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FACULTY OF CIVIL ENGINEERING AND ARCHITECTURE

in cooperation with
UNIVERSITY OF NOVI SAD
FACULTY OF TECHNICAL SCIENCES
DEPARTMENT OF CIVIL ENGINEERING AND GEODESY

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GRAĐEVINSKO-ARHITEKTONSKI FAKULTET

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PhIDAC 2019 PhIDAC

V INTERNATIONAL SYMPOSIUM
FOR STUDENTS OF DOCTORAL STUDIES IN THE FIELDS OF CIVIL ENGINEERING, ARCHITECTURE AND ENVIRONMENTAL PROTECTION

V MEĐUNARODNI SIMPOZIJUM
STUDENATA DOKTORSKIH STUDIJA IZ OBLASTI GRAĐEVINARSTVA, ARHITEKTURE I ZAŠTITE ŽIVOTNE SREDINE

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PhIDAC 2019 PhIDAC

EDITORAL NOTE:

The Faculty of Civil engineering and Architecture of University of Nis organizes the Fifth International Symposium of Doctoral Studies' Students in the fields of Civil Engineering, Architecture and Environmental Protection "PhIDAC 2019".

The first Symposium of the Doctoral Studies' Students "PhIDAC 2009", held in September 2009 in Nis, confirmed the expectations of Prof. Slavisa Trajkovic and Professor emeritus Radomir Folic, the founders of this symposium, that the two-day meetings of the students of Doctoral studies and their professors would be of invaluable use both for young researchers and their tutors. Namely, a great number of published and presented papers, as well as open discussion on the quality of paper, directions in further researches and relationships between doctoral students and tutors demonstrated that the Symposium fulfilled the expectations of the participants and that the organization of new meetings should be continued.

At the Second Symposium "PhIDAC 2010" held in Novi Sad, the symposium programme was expanded, i.e. the field of environmental protection was also introduced as the third thematic field with the expectation that this multidisciplinary area should be more closely introduced to young researches in the fields of civil engineering and architecture.

The organizers of the Third Symposium "PhIDAC 2011", also held in Novi Sad, decided that the symposium should be international and thus they opened new possibilities for affirmation and development of young researches from Serbia, as well as of their colleagues from the Balkans.

There were 66 papers dealing with topics in the fields of civil engineering, architecture and environment protection that were submitted for the fourth international symposium of students of doctoral studies "PhIDAC 2012". The papers covered a wide range of scientific topics. All the papers were reviewed. On the basis of the reviews, it was concluded that the young researchers provided a significant contribution to the development of scientific thinking.

Members of the international scientific committee actively participated in the preparation of the symposium and reviewing of the papers. For this symposium too, the proceedings including papers in English and Serbian were included, which provides better and more productive communication and exchange of experience with the colleagues from abroad.

We would like to thank all the authors and co-authors of the papers and their mentors, and it is our wish that the young researchers would continue their successful careers and persist in realization of the goals they have set.

Nis, October 2019 Editors

THE CONTENT:

SESSION CIVIL ENGINEERING AND ENVIRONMENTAL PROTECTION / OBLAST GRAĐEVINARSTVO I ZAŠTITA ŽIVOTNE SREDINE

PhIDAC 2019 PhIDAC
V INTERNATIONAL SYMPOSIUM FOR STUDENTS OF DOCTORAL STUDIES IN THE FIELDS OF CIVIL ENGINEERING, ARCHITECTURE AND ENVIRONMENTAL PROTECTION

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ОДРЖИВИ ДИЗАЈН ЕНТЕРИЈЕРА - ПРИМЕНА ЕКОЛОШКИХ И РЕЦИКЛИРАНИХ МАТЕРИЈАЛА

Резиме: *Последњих година, све се више употребљавају појмови одрживог дизајна ентеријера и еколошких ентеријера. Примењује се потпуно нови приступ пројектовању унутрашње архитектуре, узимајући у обзир окружење, социолошке и економске принципе. Одрживи дизајн ентеријера фокусира се на квалитет живота корисника, али и на ефекат примењених принципа на околину. У раду је представљен значај и примена одређених материјала у одрживом дизајну ентеријера. Такође, приказани су и основни принципи одрживог дизајна и примери изведених пројеката са освртом на екологичност. Предмет овог рада је анализа појма одрживог дизајна и примене еколошких и рециклираних материјала у дизајну ентеријера објеката различитих намена. Коришћене су метода анализе, синтезе, моделовања и компарација датих примера. Циљ овог истраживања је испитивање и показивање значаја употребе одговарајућих материјала приликом пројектовања унутрашње архитектуре.*

Кључне речи: *одрживост, еколошки материјали, дизајн ентеријера, рециклажа, очување животне средине*

SUSTAINABLE INTERIOR DESIGN - USE OF ECO-FRIENDLY AND RECYCLED MATERIALS

Abstract: *In the recent years, the concepts of sustainable interior design and eco-friendly interiors have been increasingly used. A new approach to the design of interior architecture has been implemented. Sustainable interior design is focused on the living quality of users, but also on the effect of applied principles on the environment. In the paper is presented the importance and implementation of certain materials in sustainable interior design. Also, the basic principles of sustainable design and examples of realized designs with the accent on eco-friendliness are presented.The subject of this paper is the analysis of the concept of sustainable design and implementation of eco-friendly and recycled materials in the design of interior of buildings having different purposes. Synthesis, analysis methods, modeling and comparison of given examples have been used. The goal of this research is examination and demonstration of the importance of use of appropriate materials when designing interior architecture*

Key words: *sustainability, eco-friendly materials, interior design, recycling, environment preservation*

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1. INTRODUCTION

Global environmental crisis occurred as a consequence of long-lasting negative impacts on the environment, and by development of industries and technologies. Since there is a rising global awareness about the importance of preservation of the environment in which we live, new building and design systems are being developed. The goal is not only to improve the exterior but also the interior of a structure. Interior design, i.e. interior architecture represents an important aspect of the entirety of design of quality structure. The concept of sustainability in the interior has been increasingly used. Thus, for the sustainable development, it can be said that it is "development that meets the present needs without compromising ability of future generations to meet their own needs" [7]. That is, with the aid of sustainable development, as few detrimental effects on the environment as possible should be generated, and natural resources should be preserved. Sustainable design can be defined as a design which reflects human respect towards our planet, which preserves the resources for the present and future generations [7].

Designers can make a considerable change and improvement in terms of eco-friendliness using the appropriate methods. The changes can be achieved by the combination of learning and from the existing examples and through adoption of new technologies. It is very important that the interior designers first consider which approach is the best. This comprises overcoming of potential barriers towards realization of an eco-friendly design, simultaneously considering the consequences of own decisions, and posing the right questions during the designing process [4].

In order to obtain a quality design, designers need to understand the basic principles of sustainable design. In addition to the design of the form and construction of the building, the choice of energy sources and the water supply system, the selection of materials plays a very important role. Interior design and materials used for the production of furniture, interior structural elements, paneling of walls and floors, affect the aesthetic aspect, but also the comfort of users of space. Although aesthetics is an integral part of environmental design, most of the benefits are not seen but felt. Excellent results are obtained in terms of improving air quality, eliminating toxins, separating waste, and reducing water and energy consumption. Using easily accessible materials is emphasized. Particular attention is paid to assessing the life cycle of the material as well as meeting the appropriate standards.

This paper deals with the special importance of eco-friendly and recycled materials and their application in order to achieve sustainable interior design. Also, examples of the use of appropriate materials in the design of interior architecture are presented.

2. SUSTAINABILITY AND THE ROLE OF THE DESIGNER

Sustainability is one of the key components in addressing the global warming and environmental pollution problems. In construction, it was implemented through sustainable design. Although sustainability can be viewed through social, economic and environmental aspects, this paper focuses on the environmental aspects of sustainability. As the built environment or the construction industry has a very big impact on the environment, designers can take a significant step towards an ecological future.

Renovation of existing buildings and interior improvements is one of the best solutions for reducing carbon dioxide emissions. According to research, existing buildings in Canada emit about 40% CO_2, while in New York the value is up to 79%. An Athens Institute, has come to the conclusion that it is better to renovate existing buildings than demolish them and build new ones [4]. Interior designers and designers play a very important role in this case. They must first understand the concept of sustainable design, its meaning, components, application and availability in the local market. The designer is responsible for selecting the right finishing, lighting, carpentry, equipment, plumbing, as well as selecting interior details.

In order to obtain a quality and environmentally friendly design, the interior designer must adhere to certain principles and answer key questions (Figure 1). Seven issues have been singled out that follow the life cycle of a space, and it is important that each stage of the project is approached with a focus on sustainability and eco-friendliness. This is a universal scheme of the problem-solving process, and also shows the most important steps that a designer takes in sustainable interior design. During the whole design process, he must be prepared to compromise and think about the consequences of each step taken. As mentioned above, designers, through their work, can make significant changes and create the conditions for implementing the idea of sustainability and environmental conservation.

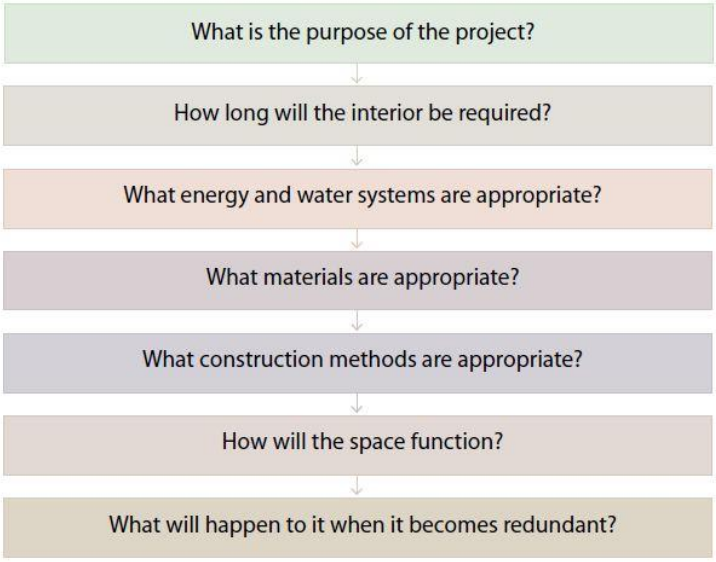

Figure 1- A diagram of questions to be answered by a designer [4].

3. PRINCIPLES OF SUSTAINABLE INTERIOR DESIGN

Sustainable interior design is defined as a process that significantly reduces or eliminates the negative effects of interiors on the environment. In other words, it is an approach that recognizes environmental impacts throughout the life cycle of an interior [6]. Pilatovicz defines sustainable interiors as interiors designed in such a way that they reasonably address the impact of all their functions, parts and elements on the global environment. It also regards eco-friendly interior design as a professional practice that tries to create an interior space that is environmentally sustainable and healthy for its users. [5]

Factors related to the reduction of the use of harmful building materials, recycling and pollution prevention are the most important aspects of sustainability in the context of interior architecture. In European Union countries, total energy consumption is 40%, carbon dioxide emissions are 30%, while 40% of synthetic waste is generated as a result of production in the construction industry [1]. As the built environment is one of the main sources of pollution, certain evaluation criteria have been formed. The evaluation criteria, as well as the assessment systems, aim to increase the number of designers and engineers using environmentally friendly and sustainable methods. There are numerous assessment methods such as LEED (USA), BREEAM (England), SBTool (International), Green Star (Australia), EcoProfile (Norway), Promise (Finland), Green Mark of Buildings (Singapore), CASBEE (Japan)). The most commonly used are LEED (Leadership in Energy & Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method). According to the LEED system, the following categories for evaluation stand out:

- Sustainable development of the location,
- Efficient water consumption,
- Energy efficiency,
- Material choice,
- Quality of the environment in the indoor space,
- Innovation and design process [2].

While according to the BREAAM method, the following criteria can be singled out:

- Management,
- Health,
- Energy,
- Transport,
- Water,
- Materials,

- Waste,
- Land use and ecology,
- Pollution: water and air pollution assessment [2].

Based on the previously mentioned criteria, the paper promotes four principles of the interior sustainable design:

- Energy,
- Water,
- Material,
- Health.

Energy saving is one of the guiding principles of sustainable interior design. The two main energy saving measures are the design and selection of energy efficient equipment and the use of renewable energy sources. In order to reduce power consumption, one of the solutions is natural lighting, ie. use of skylights, atriums, optimum opening area, as well as energy-efficient artificial lighting. Energy used to heat and cool a room can be reduced by using passive systems, preventing heat loss through special types of windows, window profiles and curtains. Lastly, by using renewable energy sources such as sun, wind and geothermal energy, can partially or fully meet user needs. Reducing water consumption is made possible by collecting rainwater or filtering wastewater, as well as by selecting the adequate plumbing equipment.

Material saving includes three main measures, namely flexible design, the use of eco-friendly materials and the reduction of waste. The first step to saving materials is choosing furniture and equipment that has a flexible, modular and flexible design. Also, significant amounts of materials can be reduced if long-lasting, resilient, easily maintained local materials are used. The amount of waste is reduced through the use of recyclable materials such as wood, stone, steel and aluminum, as well as the reuse of certain equipment in the space. Materials as a factor of interior sustainability will be discussed in more detail in the next section.

Preserving a healthy environment involves three criteria, namely improving air quality, thermal, visual and acoustic comfort and the use of non-toxic materials. Air quality can be improved by avoiding harmful and volatile materials such as radon and formaldehyde; as well as allowing sufficient natural ventilation. The optimum room temperature is achieved through the use of appropriate equipment and sensors, while the acoustic comfort is ensured by the use of high-quality sound proofing. Lastly, coatings with harmful vapors should be avoided [6].

4. MATERIAL AS ONE OF KEY FACTORS OF SUSTAINABILITY

The search for materials and products that have the least environmental impact becomes imperative rather than a matter of choice or luxury. The construction industry, as one of the most demanding industrial sectors in terms of environmental impact, needs to shift towards eco-friendly and recycled materials and their more widespread use. A wide range of building materials, which have a complex impact on our environment, is one of the main areas of sustainable design that can be influenced by designers. As mentioned in the previous chapter, the selection of materials is one of the main criteria of numerous sustainability assessment methods. In addition to savings and balanced consumption, it is also important to look at other factors. Below, the importance and impact of certain materials on interior design, their life cycle, as well as the selection of suitable materials for different purposes are discussed.

4.1 Material impact

The materials we choose to build and decorate the interior can further exacerbate resource depletion; influence climate change, lack of drinking water, loss of biodiversity, waste accumulation; cause pollution during production and endanger our health. The most pronounced effect of using certain materials is the depletion of resources.

A large number of natural materials are available in limited quantities and recover very slowly. One example is fossil fuels. The various types of plastics produced by their processing will become unavailable over time. Metal reserves are also limited, and global lead, zinc and copper reserves are projected to be depleted in the next fifty years [4]. The rock is formed in a natural geological cycle over thousands and millions of years. However, with the quarry's constant operation, the stone is consumed

before it can be recovered. Although stone and rock are abundant, the reserves of certain quarries will gradually diminish, leaving behind damaged natural landscapes.

Although wood is a renewable material, it takes many years for a newly planted tree to fully grow. This is especially true of hardwoods in the tropics. About 10% of existing tree species are endangered. Mahogany and certain types of walnuts are particularly endangered [4]. The use of this material is very common, but inadequate approach can result in the extinction of many plant and animal species. Also, removal of trees causes erosion of surface soil, which can adversely affect marine ecosystems and result in barren soil. Finally, massive logging reduces the absorption capacity of carbon dioxide from the atmosphere, which exacerbates climate change. For these reasons, the impact of the materials we use in interior design should be viewed from an environmental point of view and recycled whenever possible.

The use of materials has an indirect impact on the global warming, especially because of the energy consumed during their life cycle. This is called embodied energy and describes the energy necessary to obtain, process, manufacture, transport, install, maintain, demolish and dispose of a material. For example, the stone that will be used in the interior design of a space must first be processed in a quarry, then transferred to a factory, cut and formed into slabs, transported to a construction site, and eventually mounted. However, once the space starts being used, stone slab maintenance is required. Further, when the material becomes redundant, it must be dismantled and transported for possible reuse, recycling or disposal at landfill. Fuel is essential at every stage of this long process, contributing to carbon dioxide emissions and climate change. This problem can be solved with less intensive processing of natural materials. Similarly, the selection and treatment of materials affects the water consumption over the life cycle of the material.

Eventually, choosing the inadequate materials in interior design can also result in an unhealthy environment for the users of the space itself. Harmful fumes from coatings, adhesives and furniture can cause indoor air pollution. In addition to moisture and dust, this is one of the causes of asthma and "sick building syndrome".

4.2 Life cycle of materials

An analysis of construction products called "cradle-to-grave" involves monitoring the product from raw material until its use is complete. Thanks to it, long-term costs of materials can be determined. As mentioned previously, the life cycle of materials is a vital link in addressing sustainability issues. The life cycle design implies certain principles. The impact of every step of the production process from raw material collection, production, distribution and installation to completion of use and disposal is examined. Thus, the life cycle of a material can be divided into three phases (Figure 2):

- Pre-Building
- Building
- Post-Building [3].

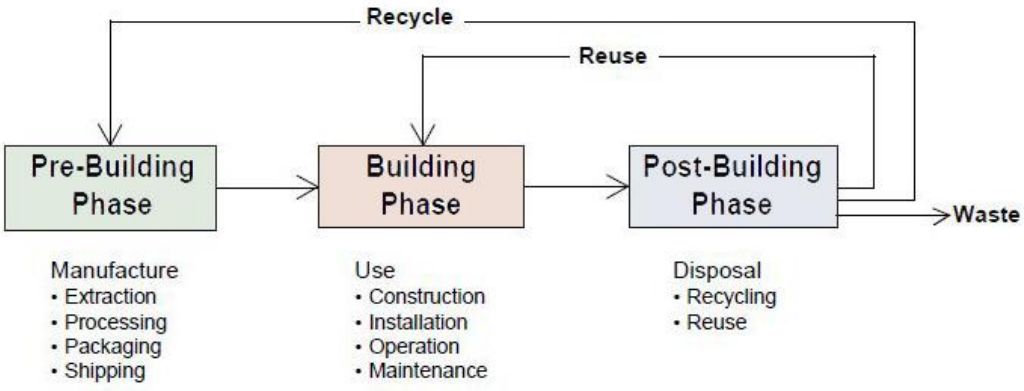

Figure 2- Scheme of a life cycle of a material [3]

The Pre-Building phase comprises material production and its transport, but not the installation. As presented in figure 2 this phase includes extraction of raw material, processing, packaging and shipping.

It simultaneously has the highest potential for creation of negative impacts on the environment. Understanding the consequences of this phase can lead to a wiser choice of building material. The Building phase relates to the use of materials, starting with installation, and includes maintenance and possible repairs. Finally, the Post-Building phase comprises the end of using a material in a certain space, i.e. its dismantling, disposal, reuse or recycling. From the designer perspective, this is the phase which is the least considered. However, it does not diminish its importance for achieving a better eco-friendly design.

4.3 Material choice – eco-friendly and recycled materials

Choosing the right materials to design the interior architecture of a given space is one of the most important factors in terms of sustainability. Based on the environmental impacts of materials described above, the standards and principles of sustainable design, some of the eco-friendly and recycled materials have been identified. In addition to the material characteristics themselves, their life cycle, that is, the environmental impact throughout its lifespan, has been taken into account; reproducibility of material sources, toxicity, as well as the possibility of reuse and recycling.

The most common materials (Base materials) used in eco-friendly interior design are wood panels, glass, metals and gypsum board. They can form a finished surface or be the basis for finishing. Wood panels include particle board, plywood, cement board and fiberboard. When choosing this type of material, care should be taken and boards containing resins residues without formaldehyde should be sought and certify whether the timber is recovered or procured from certified sources. Such panels represent the efficient and minimal use of timber for the production of quality furniture and panels of different sizes. Glass has medium energy consumption over the life cycle, as it is obtained from natural and abundant resources; it is non-toxic and recyclable. Recycled glass can be used as addition to a particular material, or for production of tiles and work surfaces. Metals are characterized by higher energy consumption, and it is recommended to use recycled metals that reduce losses and contribute to the savings of raw materials. Plasterboard has very low energy consumption (low embodied energy) and is a good insulator. The biggest problem is waste generated after installation or dismantling, however recycled-content plasterboard is available and helps divert waste gypsum from landfill [4].

There are numerous options when choosing a floor covering. Natural floor coverings include hard coverings such as wood, bamboo, ceramics or stone; smooth linings such as cork, linoleum and rubber; also rugs made of wool, cotton or vegetable fibers. However, recycled rubber, vinyl, and carpet mats are increasingly being used. The materials that are considered the best in terms of sustainability are cork, linoleum, local stone, wool, vegetable fibers, and recycled or certified wood. Also, from the point of view of material saving, the finished concrete is at the same time an excellent flooring and lining. As with basic materials, consideration should be given to energy consumption, toxic ingredients and source renewability.

Coatings and finishes include paints, sealants, plasters and wallpaper. They can be used on numerous surfaces, from walls, floors, ceilings to the furniture and other equipment. When using coatings and wallpaper, special care should be taken of what they are made of and whether they cause harmful fumes during or after application. It is advisable to avoid synthetic paints, so it is ideal to use flax oil-based emulsions with natural pigments or water-based vegetable dyes. Furthermore, it is recommended to use varnishes and coatings based on water or natural oil without additives, and products with beeswax and resin. Recycled paper wallpaper is also suitable for wall coverings, while clay-based mortars are the least harmful [4].

Numerous types of fabrics are used to finish various elements in the interior. They can be divided into natural and artificial or synthetic ones. Generally, the fabric production and dyeing process can adversely affect the environment. Natural fabrics such as wool, felt and linen are most suitable, which allow the designer to check their origin and monitor the consequences of the production process. As with flooring, vinyl, non-recycled nylon and inorganic cotton should be avoided. It is also important to use fabrics that are dyed with natural colors.

4.4. Examples of usage of eco-friendly and recycled materials in the sustainable interior design

Based on the principles of sustainability and materials discussed in the paper, some of the positive examples of the use of eco-friendly and recycled materials in interior design have been identified. These materials have a wide application, from furniture making, to the complete fitting of a space. As a first example, the possibility of making furniture from existing elements was singled out; such as shopping carts, making benches from recycled newspapers, or chairs from used fishing nets (Figure 3). Such equipment can be incorporated into interior design for various purposes and contribute to the environmental aspect of design.

Figure 3- Potential of producing furniture from the recycled materials or used products [4, 8]

Figure 4-Housing and public spaces within LEED certified buildings [8]

As mentioned previously, eco-friendly and recycled materials have found application in numerous design segments. All the interiors presented above are LEED certified (Figure 4). The first interior shown was designed by Bates Masi, located within the Annapolis residence. A special emphasis is placed on wood as a natural material and carefully selected textiles. The second segment is part of the kitchen within the offices of the Amsterdam Tech Company, where with the reuse of old products a completely new and modern space was created. The third interior is the glazed garden of Tsingpu Yangzhou Resort, which is dominated by bamboo and local stone. This briefly outlines the wide range of uses of different types of materials and the ability to design sustainable and modern spaces.

5. CONCLUSION

Interior architecture should fit the needs of users and create the most comfortable space for living and working. The problem of global pollution covers every aspect of our lives, including interior design. Sustainability must first and foremost be present in the design of interior architecture to minimize the adverse effects on our environment. The architect or designer plays a key role in achieving sustainability. Also, one of the most important segments is the selection of appropriate materials. Materials undergo a specific process that can be followed thanks to a life cycle assessment. Based on this, we come to the conclusion which material is the most suitable and causes the least harmful consequences. For interior design to be successful and in accordance with environmental standards, it is necessary to look at the

problem from several aspects and answer the most important questions. The whole process is very complex and makes only one aspect of the sustainability issue; but it is a significant step towards a better and eco-friendly future.

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