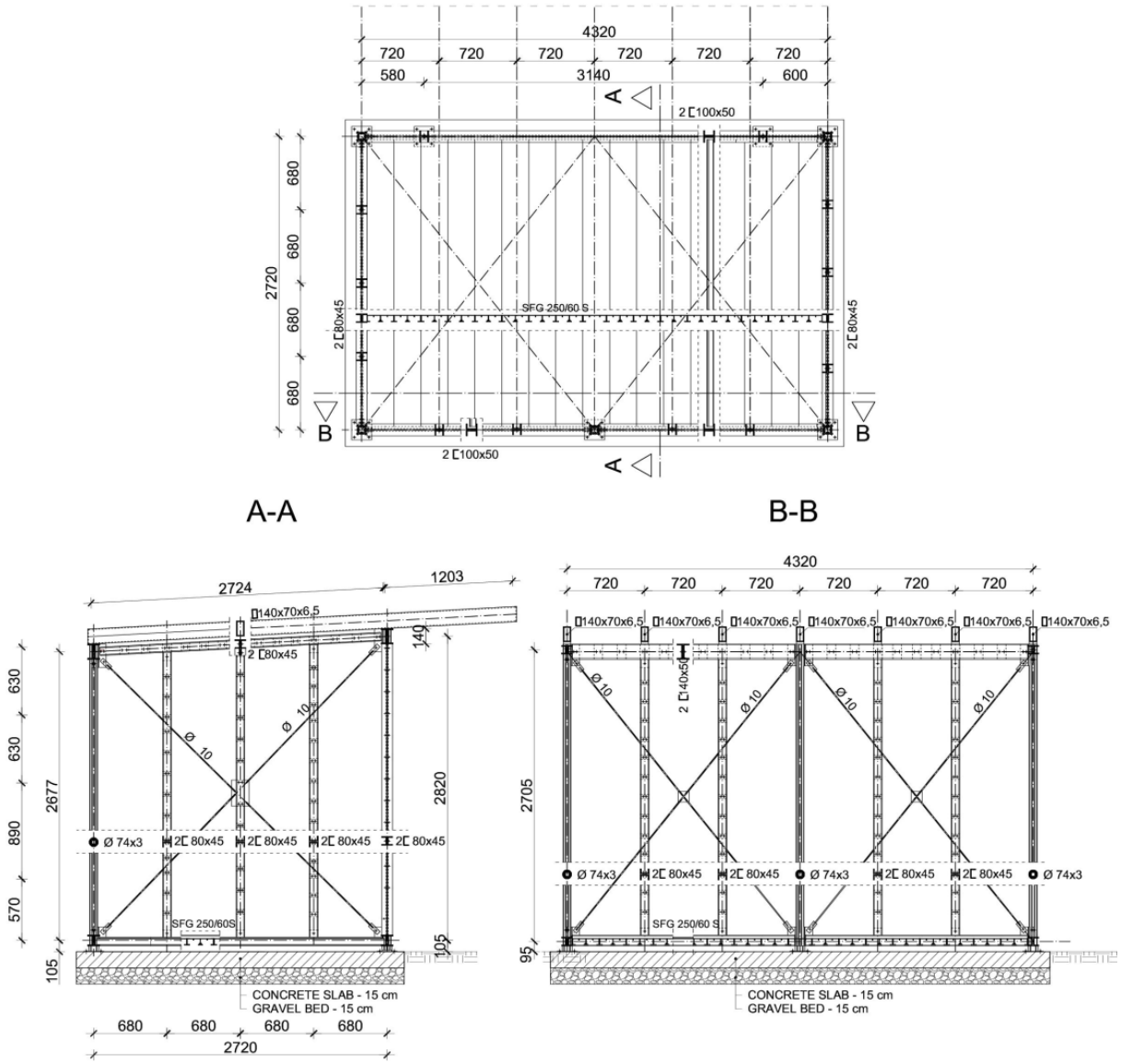


Figure 4 Structural elements layout – frames and bracing

The X (diagonal) bracing system in the roof and wall planes is made entirely of steel, as welding is required at the midpoints. Aluminium loses favorable (mechanical) properties in the heat-affected zone (HAZ) if welded, which can amount to a 50% reduction of strength [5]. All other connections were designed to be bolted. In the case of contact of aluminium with other metals that can cause contact (cathode) corrosion, it is necessary to isolate the connecting surfaces. This was the case for the contact between the bracing and the primary structure. Insulation of these contact surfaces was carried out by inserting synthetic materials (Figure 5) and through anti-corrosion protection of the steel elements. The connection between the bracing system and the columns was realized through the insertion of a designed aluminium plate into predetermined grooves of the column (Figure 5).

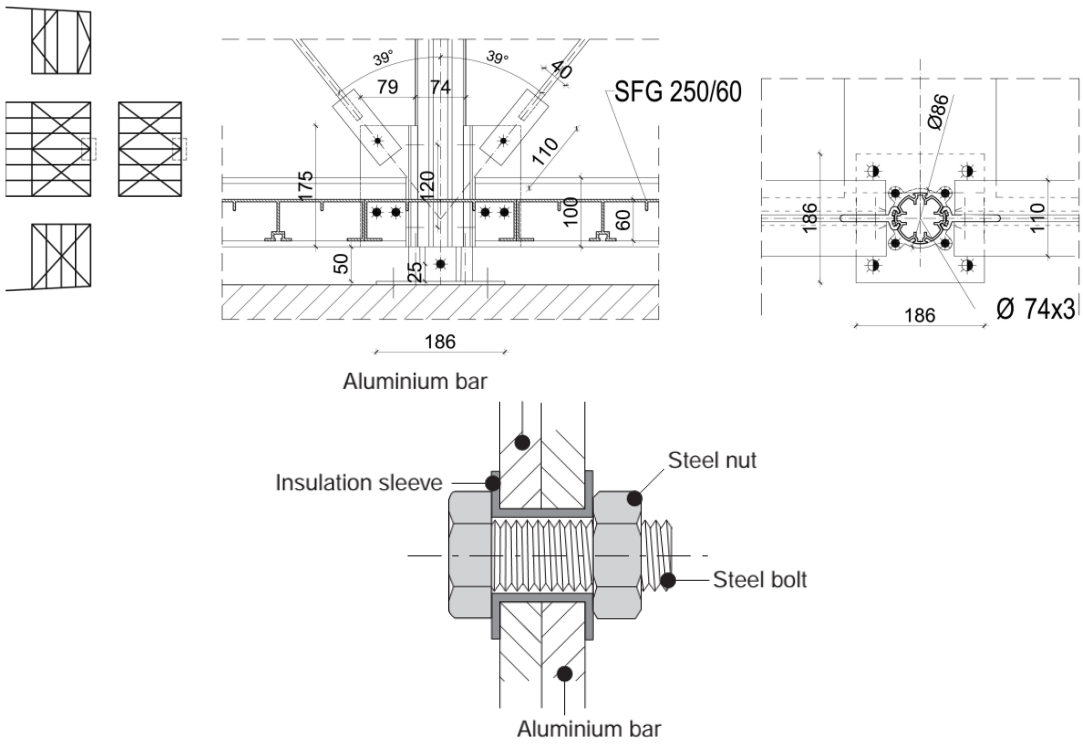


Figure 5 Detail plan of the middle column to bracing connection (top) and an example of electrical insulation for a bolted joint (bottom) [6]

Wind, snow and self-weight loads were determined in accordance with HRN EN 1991-1-1:2012, HRN EN 1991-1-3:2012, HRN EN 1991-1-4:2012 [7-9] and their corresponding national annexes. Load combination was carried out according to HRN EN 1990:2011 [10]. The design of the aluminium and steel elements was carried out conforming to HRN EN 1993-1-1:2014 [11] and HRN EN 1999-1-1:2015 [4]. In addition to wind load determination according to normative provisions, wind pressures were simulated in Autodesk Robot Structural Analysis (Figure 6) [12]. Such an analysis verified the division of surfaces and pressure values using actual geometric shapes.

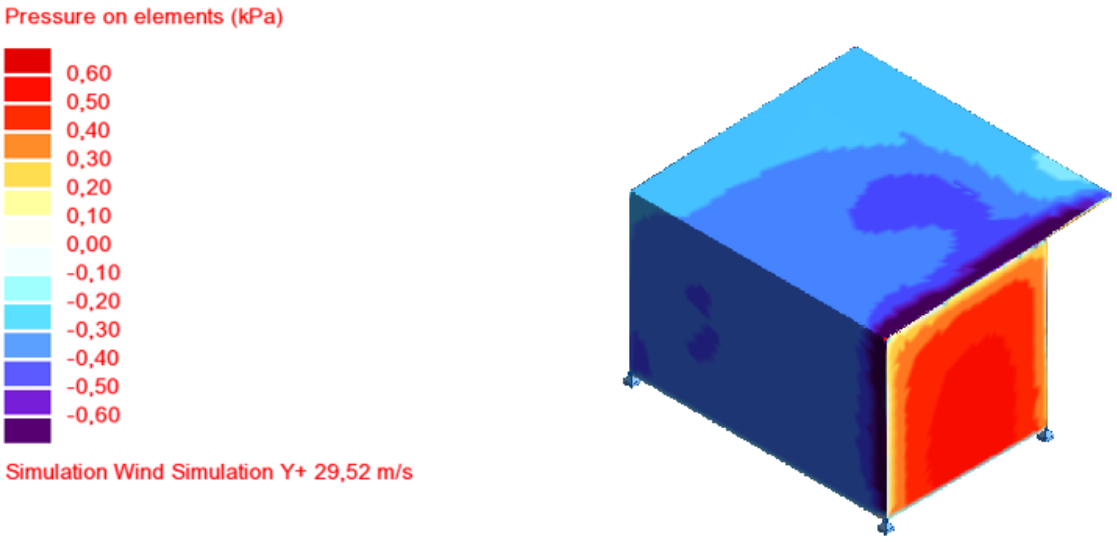


Figure 6 Simulated wind load pressures resulting from lateral wind direction, obtained by Autodesk Robot Structural Analysis [12]

5 ENERGY SUSTAINABILITY AND MATERIALS SELECTION

The kiosk electricity demands were planned to be met from renewable sources as well as from the electrical grid. Since the amount of electricity harvested from solar energy was limited by the available roof area, a connection to the grid was planned as an additional source. The planned photovoltaic system, situated on the roof, was estimated to annually generate 2,115.6 kWh (20 photovoltaic modules of assumed power of 100 W each). With such a production rate of power, a yearly decrease of CO_2 production of 630 kg is realized (according to an average CO_2 production of 298 kg/MWh [13]). In order to meet the energy sustainability requirements and to encourage rational use of energy, appliances to be used in the kiosk should have a minimum energy class A. The kiosk as a whole is classified as energy class B.

The kiosk water supply and disposal of wastewater depend on the possibility of connection to the city water and sewage systems. If a connection to the public water system is not available, a water storage tank (with a 200 l capacity and a size of 100 x 60 x 34 cm) placed on the roof fulfills the water requirements. If there is no available connection to the city sewage system, disposal of wastewater is planned via a mechanical-biological purifier in the form of a lightweight container tank, which can be easily moved during kiosk relocation.

All furniture and materials used, whether constructional or insulating, can be completely reused or recycled at the end of the kiosk service life. The furniture is made of plywood, the structure and the facade are made of steel and aluminium, and the thermal insulation consists of rock wool and EPS. A proposal to use sheep's wool or pressed straw for the insulation was also made, since these are more sustainable options than rock wool or EPS.

6 IMPLEMENTED SOLUTIONS

The kiosk design, both in terms of structural and architectural concepts, differs from existing kiosks. The focal point of its exterior is the applied Osijek skyline, and the compact volume is functional, with minimalism in mind. The roof is occupied by photovoltaic panels and, if needed, a water storage tank. Of the external features, the position of the water tank presents a possible problem in terms of architectural design—if the water tank cannot be manufactured according to the proposed dimensions, it will be difficult to conceal it behind the extended facade. A transformable interior is new to the existing designs of newspaper and retail kiosks, and thus can be considered a highly favorable attribute. The most important feature of such an interior is the capability of providing a wide range of different functions.

A great deal of attention was devoted to the facade design because of the location of the kiosk in an urban setting, but primarily because of its importance as the kiosk's thermal envelope (Figure 7). Facades are not simply barriers between the interior and the exterior; they are building systems that create comfortable spaces by actively responding to the building's external environment, and they significantly impact energy consumption [14]. The choice of colors for the facade was not easy as the selected dark gray, almost black, attracts and absorbs sunlight well. While this has benefits in the winter, it can lead to overheating during the summer months, thus resulting in a greater energy requirement for cooling during this period.

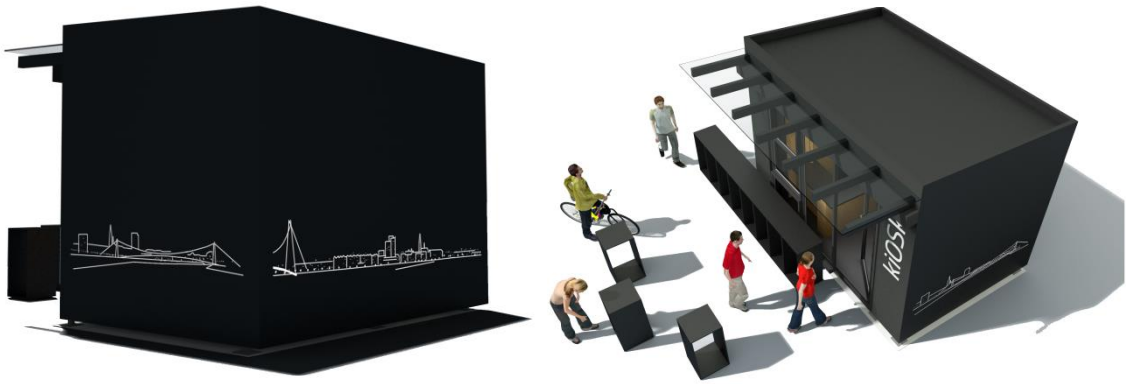


Figure 7 Visualizations of the exterior reveal elements that incorporate it in the urban fabric

EPS was proposed as a thermal insulating material for the floor owing to its good thermal properties, low cost, and simple installation. The walls are insulated with rock wool because of its beneficial properties including its high resistance to fire, microbes, insects, aging, and decomposition; its vapor permeability and partial water-tightness; and its good thermal protection. These materials were proposed owing to their ability to create a comfortable microclimate and to ensure durability of the structure. The possibility of using natural materials in the form of sheep's wool or pressed straw instead of rock wool was also considered. Of the two, sheep's wool was found to be more suitable because of its ready availability, its cost-effectiveness, and its proven adequacy as a replacement for rock wool. Additionally, the production process of such insulation requires significantly less power, and only 14% of the energy needed for the production of glass wool [15]. Nevertheless, rock wool still represents a commercially more available material with proven properties, so it was retained as the first choice.

The use of aluminium alloys for the structure is well justified by the facts already listed in chapter 5, *Energy sustainability and materials selection*. Although aluminium has a lower Young's modulus value than steel, which makes it more susceptible to stability issues, the designed bearing system negates such problems. The cross sections of the columns were specially designed for this project, in order to allow relatively simple connections to beams and bracings, and to provide a good base for buckling prevention. Avoiding welding of the aluminium prevented any weaknesses owing to heat-affected zones, and steel was used where welds could not be avoided. Although aluminium has a higher amount of embodied energy (EE) and carbon (EC) than steel and therefore is less sustainable, secondary aluminium is more sustainable as its production requires 20 times less energy than that for primary aluminium [16]. Additionally, since aluminium requires practically no maintenance and can be recycled without any loss in properties [17], when a Life-Cycle-Cost-Analysis is carried out for an aluminium structure, it can be concluded that (if designed and executed properly) it is a better ecological and economical choice than steel [18]. It should be noted that the designed aluminium frames can be reused after their planned service life.

Owing to competition requirements concerning maximum permitted gross area of the kiosk, as well as valid technical regulations, the winning project could not attain an energy class rating of A. This was primarily due to the window-to-wall ratio (WWR) and limited wall thickness. In most cases, a higher WWR results in higher energy consumption, since thermal resistance of even a well-insulated glazed facade is typically lower than that of an opaque facade [14]. The maximum permitted gross area was also a factor, since this resulted in a limitation of the possible generation of energy by the photovoltaic system located on the roof.

Table 1 provides a summary of the parameters of the winning design, including its price per square meter.

Table 1 Overview of realized parameters

Design motive	Structure	Gross area	Usable area	Total volume	Energy class	Photovoltaic system (annually generated)	Construction costs (€/m² gross area + VAT)
box	aluminium	13.64 m²	10.78 m²	41.98 m³	B	2,115.6 kWh	1,805.69

7 CONCLUSION

Sustainability is the key to negating problems arising from global ecological issues. Sustainable building is an important part of sustainability, and one method to widely spread its awareness is to exhibit successful projects that fulfill its requirements. Since sustainable building comprises a vast network of interconnected professions, collaboration of interested parties in project design and development is a necessity. The University of Osijek contest to design a sustainable kiosk required collaboration of different fields and also ecological solutions. The winning design satisfied the requirements while achieving a unique structural and architectural design.

The winning design differs from existing kiosk designs, both in an architectural and structural sense. Its transformable interior, combined with an exterior that easily integrates into its surroundings, offer a practical solution through simple, minimalistic design. The compact box-like shape easily fulfills multiple purposes, and the additional elements outside the kiosk supplement this modularity of applications.

Sustainability is ensured through electricity generation by the photovoltaic system on the roof and through autonomous water supply and wastewater disposal systems. The permitted small gross area of the kiosk limits the number of photovoltaic units; therefore, an electricity connection to the grid is also needed for the fulfillment of all energy needs. The water storage tanks are also situated on the roof, and as such could be aesthetically displeasing unless they can be manufactured in the desired dimensions, thus being concealed behind the extended facade.

The use of aluminium alloys ensures that the structure itself is very durable and maintenance costs are almost non-existent. Ease of assembly and handling is provided by simple constructional solutions that exploit the advantages of aluminium alloys, while negating their weaknesses such as stability problems and loss of favorable properties due to welding. This was accomplished through the system layout, choice and design of connections, custom design of element cross sections, and interoperability of elements.

Ecological aspects such as life cycle, cost, and embodied carbon were weighed during the design and choice of materials. For this reason, all of the implemented materials can be recycled or reused at the end of the kiosk service life.

The university's initiative proved to successfully bring about collaboration among different professions and different faculties, and provided an excellent opportunity for the fostering of teacher and student teamwork. The presented project idea shows that the inclusion of the concepts of sustainable building is possible at a small building scale. If it is constructed, the kiosk will feature as one component of a new "green" campus, which is currently being realized.

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