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An ecological approach to building design

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Abstract: An ecological approach to construction and the "green building" concept in order to force construction-process participants to meet specific requirements. In relation to designers and designing buildings, these requirements have also been defined. Additionally, social, financial, and environmental benefits throughout the entire life-cycle of a building are taken into consideration. It is important to choose materials that ensure the safety and durability of the structure, as well as its thermal insulation up to the required level, and to use construction materials and products made from recycled raw materials. Green construction is primarily about the efficient use of energy and resources, and automated construction technology, which should improve the comfort and functionality of buildings. When designing the buildings, the aim is to minimise interference with the natural landscape by fitting new buildings into the existing landforms and among adjacent existing buildings. An ecological building has an impact on both nearer and more distant surroundings, hence the right location is vital. Designing in accordance with the "green building" principles entails acknowledging the needs of society, such as ensuring accessibility for people with disabilities, creating social space and improving the quality of life of residents. The principles of sustainable development apply to both newly designed facilities and those undergoing thermal modernization. Research, interviews and seminars among engineers and contractors in the Warmian-Masurian Voivodeship have made it possible to collect reliable and up-to-date data directly from specialists in the construction industry. As a result, the article is based on reliable sources and real experiences.

Keywords: green building, materials from recycling, sustainable development

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Introduction

Architecture is currently undergoing a profound transformation. Green architecture and sustainable development have emerged as overarching facets in the construction

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industry, being driven by global fears about the degradation of the natural environment, including excessive consumption of natural resources. Traditional architecture sought to consider three basic attributes of buildings: the form, function and construction, hence buildings were designed to be aesthetically pleasing, but also durable and functional. Modern regulations, however, force architects to take a more holistic approach to building design. Modern design is responsible for the impact on the environment, as well as prioritising the comfort of using a building and its indoor climate (Elnaklah et al., 2021). A solution that has gained much popularity is the Integrated Design Process (IDP), where each problem is approached from different points of view of the stakeholders, such as the investor, architect, construction engineer, site engineer, contractor, and user. This allows the design of a building that is optimal in terms of costs within the building's entire life cycle (Ikudayisi et al., 2022). Designers of the building's architecture, construction and installations, building material manufacturers, and contractors should all be involved in efforts to achieve sustainable development goals, taking into account social, financial and environmental benefits throughout the whole life cycle of a building.

On 25 September 2015, the UN Sustainable Development Agenda called 'Transforming Our World: the 2030 Agenda for Sustainable Development', was adopted by 193 UN member states. It sets 17 goals, referred to as Sustainable Development Goals (SDGs), and associated targets, which are to be achieved by year 2030 (Przekształcamy nasz świat, 2015). The agenda focuses on 5 basic areas, the 5xPs: People, Planet, Prosperity, Peace, and Partnership. The issues related to sustainable construction are the responsibility of the Green Building Council, an umbrella name for non-governmental organisations whose main objective is to increase awareness of the need to design, build and use buildings in such a way as to minimise consumption of natural resources throughout the entire life cycle of a building. There are associations in UN member states dealing with sustainable construction, for example the Polish Green Building Council in Poland (Polskie Stowarzyszenie Budownictwa Ekologicznego), whose four pillars are: climate change, circular economy, health and quality of life, and biodiversity.

1. The premises of green building design

In the context of sustainable construction, a holistic approach is as highly important as the inclusion of all aspects of a construction process, from the design process, through construction work, to the use and maintenance of a building. The basic premises of green building design are illustrated in Figure 1.

Sustainable design underlines the need to minimise its carbon footprint. Possible solutions are passive buildings, green roofs and efficient thermal insulation systems based on natural resources. Much emphasis is placed on natural, recycled materials, and on state-of-the-art materials like bioconcrete and self-healing concrete. Other ecological materials include wood and aluminium. The latter material is gaining in popularity because of its increasingly common use for the production of window and door joinery, as a replacement of less ecofriendly PVC. Moreover, these materials

can be recycled, which significantly helps to make energy savings and achieve close--loop targets. When selecting materials, it is also worthwhile to take into consideration their natural composition, high durability, effect on air quality, availability, simplicity of use, and ease of disposal (Wang, 2022; Wang et al., 2024). While designing interiors, efforts are made to include as many materials with high heat capacity as possible, for example concrete or stone, which absorb, store and gradually release heat into the environment. This allows the regulation of temperature inside a building, minimizing temperature fluctuations, especially in changeable atmospheric conditions (Umoh et al., 2024).

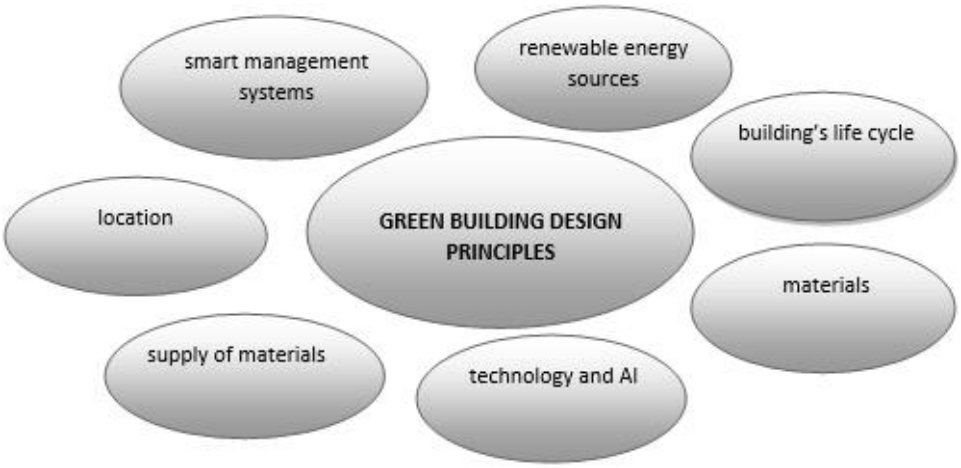

Fig. 1. Green building design premises (*own research*)

Decreased demand for energy can be achieved by tapping onto alternative energy sources. The inclusion of renewable energy sources such as solar panels, wind turbines, geothermal energy, bioenergy and other sustainable energy solutions in the building industry ensures energy self-sufficiency and contributes to reduced emissions of greenhouse gases (Chen et al., 2024; Meena et al., 2022).

Smart HVAC (Heating, Ventilation, Air Conditioning) grids and systems, which have been gaining in popularity over recent years, enable us to optimise energy efficiency in the entire life cycle of a building. To help with this, roller shutters are fitted in windows to prevent the overheating of the building's interior, while the rooms are designed in such a way as to promote natural air flow and exchange. Monitoring systems and smart lighting are also installed. To maximise the use of natural light, automatic window shutters are designed with a built-in smart timer and controller that allow their automatic closing and opening, depending on the intensity of sunlight in different times of the day and seasons of the year. When choosing sanitary fixtures and fitting, it is recommended to opt for those which allow restricted water flow (e.g. taps with aerators, water saving toilet cisterns, etc.) (Leu & Shi, 2024; Qiang et al., 2023).

Passive design takes advantage of characteristics of the landscape, climate and materials in order to create an energy-saving space. It is important to position a building

so as to allow it to harvest as much solar energy as possible in winter, but not so it is exposed to excessive sunlight in summer, which can be helped by strategically placing windows, canopies and other elements, in order to focus or block the sun. The choice of a site should help minimise the demand for transport, which is associated with better access to public transport and services. Locating a building near public transport hubs or stations is intended to encourage future inhabitants to use public transport, which reduces emissions of harmful substances to the atmosphere and consequently ensures cleaner air in the urban space. When designing buildings, it is also worth considering the natural relief of the terrain, and enact measures to protect the flora and fauna found there. This can be achieved by using natural slopes in the landscape, taking into account the existing vegetation, and adjusting the planned building to compliment those already there, in its vicinity.

Another important target is to shorten supply chains. Here, the choice of suppliers matters. One should consider both logistical issues (e.g. distance), which affect the carbon footprint of the construction, and the quality of goods. A shorter supply chain means lower environmental costs of transport, resulting in less pollutants emitted to the atmosphere by vehicles transporting materials and other elements to a construction site. It is worth asking potential partners about certificates and any other documents attesting to their reliability and adherence to the green development requirements.

Green building design and modelling is an important aspect of ecological construction because it employs software tools and methods to analyse, simulate and optimise the environmental efficiency of the building being designed. The use of IT instruments facilitates the daily work done by all participants of the building process and minimises the risk of potential errors. Automated generation of drawings, reports, analyses, timetables, and other essential information about the building under construction eliminates the risk linked to human error.

The application of building information modelling (BIM) enables the user to create a database with detailed information on the construction materials. By carefully calculating the amounts of materials needed, it is possible to minimise waste, while precise localisation of all elements of a building eliminates collisions between supplies. BIM also ensures a more rapid transfer of information between different sectors within the construction industry. Designing and modelling with the use of modern tools can help identify potential problems and threats, as well as provide solutions and recommendations to improve the design. Finally, it allows the documenting and verifying of the results of the design process, and assists in obtaining a green building certificate (Waqar et al., 2023). By performing an analysis of the design building's life cycle assessment, it is possible to optimise design and material solutions, which may have an adverse impact on the environment (Szafranko & Jurczak, 2023). BIM facilitates the acquisition of data at every stage of the design process. Based on the analyses made, it can be concluded that a building's life cycle assessment should be made right from the start of the design process in order to achieve optimisation, that is the attainment of the best possible final results (Li et al., 2023).

The review of the literature and interviews with engineers, as well as seminars dedicated to the above problems, confirm the authors' belief that it is of utmost

importance to systematise construction design principles in terms of sustainable development. Hence, the aim of this article has been to present the basic design aspects according to the green building concept and to illustrate them with practical examples in order to gain better understanding of the green building approach, to learn about the benefits derived from sustainable construction, and to identify the challenges that must be overcome for these principles to be implemented in practice.

2. Materials and methods

The first step in our study was to read the source literature, and analyse the source materials and information (stage 1 in Figure 2). The materials for the study were extracted from interviews with engineers and from seminars organised with construction contractors. With this information, we were able to summarise the data concerning the approach to building design in line with the green building principles. This allowed us to define the research problem. Finally, a case study of a building designed according to the sustainable development framework was presented.

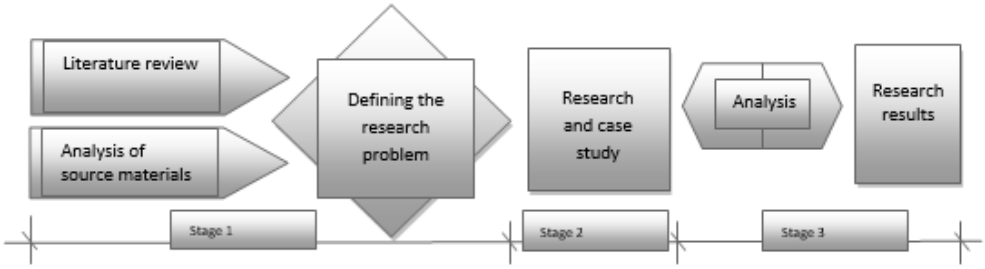

Fig. 2. A flow chart illustrating the research methodology and scope (*own research*)

3. Results

Individual interviews were conducted with 10 engineers from the Warmian--Masurian Voivodeship. Each interview lasted approximately 40 minutes, during which the following issues were discussed:

1. What technologies and materials are most commonly used in sustainable construction?
2. What advantages and disadvantages do you see in sustainable construction?
3. Have you encountered resistance from investors or contractors due to higher initial costs?
4. What are the biggest challenges in implementing green building principles?
5. What educational activities are needed to increase green building awareness and skills?

The seminars for building contractors were held in the form of workshops, attended by around 20 people from the Warmia and Mazury region. The workshops

lasted two days and included presentations, panel discussions and practical sessions. During the seminars, the same issues were raised as with the engineers during the interviews, but also contractors presented specific cases, solutions and shared their own experiences in sustainable construction.

Responses from the interviews and seminars were summarised. Respondents showed mostly similar views, but on some issues the answers were different. Most participants agreed that sustainable buildings have a positive impact on the environment, reducing CO_2 emissions and consumption of natural resources. Participants emphasised that sustainable buildings offer better indoor air quality and improve living comfort. All respondents agreed that it is necessary to increase awareness and skills in green building through training and seminars. In terms of differences, about 70 % of people felt that the higher initial costs compared to traditional buildings were the main barrier to implementing green building principles, while the rest felt that this was not an obstacle for investors due to the quick payback period. Also, some participants pointed out the difficulty of complying with various regulations and legal standards when designing according to sustainable development principles, while others thought that cooperation with local authorities would solve this problem.

The seminars compared two existing single-family buildings in the context of several design and performance aspects – a traditional building with a sustainable building. Selected issues are summarised in Table 1.

Table 1. Comparison of traditional building no 1 and building no 2 raised according to green building principles (*own research*)

Factor	Results
Initial costs	The construction costs of a sustainable building were approximately 20 % higher than a traditional building
Energy saving	A green building reduces energy consumption by up to 30 % - 50 % compared to a traditional building
CO_2 emissions	The use of energy efficient technologies in a sustainable building is estimated to lead to a 35 % reduction in CO_2 emissions
Savings from investment	An investment according to green building principles can pay for itself within 5-10 years through lower operating costs

Two single-family, one-storey houses with a habitable attic and a similar building area (approximately 150 m^2) and cubiture, both situated in a rural area, were selected for comparison. Building number 1 was designed in a traditional way, on a rectangular plan and covered with a gable roof. It was built with the traditional brick technology with reinforced concrete tie beams and ceilings. The building is connected to the municipal heating and ventilation network, including hot water supply, and with no alternative energy sources.

Building number 2, consistent of green building principles, was situated on a land parcel in such a way as to harvest the maximum solar energy – it had large south-west facing windows with roller shutters and open space rooms. The northern part of the building, which is a cool zone, has no windows and is divided with partition walls.

The walls of the house were made of expanded clay blocks, which provided the additional benefit of high accumulation mass. The gable roof was traditional but with three-layer insulation of the total thickness of 45 cm. Certified window and door joinery was used. To minimise water consumption, rainwater and grey water recovery systems were created. Mechanical ventilation with heat recovery as well as photovoltaic panels and a heat pump were designed.

4. Discussion

The research carried out and case studies from the real world offer a valuable insight into the practical application of the design techniques presented above. Interviews with engineers, seminars organised for building contractors and the comparative analysis of the two houses attested to the presence of sustainable development trends, which was described in this paper. It is worth noticing that visually similar buildings can play their functions in an entirely different manner, and have a different impact on the environment and comfort of users. Traditional construction focuses on functional and aesthetic expectations of the investor, on the use of standard materials, methods and practices in design that are well known. It also tends to generate more waste and emissions of harmful substances. In contrast, green building creates many benefits for the environment, economy and society. It contributes to the reduction in amount of greenhouse gases, CO_2 emissions and water consumption. It has a beneficial effect on the health and well-being of residents by providing them with ample natural light, ventilation, thermal comfort, and good quality indoor air, while reducing noise. This comparison of two variants of single-family houses demonstrated lower maintenance costs of building no 2, and its greater market appeal to investors owing to the compliance with certification standards. The implementation of new design principles calls for a well-integrated and well-thought-out system so as to ensure effective control and management. The initial costs of green building solutions can be challenging to investors; however, the long-term savings can offset these costs, which is proven by analyses of the life cycle of buildings. These analyses and interviews show how important it is to disseminate the sustainable development building trends, and – in the context of future studies – to acquire information about potential challenges and ways to manage them (Kalyana Chakravarthy et al., 2022; Nguyen & Macchion, 2023).

Conclusions

The article focuses on significant aspects of making sustainable building design. The main aim is to acquaint the reader with specific practical guidelines that can help architects and building designers in their daily work. Research, interviews and seminars among engineers and contractors in the Warmian-Masurian Voivodeship have made it possible to collect reliable and up-to-date data directly from specialists in the construction industry. As a result, the article is based on reliable sources and

real experiences. The analysis of actual designs allows us to understand how design techniques are transmitted from theory to practice, shaping a sustainable environment. Based on our study, we can conclude that integration of ecological solutions in a building design process contributes to reducing the negative impact of construction on the natural environment. The right approach to building design can have a beneficial influence on nature as well as generating economic benefits and improving the quality of life of the building's residents. When adopting these principles, it is worth bearing in mind that the sustainable development design guidelines allow the designer to shape a building's surroundings in a way that not only satisfies current expectations but also creates a sustainable future for following generations. Observing the horizon of trends in building design, it can be seen that green architecture is advancing towards a harmonious combination of modernity, functionality and environmental management. There are numerous challenges that green building is faced with, hence the key importance of environmental education of society. The demand for green buildings will increase with the public awareness of this approach.

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