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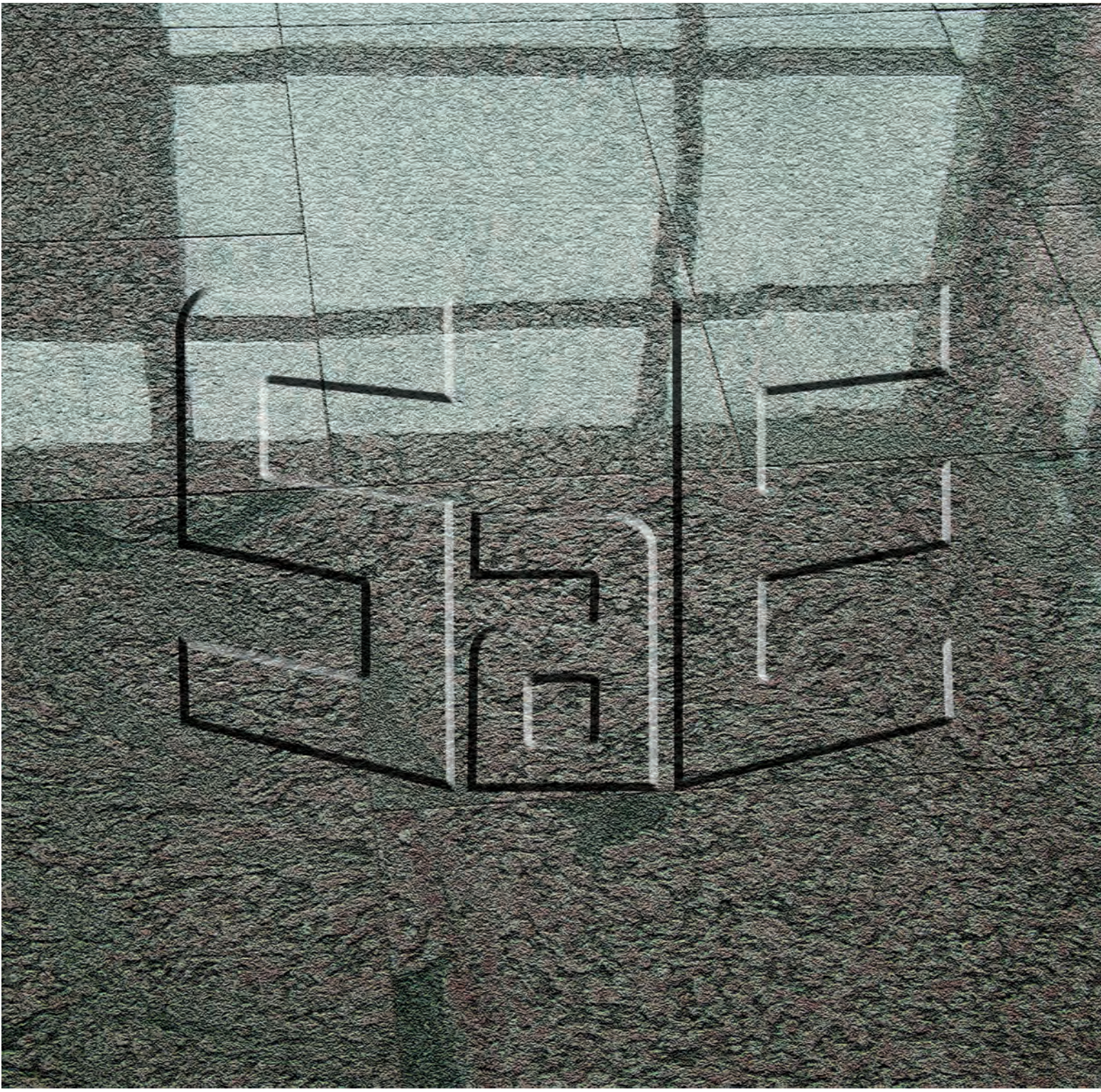

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EXPERIMENTAL STUDY ON THERMAL COMFORT AT UNIVERSITY BUILDINGS IN SLOVAKIA

EKSPERYMENTALNE BADANIE KOMFORTU CIEPLNEGO W BUDYNKACH UNIWERSYTECKICH NA SŁOWACJI

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Abstract

The paper discusses the issue of thermal comfort expressed by the students of the University of Žilina in anonymous questionnaires. The volunteers rated their thermal sensations, preferences as well as lighting conditions in the autumn season. The students were in favour of the prevailing thermal conditions – almost 88% of the volunteers expressed positive opinions about their environment. The comparison of the test results for a computer laboratory with the Fanger model calculation results was also made and indicated differences between the experimental data and values determined with the model.

Keywords: thermal comfort, thermal sensations, Fanger model

Streszczenie

W artykule omówiono zagadnienie komfortu cieplnego studentów Uniwersytetu w Żylinie w oparciu o anonimowe ankiety. Ochotnicy oceniali swoje odczucia termiczne, preferencje oraz warunki oświetleniowe w okresie jesiennym. Studenci wyrazili się pozytywnie w zakresie panujących warunków termicznych – blisko 88% odpowiedzi. W pracy dokonano również porównania wyników badań w laboratorium komputerowym z wynikami obliczeń wg modelu Fangera i wykazano różnice między danymi eksperymentalnymi a wartościami wyznaczonymi modelem.

Słowa kluczowe: comfort cieplny, wrażenia cieplne, model Fangera

1. INTRODUCTION

The need for maintaining thermal comfort conditions at buildings is related to the basic human needs and, thus, much attention should be paid to keep room users satisfied with their thermal environment. It is mostly related to air temperature, however a number of other factors might have an impact such as air humidity, activity level of the people and their clothing as well as air flow speed [1]. The mathematical description of thermal comfort has been proposed by Fanger [1] and is now part of the international standard ISO 7730 [2], which can be used to determine how people would rate their thermal environment.

The issue of providing thermal comfort is especially important for public utility buildings, where many people spend significant amounts of time. A study by Krawczyk and Kapjor [3] covered almost a hundred respondents up to 23 years old at two buildings of Kielce University of Technology (Poland). The measurements were made during winter. The authors

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indicated that the majority of the students positively assessed the indoor thermal environment, however the conditions for ca. 15% of women were described as "cold". Large difference were observed between the actual responses and calculation results according to the Fanger model of thermal comfort. Dębska [4] carried out tests of thermal comfort at the intelligent educational building in Kielce, during which 164 students were asked about their thermal sensations. It was reported that the indoor air temperature of 19.3-27.6°C was acceptable as well as comfortable for about eighty percent of the room users. Although the majority of the students was satisfied with the indoor conditions, there were some who considered it to be "too cold" or "too hot". The sensations regarding air humidity were also generally positive. In the paper by Dębska et al. [5] the test results collected from fourteen students in the room were the air temperature was very high (29.4°C) were presented. Despite such elevated temperature half of the respondents found the conditions as acceptable (40%) and comfortable (10%). Similarly, 40% of them assessed humidity as pleasant (with the measured value of relatively humidity of ca. 52%). In [6] a methodology of assessing both heat and mass transfer together with the related exergies between the human body and the environment was presented. Only four people (2 women, 2 men) participated in the testing. It was shown that women feel thermal comfort in higher climatic conditions. Jindal [7] provided data on thermal environment and thermal perception of 130 students. The respondents felt most favourably in the temperature range from 15.5°C to 33.7°C. A recent study [8] of indoor environment, lighting conditions and productivity conducted at four educational buildings over eleven months proves that for the measured air temperature range of 20-25.1°C and humidity of 18.16-50.9% the respondents were generally satisfied or neutral with regard to their well – being. They also assessed lighting conditions as being appropriate (about 82% of the votes). Moreover, the authors also noticed that productivity of the students was linked with the air temperature in a given room. The best results were recorded for the values of about 23-24°C. Kolkova et al. [9] performed tests in the intelligent building located at the campus of the University of Žilina. The experimental analyses covered two different positions of the blinds in the windows. It was stated in the paper that the optimum temperatures were not exceeded during the measurements. According to Jazizadeh et al. [10], who focused on thermal comfort tests in offices, air temperature is the most important parameter that impacts thermal sensation of the people in rooms. Naturally, other factors for example carbon dioxide concentration, light intensity and etc. might play a role. This role can be significant in certain rooms and the impact of the above mentioned factors might be bigger then the impact of relative humidity.

It needs to be added that the indoor environment consists of a number of elements other than air temperature and humidity. Carbon dioxide concentration, air contaminants, noise and other factors might influence people's well – being. Telejko et al. [11] focused on the issue of the sick building syndrome and analysed the health problems at a lecture room of almost seventy students. The number of respondents experiencing headaches was high, expecially in the group of women (with over 30% votes). Similarly other problems such as watery eyes, sore throat and concentration problems were reported by a number of people. This indicates the need for more detailed analysis of indoor environment due to the possibly negative influence on people there. Equally important is the need to consider thermal comfort in buildings undergoing modernization as pointed out by Kosiński and Skotnicka-Siepsiak [12]. The problem is currently especially vital in Poland, where many buildings require modernisation works.

Recently Orman and Wojtkowiak [13] presented test results of thermal comfort measurements at university buildings located in the Western part of Poland and found out that the majority of students were in favour of thermal conditions in two considered classrooms. Naturally, the indoor environment is dependent on a large number of factors such as heating or cooling systems. A significant impact can also be attributed to the design and operation of windows (as pointed out by Sadko and Piotrowski [14]) as well as the proper design of heat exchangers, which are part of heating systems (as indicated by Polacikova et al. [15]).

The present article aims to analyse the thermal sensations as well as lighting assessment of the students of the University of Žilina. The volunteers filled in the anonymous questionnaires regarding their current sensations. The study is also focused on the verification to what extend the Fanger model of thermal comfort can successfully determine the people's responses as given in the questionnaires. Studies of thermal comfort in Slovakia are rare (with the exception of e.g. [16]), thus the present paper will provide more information and data on this subject.

2. MATERIAL AND METHOD

The tests took place in Žilina, which is located in the Northern part of Slovakia – at the altitude of 347 m. Its average annual temperature is 7.8°C. February is the driest month, while in July precipitation is highest. The average monthly air temperature ranges from -3.6°C in January to 18.1°C in July [17].

The measurements consisted in completing a questionnaire containing questions on thermal sensations as well as light intensity assessment. The questions and answers within the questionnaire will be presented in the next section together with the test results. A total of one hundred and fourteen students participated, in various rooms. Figure 1 presents a computer laboratory at the University of Žilina as an example room, where the tests took place.

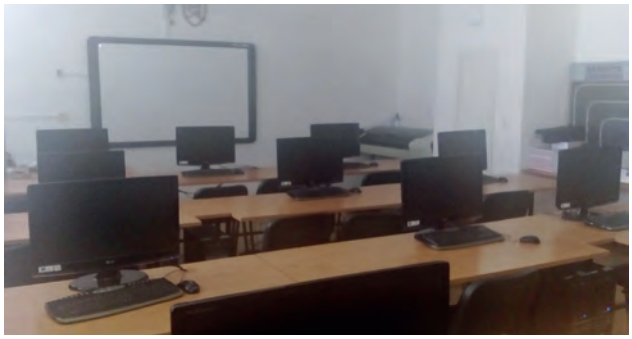

Fig. 1. An example room (computer laboratory) at the University of Žilina

Apart from collecting information about the subjective sensations of the respondents, the measurements of the indoor air parameters took place with the sensors. The measuring devices were located in the centers of the rooms, so that the gathered data could be treated as average values.

3. RESULTS AND DISCUSSION

The study was conducted in autumn, thus the respondents wore mixed clothes. They ranged from summer outfits to thick winter clothing depending on the day. However, within a given group of students occupying a certain room, the diversity in clothing was quite limited and this factor did not influence the results. Moreover, the room users adopted their clothing to the prevailing conditions in the rooms and the equipment present there that might release heat (as in the case of a computer laboratory).

The first question in the questionnaire dealt with the students' assessment on their thermal sensations at that moment of the measurements. They presented their opinions of the indoor thermal environment as "thermal sensation vote" by ticking appropriate boxes in the questionnaire ranging from "too hot" (+3), via "hot" (+2), "warm" (+1) and neutral (0) to negative values – maximally to (-3), which meant "too cold". Figure 2 presents the results of the study as a frequency count of all the answers.

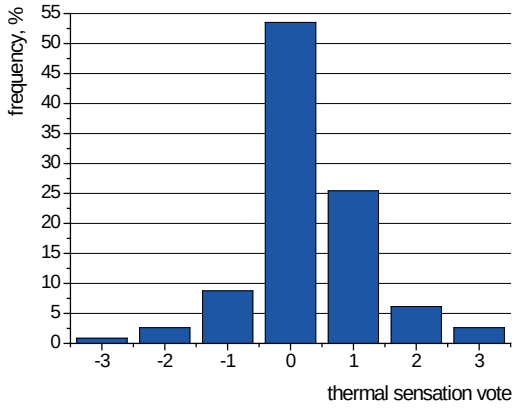

Fig. 2. Assessment of thermal sensations

53.5% of the students felt neutral, while 8.8% and 25.4% were either cool or warm, respectively. Thus, almost 88% of the respondents were generally satisfied with the environment of the rooms. It indicates a high level of satisfaction. Despite this, there were some individuals who expressed strong opinions (values of +3 and -3), however it might have been caused by health conditions, hunger or individual preferences and not necessarily by the thermal environment of the indoor space.

The next question was focused the respondents' willingness to alter the state in the rooms regarding air temperature. The students might have opted for "much warmer" (+2) via "no change" (0) to much cooler (-2) indoor environments. The obtained results have been presented in Figure 3 as the frequency count of the given "thermal preference votes".

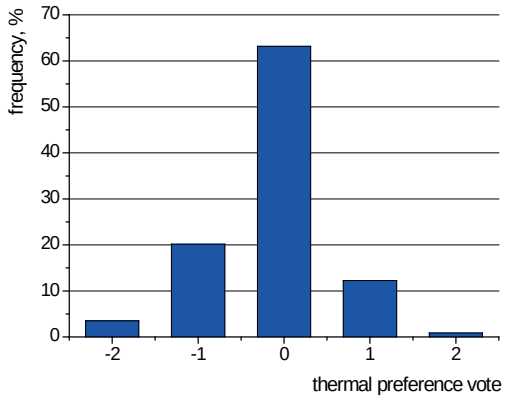

Fig. 3. Assessment of thermal preferences

63.1% of the room users wanted no change to occur in the rooms, which further backs the conclusion that the thermal environment was fine. 20.2% would like the temperature to slightly decrease, while 12.3% – to slightly increase. Both extreme responses of (+2) and (-2) did not exceed 5% of the answers.

The third question dealt with the assessment of lighting conditions. The students were asked how they rated the level of illuminance and could respond that it was acceptable (0), too strong (+1) or too weak (-1). The results have been presented in Figure 4.

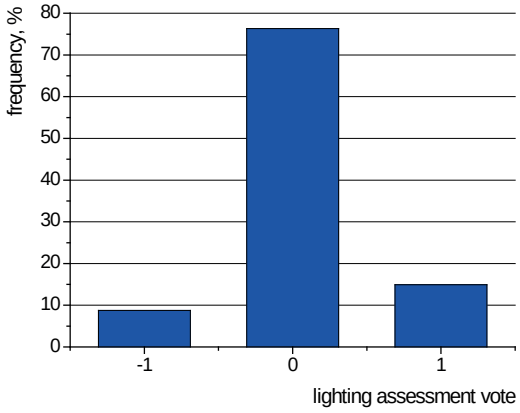

Fig. 4. Assessment of lighting conditions

76.3% of the students thought that the lighting conditions were acceptable. Naturally, it is a subjective assessment only and might be influenced by a number of factors (other than illuminance) such as the location of the light sources in the ceiling, the orientation and size of the windows in the rooms as well as part of the day, tiredness and etc. Nevertheless, this assessment is important in educational and office buildings because it might effect the productivity of the room users.

Apart from the actual testing of human thermal sensations, which is typically conducted with the use of questionnaires, it is equally important to be able to determine people's responses before the building is actually built or to be able to design heating/ventilation systems and their operation in a more user-friendly way. It is done with the view to providing room users with most preferable and comfortable conditions for living or working activities. The most common and widely accepted model of thermal comfort was developed by Fanger [1] and is used in the standard [2] throughout the world. It is able to determine the thermal sensation vote value (denoted as PMV) for a group of people in a room as well as the share of the people who are dissatisfied with the indoor environment (denoted as PPD). The value of PPD can be calculated based on the questionnaires as the ratio of the votes (+3, +2, -2, -3) to the total number of votes. The equations given in [2] have been used to calculated both PMV and PPD for a group of 10 students located in the laboratory (Fig. 1) according to the Fanger model. While the questionnaire answers provided by the students enabled to determine the experimental values of PMV (or TSV as in Figure 2) and PPD. The comparison of the experimental and calculation results has been presented in Figure 5.

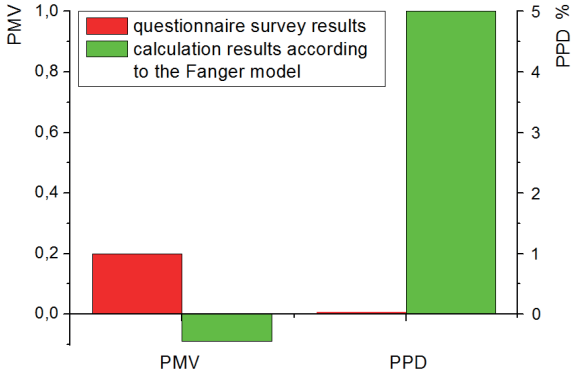

Fig. 5. Comparison of the test results for one room with the calculation results according to the Fanger model

The mean value of thermal sensation vote for the considered room was 0.2 (basing on the questionnaires), while the calculations performed with the equations constituting the Fanger model produced the value of PMV as -0.09. The difference is not significant especially that the scale ranges from -3 to +3. More significant discrepancy can be observed for PPD. The number of the students who were dissatisfied with the environment in the analysed room was 0, while the model calculations led to the value of 5%. Both of these values indicate a positive assessment of thermal comfort in the considered room. It needs to be noted that literature provides examples of much larger discrepancies, if the Fanger model is used. This fact encourages authors to developed their own modifications of the model in order to improve the accuracy of the calculations – as presented in [3, 18].

4. CONCLUSIONS

The study of thermal sensations and lighting conditions in the buildings of the University of Žilina provided new insights into the subjective assessment of the students regarding their indoor environment. It was observed that the respondents were overwhelmingly satisfied with their thermal

environment (almost 88% of the responses). Thus, they were not willing to change the indoor air parameters, as indicated by 63.1% of the "no change" option with regard to the thermal preference vote. The lighting conditions were also positively assessed.

The comparison of the experimental results for a selected room (computer laboratory) with the calculation results according to the commonly accepted Fanger model showed differences. It might be related to a small number of students in a given room and the impact of other parameters – not considered in the model calculation methodology such as carbon dioxide concentration.

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TRAFFIC ZONES ACCESSIBLE FOR ALL USERS. DESIGN SOLUTIONS AND MATERIAL RECOMMENDATIONS FOR OUTDOOR TRAFFIC ZONE PAVEMENTS

PRZESTRZEŃ KOMUNIKACJI DOSTĘPNA DLA WSZYSTKICH. ROZWIĄZANIA PROJEKTOWE I WYTYCZNE MATERIAŁOWE NAWIERZCHNI CIĄGÓW KOMUNIKACYJNYCH ZEWNĘTRZNYCH

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Abstract

This article discusses the aspects of designing the pavements of pedestrian zones, shared spaces, city squares and other public spaces in terms of the selection of their parameters, colour and texture, which can significantly improve their comfort of use and, in a wider context, improve the accessibility of public spaces and buildings. When we think about a friendly city, we aim to create urban spaces free from any barriers that could exclude some people from the social life. Urban space can be defined as friendly from the perspective of an end user who moves around on foot, or uses crutches or a wheelchair, but also in the context of fully fit people, who are nevertheless limited in their movement because they are pushing a pram, carrying a baby or heavy luggage, etc. It has been proven that a well-designed pavement can significantly improve access to an area, reducing therefore the stigmatisation of elderly, disabled, blind, visually impaired people, etc. Solutions described in this article go well beyond the applicable legal acts in the context of the building law and therefore significantly improve the accessibility of public spaces and buildings and help to create spaces that are friendly to all users – i.e. spaces that are safe and free of any risks connected with disorientation, psychological security or the possibility of collision due to the existing barriers.

Keywords: universal design, accessibility, pavement, pedestrian zone, urban environment

Streszczenie

Artykuł porusza aspekt projektowania nawierzchni ciągów pieszych, pieszo-jezdnych, placów miejskich i innych przestrzeni publicznych pod kątem doboru ich parametrów, kolorystyki oraz faktury, które w znacznym stopniu poprawiają komfort ich użytkowania, a w szerszym kontekście, zwiększają dostępność przestrzeni i obiektów publicznych. Myśląc o mieście przyjaznym, należy wziąć za cel kształtowanie przestrzeni miejskich bez barier wykluczających z życia społecznego. Należy wspomnieć, iż o przyjaznej przestrzeni możemy mówić w kontekście bezpośredniego użytkownika poruszającego się przede wszystkim pieszo lub za pomocą kul i na wózku inwalidzkim, ale również osób w pełni sprawnych, lecz ograniczonych przez np. przemieszczanie się z wózkiem dziecięcym, dzieckiem na rękach czy ciężkim bagażem itp. Wykazano, że odpowiednio zaprojektowana nawierzchnia znacząco wpływa na dostępność przestrzeni, a tym samym na zmniejszenie wykluczania osób starszych, osób z niepełnosprawnościami, niewidomych, niedowidzących itp. Przedstawione w artykule rozwiązania szeroko wykraczają poza obowiązujące akty prawne w świetle prawa budowlanego, tym

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samym znacząco wpływają na dostępność przestrzeni i budynków publicznych oraz kreują przestrzeń przyjazną każdemu użytkownikowi, czyli bezpieczną i niestwarzającą zagrożeń związanych z dezorientacją, bezpieczeństwem psychicznym i ewentualnymi kontuzjami na skutek istniejących barier.

Słowa kluczowe: projektowanie uniwersalne, dostępność, nawierzchnia, ciąg pieszy, środowisko zurbanizowane

1. INTRODUCTION

Disability is a social problem. Global forecasts indicate that by 2050, the percentage of people over the age of 65 will rise to 22% of the whole population. According to the WHO, in Europe this percentage will even rise to 33% [1]. The composition of our population is changing, which is connected with the ageing of the society and with the noticeable increase in the disability of people as a result of illnesses and accidents. Some elderly people suffer from physical limitations and lower perception. Additionally, there is a significant number of younger people with congenital disability, or disability acquired as a result of accidents or illnesses. Their numbers continue to rise together with the progress of civilisation. The current level of medicine offers a better chance of survival and continuous functioning for patients who suffer from illnesses that were previously incurable. Similarly, more people with serious accident injuries can now be saved. The functioning of such people depends to a large extent on spatial and product-related solutions in the context of the built environment [2, 3]. Groups of people with mobility impairments (the users of wheelchairs and crutches) experience discomfort when the quality of pedestrian zones is not sufficient. But mobility impairments affect a much larger group of people, including groups particularly vulnerable, such as the blind and visually-impaired persons, the elderly, or fully fit people whose movement is limited because they are pushing a pram, carrying heavy luggage, etc [4]. Limited physical ability is a frequent problem among the elderly, but it can also be a temporary issue for many young people with temporary injuries. We must also take note of the fact that the carers or assistants of elderly and disabled people also have to overcome physical barriers that exist in the urban environment (pushing wheelchairs, prams, etc.).

The concept of universal design, which represents a product- and environment-related design philosophy, attempts to answer these challenges, but is still considered to be more of a line and method of thought than a method as such [5]. The concept of universal design was created by the American architect Ronald Mace (1941-1998) and initially only related to architectural design. As an architect who had been confined to a wheelchair since birth, Ronald Mace stated that: *'universal design is the designing of products and environment to be usable by everyone to the greatest possible extent, without the need of any modifications or individual design'* [6]. The concept of universal design sets out new ways of thinking. It is based on the principle of equality to a higher extent than the concept of ensuring general accessibility to people with mobility impairments, which means that any actions related to this concept will in essence cater to the needs of all users and will not require any special solutions. Designing is therefore understood as a common term that describes all actions connected with the shaping of the environment [7]. The concept of universal design is constantly evolving because of the growing needs of disabled, elderly people, etc. and because of their ever higher conscience and willingness to participate in all aspects of the social life. In view of the above information, all actions related to universal design and spatial accessibility are significant, because they lead to the creation of friendly spaces that encourage people to walk and by this minimise the effect of social exclusion due to problems such as personal disability [8]. Research has shown that one of the main factors that affect the mobility, and therefore the social activity, of particularly vulnerable/disabled people, is an inappropriately organised pedestrian zone, in terms of the type and quality of its pavement and the method of its construction. Problems most often arise due to incorrectly designed or built sidewalks (pedestrian zones, shared spaces), poor maintenance, the absence of a smooth transition between different types of pavement, or the omission of natural terrain properties in the design. Barriers that can be found in pedestrian zones include: ridges of the height of more than 2 cm, uneven pedestrian zone pavements covered by greengrowth, inadequate, inappropriately steep pedestrian sidewalk surfaces, as well as inappropriate arrangement of the elements of street furniture, e.g. benches, rubbish bins or lampposts – which can constitute movement-restricting barriers [9, 10].

2. AIM

The aim of this publication is to establish the guidelines for the design and construction of pedestrian (shared) zone pavements and for their connection with roads, in terms of solutions related

to the type of designed pavement – dedicated under the principles of universal design in order to improve the freedom and comfort of movement, thereby improving the accessibility of public spaces and buildings for people with mobility impairments.

3. LEGAL REGULATIONS

The aspect of accessibility of buildings and spaces in Poland is defined by the *Regulation of the Minister of Infrastructure on technical conditions to be fulfilled by buildings and their location* [11].

These regulations currently define elements such as:

- pedestrian and vehicle approaches to buildings, entrances (stairways, outdoor ramps, access ramps, entry doors to buildings, etc.) (Chapter 2 – pedestrian and vehicle approaches, § 16 – pedestrian approach for the disabled);
- stairs and access ramps (Chapter 4, § 71);
- solutions for parking spaces for the disabled – their dimensions and distances from entrances to buildings (Chapter 2 – car parks and garages, § 20 – parking spaces for the disabled);
- width of corridors, pedestrian zones, their forming methodology, etc. (Chapter 5. Rooms for human accommodation, § 73, § 74, Chapter 3. Entrances to buildings and apartments, § 61, § 62);
- sanitary rooms for disabled persons (Chapter 6, § 86).

Another applicable regulation is the *Regulation of the Minister of Infrastructure of 17 June 2011 on the technical conditions to be fulfilled by metro structures and their location*, which defines, among others, the accessibility of the area within metro structures [12].

Although the applicable regulations define the principles of designing elements such as pedestrian zones, in practice the compliance with their requirements is often not sufficient to fulfil the mobility requirements of disabled persons. Therefore many spaces and buildings become inaccessible for such users, including particularly vulnerable people. The above Regulations are complemented by the so-called accessibility Standards, which were drawn up in response to the growing needs of particularly vulnerable people, in order to ensure equal access to buildings and spaces for everyone. These standards are intended to improve the levels of accessibility. They take into consideration the needs of people with different types of disability, especially those with mobility impairments, blind and visually impaired persons, deaf and hard-of-hearing persons, people with intellectual disabilities, mental disorders or illnesses, or those with communication impairments. They constitute a set of guidelines for architects and designers that include agreements on the elimination of barriers and the implementation of means that provide better access to public spaces, especially for disabled persons. These standards cover the aspects of designing sidewalks, pedestrian crossings, mass transit stops, temporary traffic organisation during renovation works, parking spaces, recreational areas and universal information (pictograms, colour scheme, etc.).

The standards may apply to individual cities, or may refer to buildings of a specific function – most frequently they apply to public buildings (as defined in the technical conditions) and to public spaces [13].

Below is a description of solutions for elements of public spaces in the context of pedestrians, i.e. for pedestrian zones and shared spaces (sidewalks, city squares, pedestrian crossings, mass transit stops, parking spaces), with the emphasis on the selection of the type and technology of their pavement, which can significantly improve their accessibility and comfort of use. Information presented below exceeds the scope of the Technical Conditions and concentrates mainly on the Standards of Accessibility of Public Spaces for Disabled Persons for the city of Kielce and on the authors' experience and research in the context of the accessibility of public spaces [14].

4. PEDESTRIAN SPACE – ANALYSIS

The aspect of accessibility of pedestrian space has been analyzed in terms of:

- selection of pedestrian route parameters (width of the string and buffer, location of accompanying elements and elimination of obstacles and barriers in space);
- selection of surface colours;
- selection of surface materials;
- organization of parking spaces;
- selection of lighting;
- overcoming terrain differences (elimination of thresholds, terrain stairs and ramps).

4.1. Pedestrian zones

A safe and obstacle-free pedestrian traffic gauge should be established in a clear and legible way, with particular emphasis on the needs of visually impaired people. The width of a pedestrian zone should be established on the basis of an analysis of the current and forecast traffic density patterns. The width necessary for two wheelchairs to pass each other should be taken into account. Technical conditions stipulate that approaches to buildings should be at least 1.5 m wide,

whereas the width necessary for two wheelchairs to pass each other is 1.8 m (the Standards recommend 2 m). Due to the tendency of pedestrians to maintain a certain distance from obstacles or from the carriageway, a pedestrian zone should include a so-called buffer zone, representing an extension of the sidewalk in the form of an additional safety zone, which will inform the pedestrians that they are crossing the border of the safe zone via a different pavement texture and colour than for the pedestrian zone. The width of the buffer zone must ensure a safe distance from all obstacles, but should also allow a blind person to touch the walls of buildings situated along the pedestrian zone with a cane. For example, the width of the buffer zone alongside a building's wall is 30-70 cm, whereas alongside the edge of a carriageway or a bike path it is 50 cm (Fig. 1).

Fig. 1. An example of a correctly implemented path on both sides of a pedestrian zone. Spain. Photo: W. Tracz

It is especially important to eliminate technical, visual obstacles, barriers and physical obstacles from the pedestrian zones that reduce the minimum width of the pedestrian zone, such as:

– elements of street furniture (benches, rubbish bins, information boards, bike racks, road signs, posts, etc.) and temporary street elements (tables, chairs, stands, booths, exhibition elements), which must not reduce the minimum width of a pedestrian zone (2 m) – it is recommended to situate them for example in the greenery belt or in the buffer zone (Fig. 2);

Fig. 2. Shared zone. The arrangement of street furniture (lighting, rubbish bins, tables) in a way that does not reduce the minimum width of pedestrian traffic space. Spain. Photo: W. Tracz

– drainage gullies and drainage gutters – which can trap a blind person's cane or the wheel of a wheelchair, or crutches (Fig. 3) – if it is necessary to situate these within a pedestrian zone or a public square, it is recommended to ensure that they are flush with the pavement (in the case of gullies), or to apply the principles of implementing ridges and the mutual connection of different materials (Fig. 4).

Fig. 3. Obstacle in the form of a drainage gutter installed below the pavement level, thus creating a ridge. Kielce. Photo: M. Wijas

Fig. 4. A correct solution of a drainage gutter, which has been installed flush with the pavement of a shared zone. Photo: M. Wijas

One of the important factors which define the safety of moving within a pedestrian zone is the drainage of storm water, which in effect reduces the risk of slipping on a wet or icy surface. Such comfort is ensured using an appropriate cross slope. According to the Regulation of the Minister, the value of the cross slope of a pedestrian zone should be between 1-3%. Whereas according to the Standards, this slope should be lower than 2%, because a higher slope means more force is needed to move a person on a wheelchair, or prevents the movement along such a zone without the help of other persons [15].

4.2. Pavement colour and contrast

An important aspect of universal design in the context of designing urban areas is the choice of colour and contrast. Very dark colours used next to each other, on similar surfaces with a similar texture, may become indistinguishable. Very bright, pastel colours used in such conditions will be blurred. We must be aware that visually-impaired and intellectually disabled people pay attention mostly to colour contrasts, while blind people to texture contrasts. According to British standards, colour contrasts are calculated on the basis of the light reflectance value (LRV). The difference in contrasts of less than 30 on the LRV scale does not generate sufficient visual information. The recommended contrast for safety marking is 70%. Ophthalmologic tests have clearly shown that the last colour seen by a human eye that is losing sight is yellow. On one hand, the colours and textures of routes should be variable (the use of different combinations of pavement types and colours on pedestrian pavements to emphasise the main directions of movement and to demarcate different functional areas), but using too much contrast must not create an impression of a difference in levels. The use of different colours and suitable colour contrast levels not only provides adequate spatial perception, but also serves to indicate risks present in this space, e.g. yellow colour of pavement next to pedestrian crossings, yellow marking of steps in the case of stairs (Fig. 5) and the edge of a railway platform (Figs. 6, 7) and a bus stop (Fig. 8), the use of different colours for sidewalks and bicycle paths, or increasingly frequent marking of pedestrian crossings with a distinctive and strongly contrasting red colour (Fig. 9).

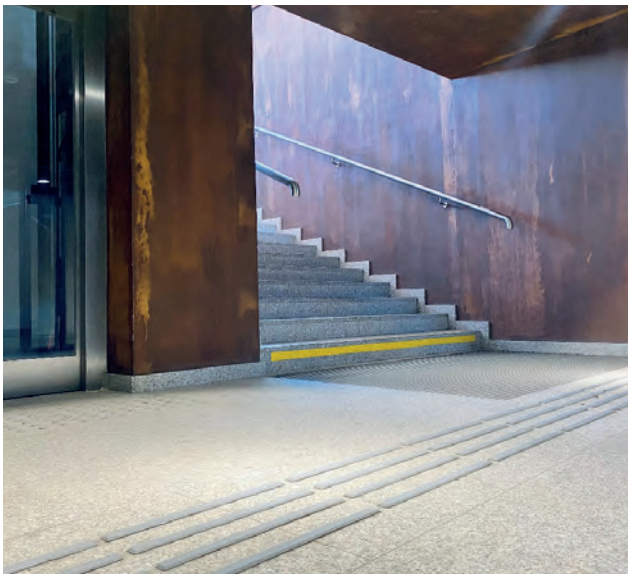

Fig. 5. An example of the correct yellow marking of staircase steps. Bus terminal. Kielce. Photo: M. Wijas

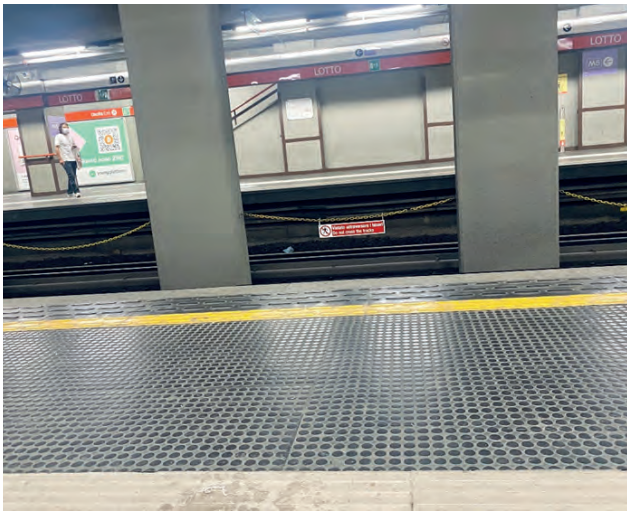

Fig. 6. The correct use of variable pavement textures and colours at a metro station. Milan, Italy. Photo: M. Wijas

Fig. 7. The correct use of variable pavement textures and colours at a transport hub, Wrocław, source: https://www.bryla.pl/bryla/1,85301,12275613,Przystanek_we_Wroclawiu__Rzezba_z_betonu__ktora_zachwycila.html

Fig. 8. The correct use of tactile pavement at a bus stop. Opole. Photo: S. Mochocka

Fig. 9 The correct use of contrasting pavement colours in the location of a pedestrian crossing. Kielce. Photo: M. Wijas

4.3. Materials

The pavements of pedestrian zones must be made of elements that ensure a hard and even surface that is comfortable not only for people in wheelchairs, but also for prams or women in heels. The pavement must maintain its properties throughout a long operating period, in variable weather conditions and must be resistant to mechanical and chemical wear (e.g. during the removal of snow or due to sprinkling with salt). Materials classified as adequate for pedestrian zones include:

– large concrete or stone slabs;
– non-chamfered concrete setts;
– asphalt, or stabilised stone dust in more natural spaces;
– tartan track or fluted panels.

The pavement of a pedestrian zone should minimise the possibility of slipping. The slip resistance of setts, concrete and stone slabs is selected on the basis of applicable standards. In locations where the intensity of pedestrian traffic makes it difficult for blind people to receive stimuli, i.e. near bus stops, in the area of intersections, pedestrian crossings or approaches to buildings, it is recommended to install tactile walking surface indicators (TWSIs) and to design tactile pavement paths, which are intended to help blind people with their orientation and to show them the direction of movement. This system should be also installed in areas without any natural navigation elements, such as: large squares, wide pedestrian zones, or other areas which require more attention from pedestrians, such as the discontinuation of protruding kerbs, in order to act as the replacement of the kerb.

The TWSI system consists of the following tactile tile types:

– directional tiles (TWSI – type A) – used to create paths that guide users along a certain route (Fig. 10);
– attention tiles (TWSI – type C) – so-called indication tiles, which are installed at the bends of a tactile path, in places where the path branches out, or before the path's end points (Fig. 11);
– warning tiles (TWSI – type B) – installed in the form of warning strips that contrast with the pavement and are installed flush with the pavement, these are used in front of pedestrian crossings, approaches to and exits from stairs, in front of surfaces with an inclination of >3%, in front of entrances to buildings, at rail platforms and bus stops and to inform the users that they are approaching an entrance to a building or a hazardous zone (e.g. an edge between a carriageway and a sidewalk) (Fig. 12).

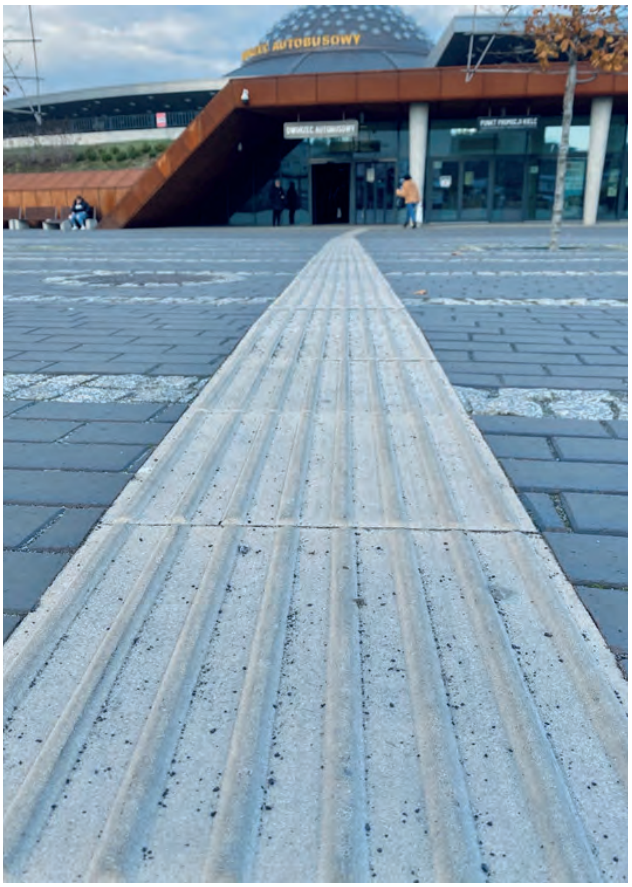

Fig. 10. Tactile path (directional tiles) leading to a railway station entry door. Kielce. Photo: M. Wijas

Fig. 11. Tactile path. Bus terminal in Kielce. Photo: M. Wijas

Fig. 12. Tactile pavement in a hazard zone (along the carriageway edge). A correct, ridge-less connection between different pavement textures. Kielce. Photo: M. Wijas

The optimum materials to be used for tactile pavement are:
– concrete and its derivatives;
– resin – considered by blind people to be the best solution, because of material differences and its high contrast with other pedestrian zone elements, as well as high anti-slip properties.

4.4. Parking spaces

Parking spaces for the disabled are one of the elements that help to improve the accessibility of public spaces and are fundamentally connected with pedestrian traffic. Apart from issues defined by technical conditions, such as their sufficient quantity, dimensions and their proximity to buildings, of significance is also their direct and appropriate connection with pedestrian zones and the suitable choice of their pavement in order to improve their comfort of use.

When designing parking spaces for the disabled, it is recommended to use an even, smooth, hard and uniform asphalt concrete or cement pavement (or possibly non-chamfered setts), in order to avoid the entrapment of crutches in openwork elements and to minimise the amount of force needed to move a wheelchair over an irregular surface (Figs. 13, 14). Stone paving setts can be used in the vicinity of historic buildings (it is recommended to use cut stone setts, which allow the construction of the smoothest and grout-free pavements). The use of unpaved surfaces is acceptable only in the case of parking spaces located within protected areas, but it is recommended to stabilise them or to strengthen them using geogrids with a cell size of less than 2 cm.

Fig. 13. Unsuitable pavement and incorrect marking of a parking space for disabled persons. Kielce. Photo: M. Wijas

Fig. 14. An example of the correct marking of a parking space for disabled persons. Ridge-less connection with the carriageway and sidewalk via a 2 cm ridge. Appropriate pavement colour and type. Kielce. Photo: M. Wijas

4.5. Illumination

The illumination of pedestrian zones significantly improves the safety of pedestrians after dark, or in difficult weather conditions. When designing the illumination of pedestrian zones, special attention must be given to light sources located below the line of sight (0-1.2 m). These elements should be installed in a way that prevents the blinding of the users, which can be achieved for example by using directional lamps. When using pavement lights installed in the sidewalk or in the floor, it is recommended to use lights with anti-slip properties and to install the lamps flush with the floor.

4.6. Outdoor stairs and ramps

Stairs are an integral element of pedestrian zones and undoubtedly present an obstacle in an area characterised by variable terrain levels. Beside ramps, they are one of the elements of the built environment that help pedestrians to scale the differences in terrain. The dimensions of stairs are defined in the Technical Conditions (Chapter 4. Stairs and Ramps). There are however many more improvements that enable appropriate spatial perception of stairs and therefore a higher comfort of using them. One of these solutions is to use a different pavement type or colour, by using contrasting marking along the entire length of the first and last step of each flight of stairs, or to use a suitable step profile to prevent pedestrians from tripping when going up, or from catching the stair edge with the back of their shoe when descending. Using single steps in urban spaces is especially dangerous, because they are difficult to notice and to detect, especially by blind or visually impaired people. Ramps are a universal solution that can be used to scale the differences in terrain, as they are useful to wheelchair users, mothers with prams, cyclists, as well as fully fit people. The gradient, as well as other parameters related to ramp design, are described in the Technical Conditions (Chapter 4. Stairs and Ramps). In practice, however, it has turned out that even the lowest recommended gradient of 6% is difficult to scale for some people, therefore it is recommended to choose the lowest possible gradient in each situation. The available ramp should: be provided with a manoeuvring area at the entrance to and at the exit from the ramp, as well as an anti-slip surface, a 50 cm wide yellow-coloured warning strip at the beginning and at the end of the ramp across its entire width, should not have a cross slope and should be equipped with appropriate hand grips and guardrails.

4.7. Ridges

Ridges are one of the main obstacles encountered by all people moving across urban spaces, especially by people in wheelchairs, on crutches, etc. The presence of ridges is a result of the incorrect connection of different types of pavement (Fig. 15) (at the point of connection of the sidewalk and the carriageway, bicycle path, at the point of connection of the carriageway and the sidewalk at pedestrian crossings (Figs. 16, 17), but also as a result of the installation of drainage gutters and of the destabilisation of pavement with time (Fig. 18). As a result, pedestrian zones, city squares and other public areas become inaccessible to elderly and disabled people without the assistance of other persons. The maximum allowable ridge height is 2 cm and if the difference in levels is higher, the ridge has to be replaced with

a slope of the maximum inclination of 1:12. In the case of a ridge of the height of less than 1 cm, it will be rounded or bevelled with a gradient of 1:1, whereas the height of 1-2 cm will be replaced with a wedge of the gradient of 1:2 (Fig. 19). However, the best solution seems to be the complete elimination of all ridges (Figs. 20-23).

Fig. 15. An incorrect transition between a carriageway and a sidewalk at the location of a pedestrian crossing. Opole. Photo: M. Wijas.

Fig. 16. An incorrect transition between a carriageway and a sidewalk at the location of a pedestrian crossing. Opole. Photo: M. Wijas

Fig. 17. An incorrect transition between a carriageway and a sidewalk. Obstacle in the form of a ridge of the height of more than 2 cm. Opole. Photo: M. Wijas

Fig. 18. A barrier in the form of deformed sidewalk pavement. Opole. Photo: S. Mochocka

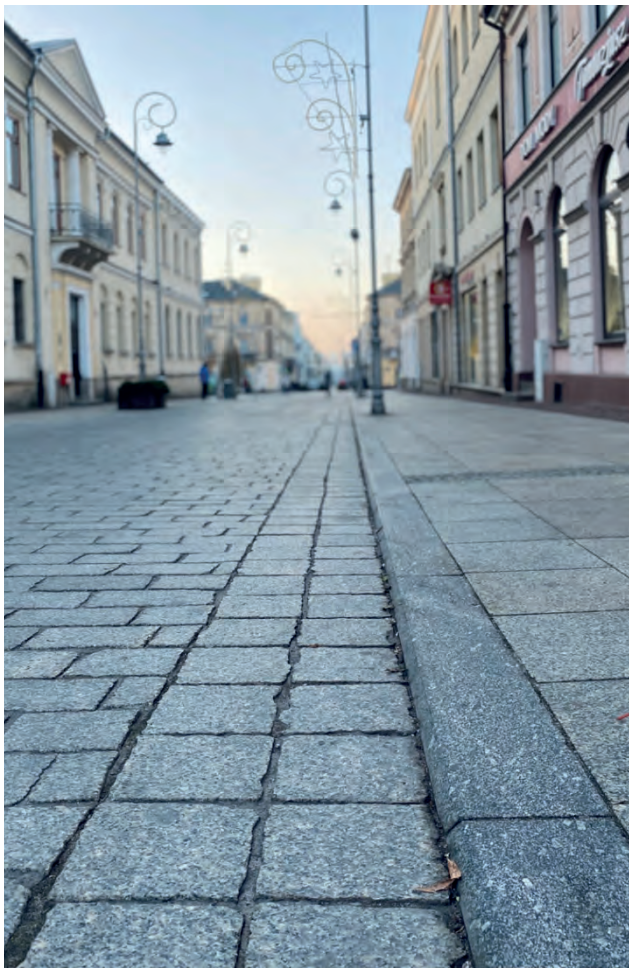

Fig. 19. An acceptable transition between a shared zone and a sidewalk using a 2 cm high wedge. Sienkiewicza Street in Kielce. Photo: M. Wijas

Fig. 20. A ridge-less connection of different pavements that constitute the Porta Nuova square in Milan, Italy. Photo: M. Wijas

Fig. 21. A ridge-less connection of different pavements that constitute the Porta Magenta square in Milan, Italy. Photo: M. Wijas

Fig. 22. An example of the correct transition between pavement types at the approach to building and the correct installation of an outdoor entrance doormat flush with the sidewalk surface. Opole. Toyota Park. Photo: M. Wijas

Fig. 23. A correctly installed door sill at the entrance to a shopping mall. Opole. Photo: M. Wijas

5. SUMMARY

Public spaces, in accordance with the requirements of sustainable development and universal design, should be accessible to all residents, irrespective of their level of mobility or perception. Self-reliance is very important in the context of the development of social integration of elderly and disabled people. Such people stress out the importance of safety in the context of using public spaces. The urban landscape is suitable mainly for people without visual impairments – we receive 86% of all information via visual perception. Solutions related to pedestrian zones, city squares, public spaces presented in this article in the context of texture, colour and construction, significantly affect the accessibility of public spaces and buildings and help to create spaces that are friendly to all users. Suitable design and technological solutions help to eliminate spatial barriers and provide comfort to those with wheelchairs, crutches, prams, heavy luggage, etc. The use of appropriate pavement texture and colour can consciously 'guide' users with perception disorders. Solutions related to pavements presented in this article go beyond the applicable standards and provide user comfort and safety, and in a wider context improve the accessibility of public spaces and buildings.

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AL HERITAGE OF UKRAINE AND WAYS OF THEIR RECREATION LOST MONUMENTS OF THE CULTUR

UTRACONE ZABYTKI DZIEDZICTWA KULTUROWEGO UKRAINY I SPOSOBY ICH ODTWORZENIA

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Abstract

The article deals with scientific and practical issues of solving the problem of lost cultural monuments in Ukraine. It highlights the loss of Ukrainian cultural heritage sites as a result of war crimes of the Russian Federation and considers possible ways of recreating them, taking into account existing practice, which will serve as a useful example for the subsequent incarnations of the lost architectural monuments. The questions of the legitimacy of the reconstruction of various objects of cultural heritage in accordance with domestic and international standards are discussed. Some financial and economic aspects of restoring the cultural heritage of Ukraine are considered.

The purpose of this study is to highlight the problems of destruction and damage of Ukrainian cultural heritage sites' after full-scale Russian aggression and directions of their recreation considering domestic and foreign experience.

Keywords: cultural heritage sites, lost architectural monuments, Russian aggression, recreation, directions.

Streszczenie

Artykuł dotyczy naukowych i praktycznych zagadnień rozwiązania problemu zaginionych zabytków kultury na Ukrainie. Zwraca uwagę na utratę obiektów dziedzictwa kulturowego Ukrainy w wyniku zbrodni wojennych popełnionych przez Federację Rosyjską i rozważa możliwe sposoby ich przywrócenia z uwzględnieniem istniejącej praktyki, co posłuży jako użyteczny przykład dla kolejnych wcieleń utraconych zabytków architektury. Omówiono kwestie zasadności odbudowy różnych obiektów dziedzictwa kulturowego zgodnie ze standardami krajowymi i międzynarodowymi. Rozważono niektóre finansowe i ekonomiczne aspekty przywracania dziedzictwa kulturowego Ukrainy.

Słowa kluczowe: obiekty dziedzictwa kulturowego, zaginione zabytki architektury, agresja rosyjska, odtworzenia, kierunki.

1. INTRODUCTION

Original historical and cultural relics, located in the territory of modern Ukraine, are an integral part of the World and European historical and cultural heritage. The process of formation of an independent state, ethnic self-identification of the people causes increasing interest of the society to monuments of architecture and urban planning.

An important role in the protection of historical and cultural monuments belongs to the re-creation of objects of cultural heritage lost due to certain tragic events, that fate lavishly brought into the history of Ukraine.

In recent years, before the Russian aggression, Ukraine has carried out numerous activities aimed at bringing order to the protection of cultural heritage in order to preserve and use its facilities in the life of society, to protect the historical and traditional environment for the benefit of present and future generations. At the same time, both similar world experience and international legislative documents

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in this sphere were fully taken into account [1-4]. Important documents were developed and adopted for implementation – laws, decrees, orders, which brought to the new, higher in comparison with the past level the entire system of work in the field of cultural heritage protection in Ukraine [5, 6].

2. LOSSES OF OBJECTS OF CULTURAL INFRASTRUCTURE OF UKRAINE AS A RESULT OF WAR CRIMES OF RUSSIA

After the full-scale invasion on February 24, 2022, the occupying Russian army has been shelling Ukrainian cities and towns daily for almost a year. The scale and barbarity of such destruction in a European country in the 21st century seems unthinkable, but, unfortunately, it is a reality.

The Ministry of Culture and Information Policy of Ukraine continues to document the damage to cultural infrastructure in Ukraine as a result of Russian aggression. Thus, as of December 25, 2022, 1,189 objects of cultural infrastructure were damaged. Almost a third of them – 446 objects – were completely destroyed. Cultural infrastructure suffered the greatest losses and damages in Donetsk, Kyiv, Kharkiv, Luhansk, Mykolaiv, Zaporizhzhia, Sumy and Kherson regions. Currently, almost the entire territory of Luhansk and significant parts of the territories of Kherson, Zaporizhzhya and Donetsk regions are still under temporary occupation. Because of this, it is impossible to calculate the exact number of objects of cultural infrastructure that were damaged during the hostilities and occupation. "The Russian occupiers continue to destroy everything Ukrainian. They target clubs, libraries, museums, theaters, philharmonic societies, art schools and colleges, as well as cultural heritage sites. To date, the number of cultural infrastructure objects that have suffered damage has increased almost 7 times compared to April 2022. At that time, 169 objects were damaged. Since Kherson Oblast was recently heroically liberated by our soldiers, new facts of Russian vandalism were revealed to us. The total number of affected objects increased by another 75 units. These are colossal, unprecedented losses for our culture," said Oleksandr Tkachenko, Minister of Culture and Information Policy of Ukraine [7].

Here are just a few examples of the most painful losses of cultural heritage monuments from different regions of Ukraine in accordance with the project data "Postcards from Ukraine". This project aims to record and demonstrate the damage caused to the Ukrainian culture by the Russian troops as a result of the bombings and shelling during the full-scale war that Russia launched against Ukraine on February 24th, 2022. The project "Postcards from Ukraine" was developed by the Ukrainian Institute with the support of the USAID project and in cooperation with the creative agency Green Penguin Media [8].

The building, which until recently housed the Literary Memorial Museum of Hryhorii Skovoroda, was built in the 18th century. The museum was founded here in 1972. Ukrainian philosopher, theologian, and poet Hryhorii Skovoroda influenced not only his contemporaries but many generations of Ukrainians as well. He did this through his teaching and own lifestyle, his words always matching his deeds. Skovoroda is a symbol of Ukrainian philosophy today. On May 7, 2022, the Russian army shelled the roof of the building, and the fire engulfed the entire museum. The 18th century building, which was initially a home for guests at the manor of the Kovalivski landowners, home for Hryhorii Skovoroda and preserved the memory of his last years of life, is now completely destroyed (Fig. 1).

Fig. 1. National Literary Memorial Museum of the Ukrainian Philosopher and Poet Hryhorii Skovoroda. Skovorodynivka village, Kharkiv region: a) before May 25, 2022. Photo: FIND-WAY.COM.UA; b) after May 25, 2022. Photo: Sergey Kozlov. Link; https://ui.org.ua/en/postcard/hryhorii-skovoroda-museum-en/

In 1902, the only Ukrainian museum in the Russian Empire was opened in Chernihiv, the initiator of the creation of which was Vasyl Tarnovskyi, a patron, collector and descendant of a noble family. He presented the city of Chernihiv with a unique collection. In addition, the collection contained Ukrainian historical and cultural artifacts of the XVII-XIX centuries, Cossack antiquities, as well as manuscripts, works of art, and personal belongings of the outstanding Ukrainian poet and artist Taras Shevchenko. At the end of the 19th century, this building was reconstructed in the neo-Gothic style, acquiring pointed arches and decoration with pilasters of various shapes resembling columns. The Chernihiv Regional Youth Library, which had survived Bolshevik attacks in 1918 and 1919 and Nazi bombings during the Second World War, was destroyed by Russian troops on March 11, 2022. They dropped a 500-kilogram high-explosive bomb on the library yard, demolishing the walls and ceilings of the building (Fig. 2).

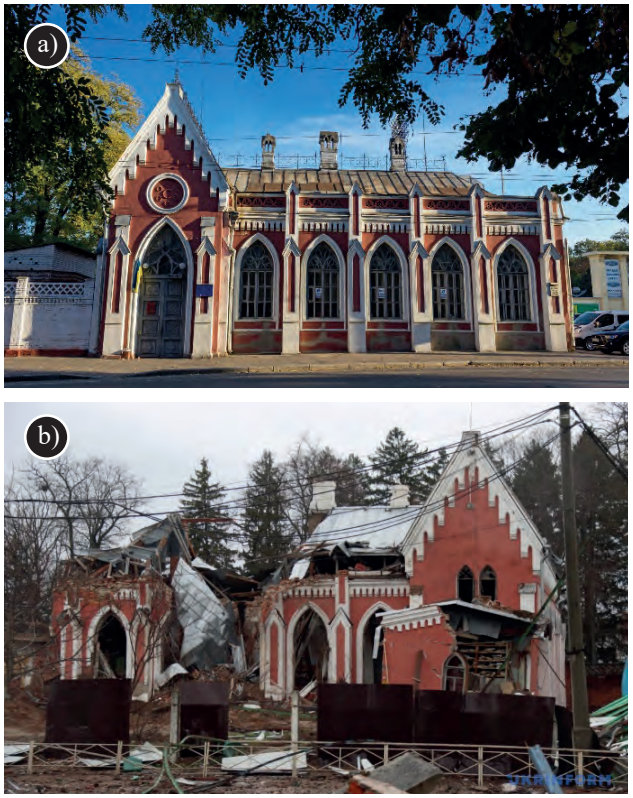

Fig. 2. Chernihiv Regional Youth Library. Chernihiv region:
a) before March 11, 2022;
b) after March 11, 2022.
Link:https://ui.org.ua/en/postcard/chernihiv-regional-youth-library/

For decades, Mariupol was known in Ukraine and worldwide as a center of the metallurgical industry. Since the start of Russia's invasion of the Donetsk and Luhansk regions in 2014, it has become a widely known front-line city. The former manor of Abram Trehubov is a reminder of the time when the city did not yet have a distinct industrial image before the Bolshevik Revolution of 1917. The possessions of Tregubov, a well-known public figure and active philanthropist, included a number of buildings in the center of Mariupol. Among them stood out a house with a pointed tower, which has survived to this day and was restored in 2012. The shelling of Russian forces damaged the facades, windows, roofs, and interiors of three historical buildings of the Trehubov estate and caused a severe fire (Fig. 3).

Fig. 3. Buildings of the former manor of A. Trehubov. Mariupol, Donetsk region:
a) before april 10, 2022. Photo: LB.UA;
b) aftere april 10, 2022. Photo: WWW.RFL.FR.
Link: https://ui.org.ua/en/postcard/buildings-of-the-former-manor-of-a-trehubov/

The all-holiday hermitage of Sviatohirska Lavra, located in the Donetsk region, was impressive at first glance. All the buildings of the hermitage (both temples and cells) are built of massive pine trunks and decorated with carvings. Having arisen on the ruins of the destroyed church, the skete was a reminder of the times when it was forbidden to worship, think, speak, and live freely in Ukraine. In the 21st century, this place also became evidence of the crimes committed by the Russian army that took thousands of lives and hundreds of cultural heritage objects in Ukraine (Fig. 4).

a)

b)

Fig. 4. A ll Saints Skete of Sviatohirsk Lavra. Tetianivka, Donetsk region:
a) before June 4, 2022. Photo: SVLAVRA.CHURCH.UA;
b) after June 4, 2022. Photo: KP.UA
Link: https://ui.org.ua/en/postcard/all-saints-skete-of-sviatohirsk-lavra/

Popov Manor House is one of the largest aristocratic estates in southern Ukraine of the late 18th and 19th centuries and a landmark of regional history and architecture. The architecture of the palace and park complex is eclectic, which was quite common in the late 19th century. The horse-stead was built according to architectural canons of the Northern Italian Renaissance. Popov's estate is one of the two examples of such architecture in Eastern Europe.

The complex also includes the Western wing or so-called 'English Castle', constructed in the Neo-Gothic style with a multi-level roof, referring to the era of medieval Europe.The next attractions are the symmetrical North and East outbuildings for guests of honor built in the Neo-Moorish style with elements of Neo-Gothic and an extremely proportional eclectic observation tower. The center of the complex is a two-storey palace with five towers built in the Neo-Moorish and Neo-Gothic styles of red and yellow brick. In the palace, the Popov family kept their ethnographic collection, and its walls were decorated with the works of such European geniuses as Titian, Goya, Rembrandt. On March 7 of 2022 during the shelling, the Russian military damaged the walls of the horse-stead and other buildings. The Local Lore Museum, located in the complex, was looted by the occupiers [8] (Fig. 5).

a)

b)

Fig. 5. Popov's Castle. Vasylivka town, Zaporizhzhia region:
a) before April 7, 2022. Photo: Irina Mirochnikova;
b) after April 7, 2022. Photo: Anna Golovko.
Link: https://ui.org.ua/en/postcard/popovs-castle-2/

3. USING THE EXPERIENCE OF RESTORATION OF CULTURAL HERITAGE OBJECTS.

Today, Ukraine is supported by the entire civilized world in overcoming the consequences of war crimes committed by Russian troops in 2022-2023. And now the country is preparing to restore the development of cities and lost monuments of architecture and urban planning.

Let's consider possible ways of recreation cultural heritage objects, taking into account the use of such practices before the Russian aggression. The heavy and sometimes irreparable loss of architectural masterpieces in the twentieth century (mainly during the Stalinist repressions of 1934-1939 and the Second World War) necessitated the recreation of the most outstanding and valuable architectural objects, as well as the complex regeneration of the historical environment and entire urban development complexes.

The first direction is the recreation of the architectural and artistic appearance of historical buildings, which is achieved by construction of a new building on a reliable basis. Of course, such a *new building* cannot be classified as a cultural monument, whose architectural objects are carriers of certain historical information and unique witnesses of the era only in the case of their authenticity.

In 1997-1998, one of the most ancient and legendary cathedrals of not only Kiev, but also all Ukraine was rebuilt – the Kyyiv-Mykhailivskyy Golden-domed Cathedral, lost in 1934-1937. Restoration of this main cathedral of the Ukrainian Orthodox Church with the first in the practice of Russian stone architecture gilded dome was a sign of the spiritual revival of Kyyiv – the cradle of Russian Christianity and all of Ukraine as a civilized European state. Recreation was done through a restoration reconstruction based on reliable iconographic materials and was of great importance, both from the point of view of town-planning regeneration, and from the viewpoint of restoration of the sacred axis with the cultural and architectural dominance of the complex of structures of the St. Sophia Cathedral. The same scientifically substantiated and reliable act was the re-creation of the pearl of ancient Russian architecture – the Assumption Cathedral of the Kyyiv-Pechersk Lavra, destroyed in 1941, the first stone church on its territory. Created from the ruins and consecrated on August 24, 2000, it again invitingly shines his seven golden domes, reaching 52-meter height above the Kyyiv hills, and is now, as before, the main spiritual accent of the historical and architectural environment of the Kyyiv-Pechersk Lavra (Fig. 6).

Fig. 6. The Assumption Cathedral of the Kyyiv-Pechersk Lavra:
a) photo 1942. Link: https://day.kyiv.ua/article/ukrayina-incognita/chomu-buv-zruynovanyy-uspenskyy-sobor-kyyevo-pecherskoyi-lavry;
b) photo 2000 after restoration. Link: https://etnosvit.com/uk/kyyevo-pecherska-lavra/

This approach can be applied to completely destroyed architectural monuments, such as the historical railway station in the city of Okhtyrka, the Grigory Skovoroda Museum, the historical buildings of Mariupol and many other lost objects.

Another well-known area is the *repair and restoration* of damaged architectural monuments. There are many such good examples, including those taking into account the adaptation of historical buildings for public needs. As one of the successful examples, we can cite the famous architectural monument – the Russov House in Odessa, built in 1897-1898, which was almost completely destroyed as a result of repeated fires in 2006-2009. It was in a state of disrepair for more than 10 years. Thanks to the efforts of the city authorities, in 2018, work began on the restoration of the Russov House, adapting it to a public building, and at the end of 2019, a solemn ceremony of its opening took place (Fig. 7).

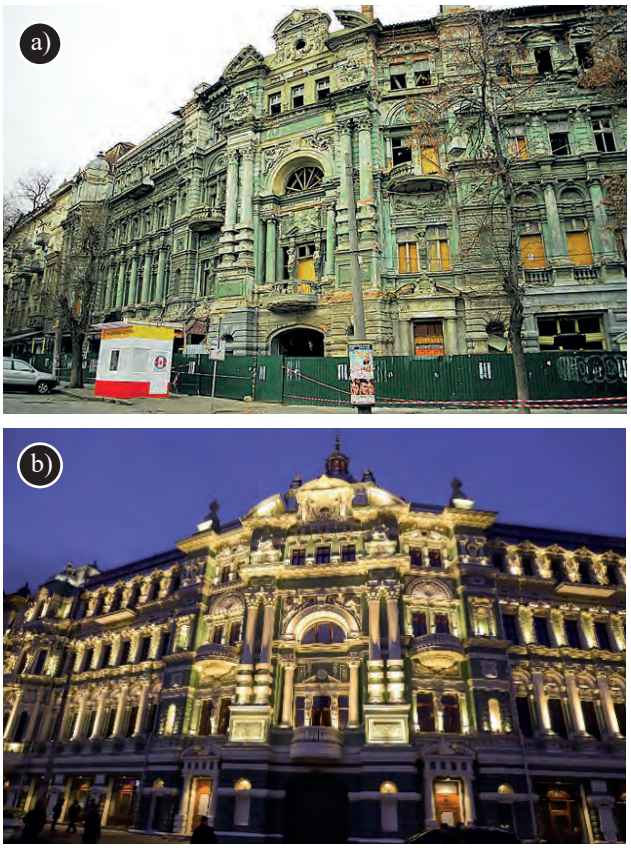

Fig. 7. Repair and restoration the Russov House in Odessa: a) building before restoration. Link: https://www.segodnya.ua/regions/odessa/mnogostradalnyy-dom-russova-vernuli-odesse-ruiny-ohranyaet-strazha-1104640/g59838_645931.html; b) building after restoration in 2020. Link: https://mayor.omr.gov.ua/news/m220205/

The next way, along with repair and restoration, is the *reconstruction and expansion* (completion, extension) of the damaged historical building. It should be noted that this direction should be interconnected with the legislative framework of Ukraine, since changing the compositional-spatial and stylistic structure of a cultural heritage monument is currently prohibited in accordance with the 'Cultural Heritage Protection Law". Another thing, of course, is changing the original function of a historic building and adapting it to the new needs of customers and localities. An example of such a decision is Athena shopping center in 2004, after years of construction, in the center of the Gretska Square in Odessa, which unfortunately, in some way violated the scale of the architectural environment of the historic center of Odessa. In our time, already during the war, Kharkiv architects are working in this direction on various options for restoring the historical buildings of the city, including the building of the Kharkiv State Regional Administration (Fig. 8).

Fig. 8. Restoration project with completion of the building of the Kharkiv State Regional Administration. Link: https://news.zerkalo.io/cellar/12474.html

In some cases, with significant damage to historical areas, it seems appropriate *to regenerate the lost valuable historical and architectural environment* with its scientifically grounded recreation of its historical analogues, while strictly observing the provisions of the Riga Charter [6], especially those relating to the need to return the historical locality of its cultural significance with compensation for the tragic losses and the need to recreate the objects of cultural heritage in their primordial place. In this

aspect, the project of urban planning regeneration of the historical and architectural ensemble of the Kontraktova Square in Kyyiv, developed in the 1970s by Kyyiv architects, is of interest. This project provided for a comprehensive restoration of all monuments of architecture, as well as scientific and documentary reconstruction of lost objects. (Fig. 9). It would be advisable to apply such approaches to the historical environment of the cities of Kharkov, Mariupol, Chernigov and others that was lost, or rather destroyed by the Russian aggressors.

Fig. 9. Historical and architectural ensemble of Kontraktova Square in Kiev. Link: https://en.wikipedia.org/wiki/Square_of_Contracts_%28Kyiv%29

It should be noted here that in resolving legal issues of recreating cultural heritage objects, an important role is played by the compliance of domestic regulations with generally accepted international standards. Integration of Ukraine into the international community determines the correlation of the national legislation on the protection of heritage with international Conventions and Charters adopted by UNESCO, the Council of Europe, and ICOMOS [2-4]. The Riga Charter, adopted at the *Cultural Heritage: Authenticity and Historical Heritage* conference of ICOMOS, is especially relevant in the context of the issues under consideration. Considering that in countries that have recently renewed their independence, the issues of reconstruction and authenticity have acquired special importance, since a significant number of such events are planned and implemented, the main idea of the Charter is that the interference in the monument should be reduced to the necessary minimum.

4. SOME FINANCIAL AND ECONOMIC ASPECTS OF THE RESTORATION OF HISTORICAL HERITAGE AS A RESULT OF RUSSIAN AGGRESSION

At the end of this article, it is advisable to highlight the financial and economic aspects of the restoration of historical heritage as a result of war crimes of the barbaric Russian aggression.

Already today, it is necessary to create a State program for the restoration of Ukrainian inhabited cities and objects of their cultural heritage, together with recreational and tourist infrastructure. For this purpose, it is necessary to define regional programs in accordance with the priorities and phasing of the restoration of cultural heritage objects. At the same time, the sources of funding for such programs should be the following:

– State budget of the country;
– Money from local budgets of Ukraine:
– Investments of international funds;
– Domestic investments;
– Foreign investments;
– Charitable and public organizations.

It is obvious that in today's conditions, the main sources of financing will be investments of international funds and foreign investments, which should be taken into account when developing and implementing relevant regional programs.

5. CONCLUSIONS

As a result of aggression and war crimes of the Russian Federation in Ukraine, cultural heritage sites have been significantly damaged and lost, some examples of which from various regions are given in this article. The ways and directions of the recreation's practice of cultural monuments in Ukraine, considered in the article, will serve as a useful example for subsequent incarnations of cultural heritage sites. Solving the problems of lost monuments should be carried out on the basis of a comprehensive analysis of various factors and local conditions, including national traditions, taking into account domestic and international legislation in the field of cultural heritage protection. It is important to create regional programs with priorities and stages of restoration and reconstruction of cultural heritage sites, taking into account various sources of funding, a significant part of which will belong to the investments of international funds and foreign investments.

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"AN ACCESSIBLE CITY" – A LOOK FROM THE PERSPECTIVE OF THE '60+' GENERATION

„DOSTĘPNE MIASTO" – PRÓBA SPOJRZENIA Z PERSPEKTYWY POKOLENIA „60+"

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Abstract

This paper presents the results of workshop experiments aimed at realising the concept of the accessible city and identifies key considerations for enabling seniors to function better in the city's public space, based on the real needs of an ageing population. The study used field research (in situ), functional-spatial analysis (case studies) and data synthesis. The latest available data from the Statistics Poland on the demographic situation of senior citizens, government programmes and current legislation – depicting the current and projected situation in Poland were analysed. Faced with alarming data indicating that Poland's population will continue to grow older until 2050, with the number of people aged 60+ reaching 40.4% of our country's total population, field research was carried out into the accessibility of selected urban spaces and a set of architectural and urban planning recommendations were presented to address the most important needs and better functioning of the 60+ generation. As the Świętokrzyskie Voivodeship is currently home to the largest total population of senior citizens, the region's capital, Kielce, was chosen as the location for the analysis.

Keywords: Accessibility Hub, senior-friendly cities, creating age-friendly environments, lifelong learning, the '60+' generation, Kielce.

Streszczenie

W artykule przedstawiono wyniki eksperymentów warsztatowych ukierunkowanych na realizację koncepcji miasta dostępnego oraz wyłoniono najważniejsze przesłanki umożliwiające lepsze funkcjonowanie seniorów w przestrzeni publicznej miasta, opierając się na rzeczywistych potrzebach starzejącego się społeczeństwa. W pracy posłużono się badaniami terenowymi (in situ), analizą funkcjonalno-przestrzenną (case studies) oraz syntezą danych. Przeanalizowano dostępne najnowsze dane GUS w zakresie sytuacji demograficznej seniorów, programy rządowe i obowiązujące przepisy – obrazujące obecną i prognozowaną sytuację w Polsce. W obliczu niepokojących danych wskazujących, że do 2050 r. populacja Polski wciąż będzie stawała się coraz starsza, a liczba osób w wieku 60 lat i więcej osiągnie 40,4% ogółu ludności naszego kraju, przeprowadzono badania terenowe pod kątem dostępności wybranych przestrzeni miejskich oraz przedstawiono zestaw zaleceń architektoniczno-urbanistycznych uwzględniających najważniejsze potrzeby i lepsze funkcjonowanie pokolenia „60+". W związku z faktem, że obecnie najwyższa liczba osób w wieku senioralnym zamieszkuje w województwie świętokrzyskim, na miejsce analiz wybrano stolicę regionu – Kielce.

Słowa kluczowe: Hub dostępności, miasta przyjazne seniorom, kreowanie przestrzeni przyjaznej starości, kształcenie przez całe życie, pokolenie „60+", Kielce.

1. INTRODUCTION

The trend of an ageing population is nowadays a global phenomenon. At the same time, a trend towards a decreasing population is increasingly evident in many Polish cities [1]. This situation has certainly been significantly influenced by the SARS-CoV-2 virus pandemic, the effects of which have been particularly severe for senior citizens. Additional

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restrictions on access to services, especially health services, have exacerbated the problems they face on a daily basis. However, although this topic has been relevant since 2002, when the World Health Organization (WHO) developed recommendations on the functioning of older people (the Policy Framework on Active Ageing programme) and subsequently implemented the Global Age-Friendly Cities project [2], there is still a lack of comprehensive measures to eliminate the problems, and inaccessible design solutions can be found in the space of many cities, creating numerous barriers for the '60+'generation.

In Poland, senior citizen policy has been in place at the central level since 2012, and in the second decade of the 21st century the issue of urban accessibility has taken on particular importance. The addressed topic of urban accessibility involves a wide spectrum of coupled issues, linked not only to architecture and urban planning, but also to environmental psychology and other social science disciplines such as gerontology, sociology and social pedagogy. The literature in this area is extensive, but mainly covers a narrow range of specialised studies. In contrast, there is still little interdisciplinary research on the issue showing the needs associated with the functioning of seniors in the urban environment. The most recent extensive research in the discipline of architecture and urban planning mainly concerns two thematic groups related to the built environment and housing. In this field, the activities of Polish academia should be singled out: Faculty of Architecture of the Gdańsk University of Technology (A. Gawlak) [3], Faculty of Architecture of the Silesian University of Technology (E. Niezabitowska, B. Komar, I. Benek, A. Labus) [4-6], Faculty of Architecture of the Wrocław University of Science and Technology (B. Gronostajska, Scientific conferences: "Habitat", "Architektura bez granic" [Architecture without borders] [7], the Faculty of Architecture of the Cracow University of Technology (P. Haupt[1], G. Schneider-Skalska) [8, 9], as well as research conducted by the Department of Architectural and Urban Design Theory and Planning at the Faculty of Civil Engineering and Architecture of the Kielce University of Technology (W. Seruga, S. Wehle-Strzelecka, J. Gil-Mastalerczyk[2]) [10-12].

1.1. Purpose and methodology of research

The aim of this paper is to present the results of workshop experiments aimed at realising the concept of the accessible city and to identify the most important prerequisites for enabling seniors to function better in public space – linked to the physical characteristics of the city, based on the real needs of an ageing population. It should be emphasised that other aspects not covered in the study, such as the ageing process, social psychology, the residential environment or the quality of life of seniors, are also inextricably linked to this issue [3-7, 9-11].

The paper is based on field research – *in situ*, functional-spatial analyses – *case studies* and data synthesis. The latest available data from the Statistics Poland on the demographic situation of senior citizens, government programmes and current legislation, depicting the current and projected situation in Poland and forecasts for the future were analysed. Then, to find out how the public space of a contemporary city is shaped and accessible to seniors, field research was carried out in the surroundings of the campus of the Kielce University of Technology. On the basis of the field research of selected urban spaces carried out, a set of architectural and urban planning recommendations were presented that take into account the most important needs and better functioning of older people.

2. CURRENT DEMOGRAPHIC SITUATION OF SENIORS IN POLAND

According to the most up-to-date results of research carried out by the Statistics Poland and aggregate data compiled at the Statistics Poland on the basis of departmental reporting, demographic projections indicate that Poland's population will continue to grow older until 2050. The steadily increasing process of population ageing has been observed in

[1] Project manager for the "Hub dostępności – centrum praktycznej nauki dostępności" [Accessibility hub – centre for practical accessibility training] (Project POWR.03.05.00-IP.08-00-CWD/20, implemented under the Operational Programme Knowledge Education Development 3.5 Comprehensive programmes of higher education institutions, Higher Education for the economy and development; co-financed by the European Social Fund – funded from the European Funds) carried out by Cracow University of Technology and Kielce University of Technology, which is the project partner (2021-2023).

[2] Project manager for the "Hub dostępności – centrum praktycznej nauki dostępności" [Accessibility hub – centre for practical accessibility training] at Kielce University of Technology (project partner) carried out jointly with Cracow University of Technology POWR.03.05.00-IP.08-00-CWD/20, implemented under the Operational Programme Knowledge Education Development 3.5 Comprehensive programmes of higher education institutions, Higher Education for the economy and development; co-financed by the European Social Fund – funded from the European Funds), 2021-2023.

Poland since 2006. In 2005, the share of seniors in the country's population increased by 17.2%, while in 2021 it reached 25.7% (Fig. 1).

The country's current population – equal to 37,907,700 – will fall to 34.0 million in 2050. In contrast, the number of seniors, which stood at 9.7 million at the end of 2021, is expected to increase, according to the Statistics Poland's forward-looking projections, to 10.8 million in 2030, to 12.3 million in 2040 and to reach 13.7 million in 2050. This means that the number of people aged 60 and over will account for 40.4% of Poland's total population (Fig. 2).

The current demographic state of Poland has undoubtedly been influenced by the 2021 situation caused by COVID-19. Nationwide, 450,500 people aged 60 and over died at the time, accounting for 86.7% of the total number of deaths. Compared to 2020, this number has increased by 37,700, or 9.1% [13].

Fig. 1. Share of people aged 60 and over in the population of Poland – total. As of 31.12.2021. Source: [1]

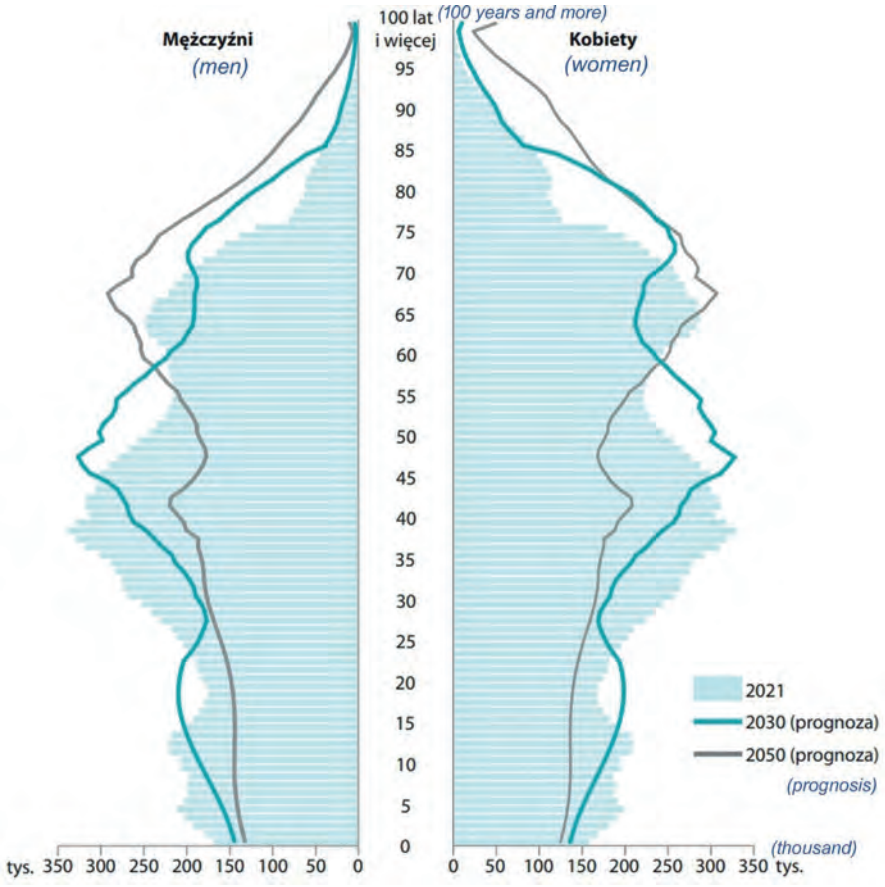

Fig. 2. Population of Poland by sex and age. As of 31.12.2022. Source: [1]

2.1. Share of seniors among urban residents

On the basis of the above analyses, it should be noted that the share of older people continues to increase, including urban residents. In 2021, it was 27.7%, and in the Statistics Poland's projections, it will settle at 42.4% in 2050. At the same time, the number of senior citizens varies significantly spatially due to the disproportion of the total population in the individual voivodeships. In 2021, the lowest share of older people, at 23.6%, was recorded in the Małopolskie Voivodeship. In contrast, the highest number of senior citizens resides in the Świętokrzyskie Voivodeship, standing at 28.5% (Fig. 3).

Overall, the largest group of seniors are those aged 60-64 and the smallest are those aged 85 and over. The expected steady increase in the number of senior citizens, but also the decline in the total population, have resulted in a dynamically increasing old-age dependency ratio (number of people aged 65 and over per 100 people aged 15-64) since 2011 (Fig. 4) [1].

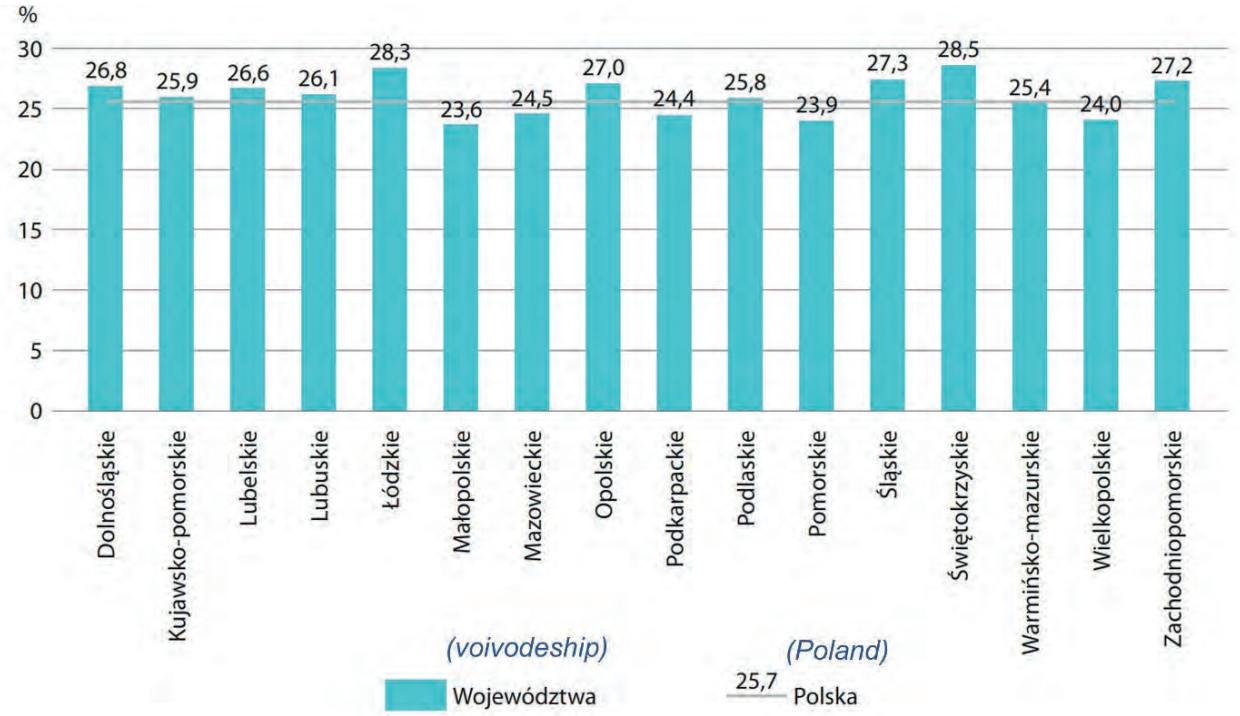

Fig. 3. Share of persons aged 60 and over in the total population of Poland – by voivodeship in 2021. As of 31.12.2021. Source: [1]

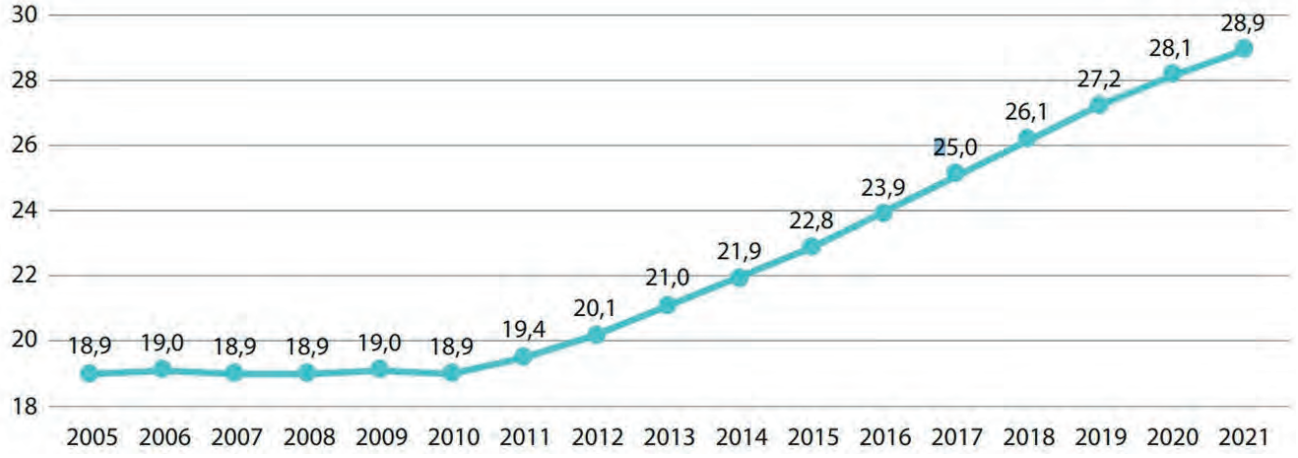

Fig. 4. Elderly dependency ratio (aged 65 and over). As of 31.12.2021. Source: [1]

3. SENIOR CITIZENS AND THEIR RIGHT TO ACCESSIBILITY. SENIOR CITIZEN POLICY AT CENTRAL LEVEL

Poland has a number of regulations in place to ensure equitable access to public spaces and facilities for seniors. This is due to the provisions in force since 20 September 2019 – the Polish Act on Ensuring Accessibility for Persons with Special Needs [Ustawa o zapewnieniu dostępności osobom ze szczególnymi potrzebami] [14] and the Polish Act on Ensuring Digital Accessibility of Websites and Mobile Applications [Ustawa o zapewnianiu dostępności cyfrowej stron internetowych i aplikacji mobilnych] [15]. The Acts guarantee that all public entities meet minimum requirements for older persons in three areas of accessibility: architectural, digital, information and communication (in accordance with Article 6 of the Accessibility Act) [14]. Exceptions include situations where, for various reasons, e.g. legal, technical, such as the preservation of the building, the fulfilment of the statutory conditions has to be achieved by alternative access. Under current government legislation and programmes, people with special needs, including the '60+' generation, are guaranteed the full right to accessibility, but for the moment only by public entities. It has been announced that by 20 September 2024, implementing regulations for the Act of 7 July 1994 – Building Law [Ustawa z dnia 7 lipca 1994 r. – Prawo budowlane], concerning the technical conditions to be met by buildings and their location – taking into account the needs of persons with special needs (Article 44 in conjunction with Article 66) will be issued [14].

The Polish government's 'Accessibility Plus' programme, which has been in operation for several years, should also be pointed out. Its aim is to ensure that the whole of society, including the '60+' generation, is provided with the right conditions to live with dignity, to function independently, to participate in society. There are extensive activities focusing on accessibility to public spaces, transport, education, health and many other areas. This is expected to result in the removal of architectural barriers and the provision of full accessibility in clinics, hospitals, offices, schools, universities, multi-family housing, train station facilities and urban public spaces.

Poland also has an Accessibility Council, set up by a group of experts representing various backgrounds. It is made up of government representatives, entrepreneurs and accessibility experts. The main tasks of the council include *opinion giving and advising in the process of drafting legislation, recommending changes in legislation resulting from accessibility needs, expressing opinions and taking positions on the needs of people with disabilities and on measures to improve public awareness of accessibility, as well as preparing expert opinions and analyses necessary for the implementation of activities planned in the programme* [16].

The Accessibility Partnership is also being implemented and currently has 241 Signatories[3] [17]. This is a commitment to working together to implement the Accessibility Plus Programme, which involves sharing experiences and creating ideas on the development of accessibility in Poland.

The activities carried out within the framework of the National Urban Policy 2030, an instrument to guide government policy towards cities and urban functional areas, are also becoming crucial [18]. The essence of urban policy is, among other things, to improve the quality of life of city dwellers, especially as they make up around 60% of Poland's population. The key goals for long-term urban development, along with the compact city, the green city, the productive city, the digital city and the efficient city, include the accessible city, understood as *not only bridging barriers through rational organisational and functional improvements, but also as a guarantee to ensure equal opportunities for all inhabitants and their full participation in community life and access to public services regardless of size and location in the settlement structure* [18].

In the sphere of universal accessibility, all activities initiated by local governments, cultural institutions, and other entities, as well as projects and collective guidelines implemented by academia to increase universal accessibility are equally important[4].

[3] Data as at 28.11.2022, source: [17].

[4] Within the framework of the project "Hub dostępności – centrum praktycznej nauki dostępności" [Accessibility hub – centre for practical accessibility learning] (Project POWR.03.05.00-IP.08-00-CWD/20), a "Accessibility Knowledge Centre" was established at Kielce University of Technology, Faculty of Civil Engineering and Architecture, as a unit supporting the application and dissemination of universal design principles in the area of higher education, in particular by disseminating universal design principles and initiating cooperation with the socio-economic environment of the university, in order to develop innovative products and standards for universal services based on universal design principles. As part of a joint activity with the Cracow University of Technology, the following will be created and made available: a database of accessibility knowledge in architectural and urban design, construction and landscape architecture, a library of good practices in architecture, urban planning and construction, a database on improving air quality in therapeutic and rehabilitation spaces through the active use of plants, a database of design materials in the form of an online catalogue for designers, a database of plants improving aerosanitary conditions in the human environment depending on scale and spatial possibilities.

To conclude this part of the demographic, statutory analyses, it should be emphasised that social policy towards seniors is not only about legal regulations, but also about direct and indirect interventions and the shaping of a new, high-quality living and functioning environment for the '60+' generation. However, the near future will tell what effect all the planned and initiated measures will have on the real accessibility of Polish urban spaces.

4. "KIELCE – AN ACCESSIBLE CITY". SELECTED EXAMPLES OF URBAN SPACES – CASE STUDY

As the capital of the region and of the Świętokrzyskie Voivodeship – which has the highest number of senior citizens in the country (Fig. 3) – the city of Kielce has been facing a serious demographic and accessibility issue for years. In addition, the overall population is steadily declining in the entire voivodeship and in the Kielce Functional Area. Moreover, the city of Kielce itself is the municipality with the highest share of '60+' people in the population, with those aged 60-64 and 65-69 making up the largest proportion of the total. [19]. The ageing of the population here becomes not only a demographic problem, but also a key social issue and a challenge for today's city authorities. For these reasons, various initiatives are being taken in Kielce towards this group of city dwellers. Forecasts and studies on the implementation of senior citizenship policy are being developed, addressing measures relating to the creation of friendly living conditions, the identification of areas of intervention, and measures focusing on inclusive growth. These include:

– *Polityka senioralna kieleckiego obszaru funkcjonalnego na lata 2020-2030. Aktualizacja październik 2022 [Senior Policy of the Kielce Functional Area for 2020-2030. Update October 2022].* The document sets out strategic objectives, which include, above all, improving the quality of life of seniors, activating seniors, and developing forms of social support for seniors [19].
– *Polityka senioralna miasta Kielce: Seniorzy aktywni dla Kielc – Kielce przyjazne seniorom*, 2018-2022 *[Senior Policy of the City of Kielce: Seniors active for Kielce – Senior-friendly Kielce, 2018-2022]*. A reporting and information study on the availability of places and forms of support for seniors [20].
– *Rekomendacje dot. realizacji polityki senioralnej w Kielcach, Wyniki prac Kieleckiego Forum Seniorów – 5 zespołów roboczych utworzonych przez Fundację „PEStka" przy Kieleckiej Radzie Seniorów w ramach szerszego przedsięwzięcia pn. „Senior kielecki – świadomy i odpowiedzialny" [Recommendations on the implementation of senior citizens' policy in Kielce, Results of the work of the Kielce Senior Forum – 5 working groups established by the "PEStka" Foundation at the Kielce Senior Citizens' Council as part of a broader project entitled "Seniors of Kielce – aware and responsible"], 2019* [21].
– *Strategia rozwoju miasta Kielce na lata 2007–2020 [Development strategy of the city of Kielce for 2007-2020].* One of the operational objectives is: to improve the quality of life of the city's residents, including people with disabilities and senior citizens [22].
– *Wojewódzki program przeciwdziałania wykluczeniu społecznemu na lata 2018-2023 [Voivodeship Programme Against Social Exclusion for 2018-2023].* One of the operational objectives is to address the social exclusion of people with disabilities and those affected by mental disorders [23].

4.1. Field research

Testing the accessibility of the urban space of Kielce for the general public

At Kielce University of Technology, experiments related to the accessibility of a specific urban space in Kielce were carried out as part of the newly established, state-of-the-art laboratory "Accessibility Knowledge Centre", which has been in operation since 2022 at the Department of Architectural and Urban Design Theory and Planning of the Faculty of Civil Engineering and Architecture. The pilot experiments took place within the workshop "Projektowanie uniwersalne – aspekt dostępności obiektów i przestrzeni" [*Universal urban design – accessibility aspects of civil structures and spaces*] [8] with the participation of representatives of the socio-economic environment, including designers, real estate developers, experts, employer organisations, business representatives, local authorities. The workshop formula was based on two independent and freely modifiable blocks, depending on the needs and level of involvement of group participants. They were given the chance to test first-hand the limitations associated with various medical conditions in the elderly (Figs. 5, 6) using special disease and defect simulators, including the 'GERT' age simulation suit. Through a set of separate elements simulating the effects of ageing and intellectual disability, the direct experience of the difficulties that seniors

face in everyday life situations became real. The interaction of special elements made it possible for the participants to experience first-hand the effects imitating the sensory impairment associated with changes in the human body over time. These mainly include the following:

– limitation of movement and an age-related hindered, unsteady gait – shoe covers and ankle weights have allowed them to experience balance problems and weakened leg strength;
– pressure on the spine, tilting of the pelvis, postural discomfort, increased physical strain, loss of strength and even imbalance – caused by a special suit with knee stiffeners that restrict movement of the knee and elbow joints;
– altered and impaired grip, feeling of impaired hand dexterity, restricted freedom of movement – with special gloves;
– increasing a person's weight by several kilograms – through appropriate weights adding around 40 years or more;
– hearing and sight impairment – using special headphones and goggles – simulators for age-related eye diseases and sight impairment.

Fig. 5. Simulator instruction conducted in a safe laboratory setting – Accessibility Knowledge Centre – prior to the start of field experiments, Kielce University of Technology, December 2022, photo by Joanna Gil-Mastalerczyk, Rafał Głogowski

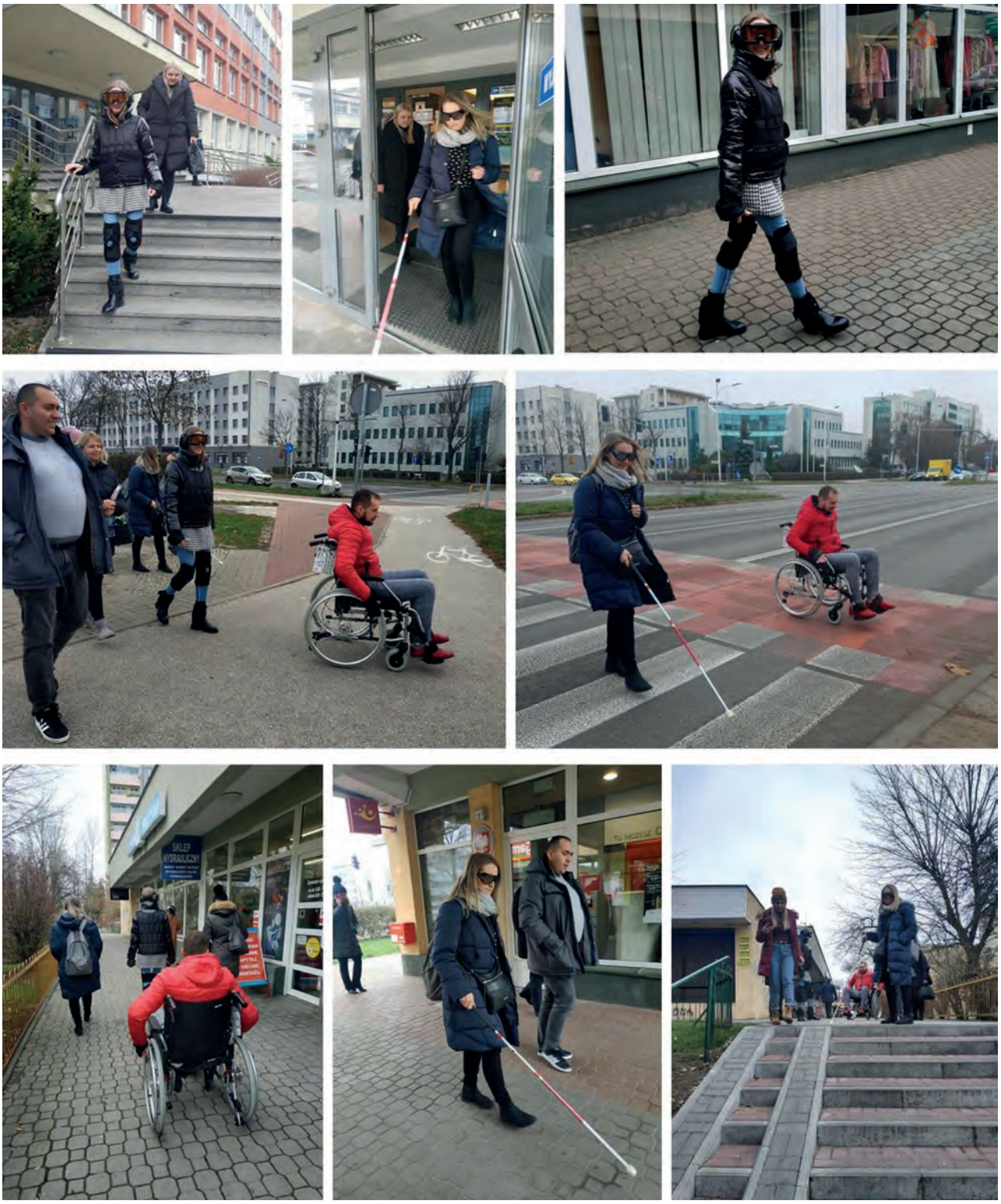

Fig. 6. Workshop experiments conducted with representatives of the socio-economic environment in the public space of the city of Kielce (designers, experts, Kielce Housing Cooperative, Foundation Centre for Local Europe), December 2022, photo by Joanna Gil-Mastalerczyk

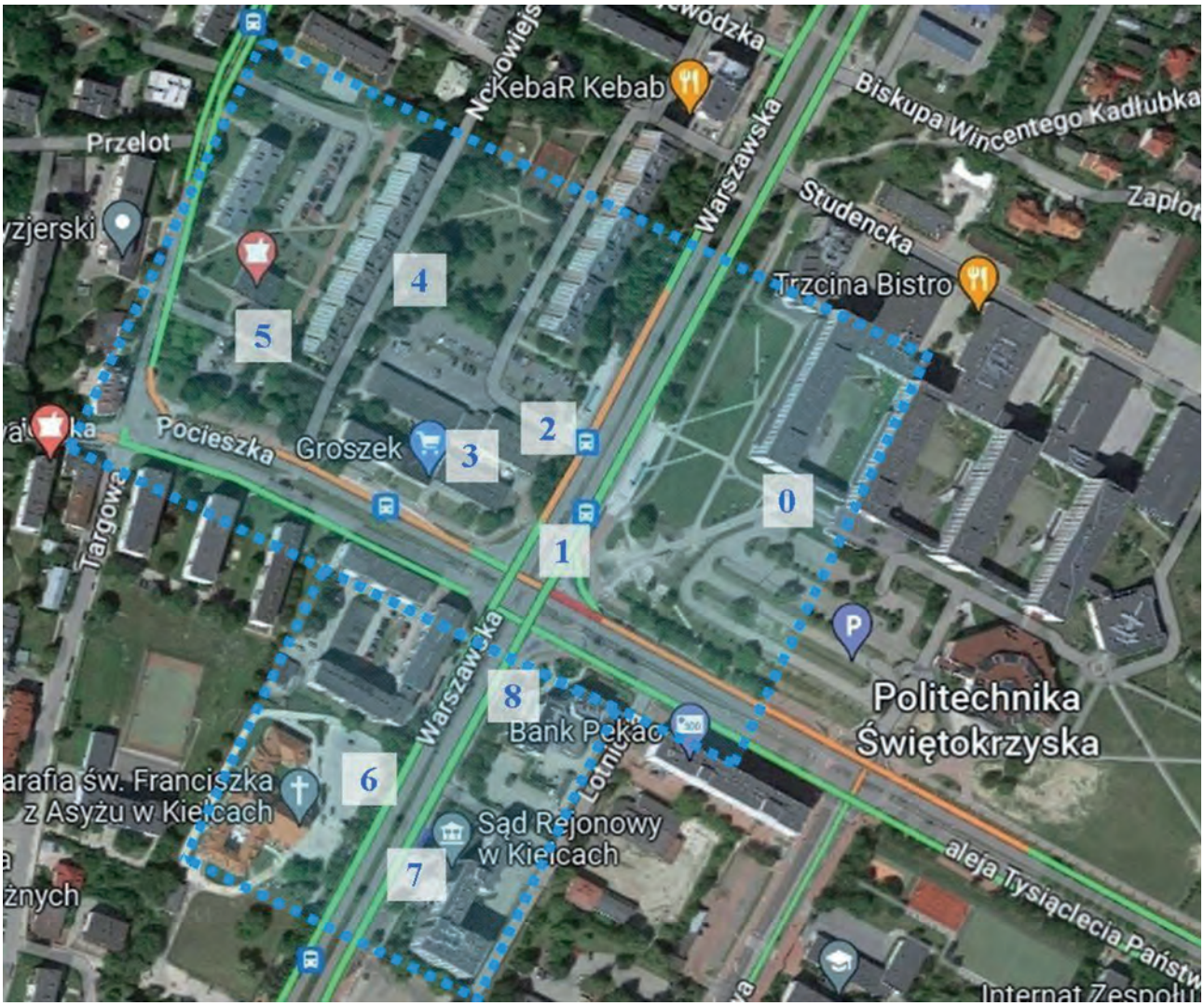

Fig. 7. Overview map illustrating the space being tested: 0 – exterior zone in front of the Faculty of Civil Engineering and Architecture of the Kielce University of Technology – starting point of the experiment; 1 – public transport zone, crossing lanes at the intersection of roads with heavy traffic; 2 – bus stop with ticket machine; 3 – service zone: grocery, butcher's shop, plumber's shop, Municipal Sports Club, Post Office, and other small services; 4 – green areas, recreation and leisure; 5 – community space at the housing estate "KSM Sady"; 6 – space of the sacral complex of the parish of St. Francis of Assisi with the Capuchin Monastery; 7 – space in front of the District Court; 8 – space in front of the National Bank of Poland Regional Branch in Kielce

The field research encompassed publicly accessible space in the surroundings of the campus of Kielce University of Technology, along busy Warszawska Street, Aleja Tysiąclecia Państwa Polskiego, Pocieszka Street, Nowowiejska Street, in the service and social space next to the KSM "Sady" housing estate, the space of the sacred complex of the parish of St. Francis of Assisi with the Capuchin Monastery, the space in front of the District Court and the National Bank of Poland Regional Branch in Kielce (Fig. 7). Analyses of the design and functionality of the solutions used in the city's structure – from the perspective of users with disabilities, as well as analyses of compliance with current legislation – were carried out. Pedestrian zones, the accessibility of bus stops and bus services, the location of individual urban infrastructure facilities and transport links between them, the proximity of shops and services, squares and urban greenery were tested. In addition to the sheer opportunity to experience disability, in-depth reflection on the barriers and needs of seniors with a variety of limitations was important in the experiment.

The analysis of the existing solutions was sufficient to draw up a summary of the barriers encountered and thus develop key demands, which include:

– infrastructure improvements to pavements, including removal of high thresholds, steep ramps;
– creation of a good structure of footpaths, continuation of guiding paths – especially at road junctions, where it is necessary to stop and get information confirming the current route;
– installation of landscaping elements, including benches and railings at ramps, exits to communal green areas, estates;
– eliminating the unevenness of a neglected area;
– the appropriate dimension and the accessibility and usability of the space;
– development of recreational and leisure spaces adapted to the needs of older people;
– installation and upgrading of lighting along footpaths and walkways;
– providing clear view axes at the end of traffic routes, and providing a wider field of view;
– introduction of separate cycle lanes;
– preservation of areas of natural greenery, proposal to introduce scented greenery;
– visible and comprehensible signage with discernible graphic information, e.g. to find one's way (given the spatial orientation problems experienced by senior citizens), warnings of dangers in public spaces;
– the use of markings for the visually impaired, e.g. a textured stripes, special lines or convex patterns – allowing the space to be explored e.g. with a cane, feet (the use of audible signalling of the situation in the space at all tested crossings is valuable).

5. DISCUSSION AND RESULTS

The main goals of the experiments were to understand the concept of accessibility and to correctly identify and define the needs of people with disabilities – in the public space of the city, to be aware of the existence of barriers and accessibility restrictions and to know how to prevent them. The idea was also to provide knowledge on how to ensure accessibility, understanding the need for an appropriate approach to the design of services and civil structures from the perspective of the user with special needs. In doing so, it was important to acquire practical skills for creating new solutions to facilitate the functioning of seniors – as people with special needs – in the physical structures of the city.

The research undertook an empirical exploration of the sense of identity of '60+' seniors in the situation of various disabilities they experience. In this way, the participants tested the possibilities for a generation of older people – users of architecture with multiple disabilities – to move and act freely in the built environment. The debriefing and concluding discussions critically analysed current solutions and spatial barriers, as well as proposals for introducing solutions that could be implemented under the conditions of the city of Kielce, especially what could be done better, what can be improved. Participants presented interesting ideas on how to make a specific place accessible to people with disabilities, proposed solutions and the use of social innovations from the area of the tested space, locating products and civil structures in it – created with users with special needs in mind. It was found that older people, who are most often faced with multiple and varied ailments, are generally less mobile and spend much more time in their immediate environment. It is therefore imperative for municipal authorities and managers of public spaces to ensure, through proper management, that their users can remain independent in their local environment for as long as possible in the future. The conclusions state that it is becoming fundamental to work towards the concept of a fair and ageing-friendly city, thus taking into account the needs of different user groups, including the '60+' generation.

In summary, as a result of the experiences – based on selected public spaces of the contemporary city of Kielce – and barriers encountered on an architectural and urban scale, it was unanimously concluded that all residents should have an unrestricted right to use the infrastructure and services offered by the city without problems. An 'accessible city' only becomes fair and friendly when all its users, regardless of age can:
– move freely on the streets;
– receive comprehensible information – very important for hearing-impaired, blind people;
– enter all service buildings (shops, laundries) and public buildings (post office, clinic);
– use public services without hindrance, especially people with special needs (such as: visually impaired, wheelchair users), otherwise this translates into exclusion from social and urban life;
– easily, with simple and intuitive operation – purchase a bus ticket from a ticket machine, a parking ticket from a parking meter;
– freely get on the bus and move in any direction, with all buses having a lowered floor, equipped with ramps so that wheelchair users can use them without hindrance and parents or grandparents with pushchairs have no problems in using them (Fig. 8).

Fig. 8. Senior-friendly elements when traveling by public transport: light and sound signaling at crossings, stable and safe bus passage thanks to batteries in the floor, comfortable space for wheelchairs, seats, handrails, buttons – dedicated to seniors. Photo: Joanna Gil-Mastalerczyk

Figure 9 illustrates the key elements that constitute the accessibility of public space – related to the physical features of the city. The synthesis of the proposals indicates: service and residential development, public and social space and transport. These components impinge on the safety, accessibility and seamless movement of an ageing population in urban spaces.

Fig. 9. Key elements that constitute the accessibility of the city's public spaces. Own elaboration

6. SUMMARY

Taking into account the latest demographic forecasts, the disablement that increases with age and, above all, the fact that we are all getting older, multifaceted action is becoming a priority, in terms of:

- building a senior-friendly public space and local living environment;
- making urban spaces safe and more accessible;
- high architectural and urban quality as well as aesthetic and landscape value of publicly accessible urban spaces;
- the involvement of local and regional authorities in transforming and improving cities to meet the changing needs of their citizens.

In the light of the experiments presented and described, it also becomes crucial to shape positive perceptions of old age in society by implementing the principles of accessibility – through education and awareness-raising of stakeholders – civil servants, employers' organisations, designers, institutions (...), as well as continually raising awareness among young people. Equally important is public participation – at every stage of seniority policy, and the dissemination of knowledge and action for education *for old age, into old age, through old age (from the youngest generation) and education in old age (older people)* [19].

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PAPER – SAWDUST COMPOSITES: FABRICATION AND COMPARISON IN TERMS OF HEAT TRANSFER AND STRENGTH PROPERTIES

KOMPOZYTY PAPIEROWO-TROCINOWE: WYTWARZANIE I PORÓWNANIE WŁAŚCIWOŚCI CIEPLNYCH I WYTRZYMAŁOŚCIOWYCH

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Abstract

This study was designed to examine the feasibility of recycling cassava effluent, sawdust, and unused paper products to enhance their utilization for beneficial purpose. Waste newspaper paste (WNP), Waste writing – paper paste (WWP), and Waste carton paper paste (WCP) were prepared and then used separately to similarly fabricate composite panels with Sawdust particle (SDP) proportioned at 0%, 25%, 50%, 75%, and 100% by weight. The binder used was cassava starch slurry prepared from the effluent. Bulk density, water absorption, thermal conductivity, specific heat capacity, thermal diffusivity, nailability, and flexural strength were determined for the developed samples. From the results obtained, the samples were found to be light-weight and their thermal insulation performance improved with increasing proportions of the SDP. Though samples containing the WCP exhibited the best satisfactory performance, it was found that all the studied samples could perform more effectively and efficiently as ceilings compared to some of those reported in the literature. From scientific-economic viewpoint, valorizing the above-mentioned wastes as described in this paper could help to protect the environment and also yield value-added insulation ceilings for enhancement of sustainable building construction especially in tropical areas.

Keywords: Cassava Effluent, Ceiling, Flexural strength, Nailability, Thermal conductivity, Water absorption

Streszczenie

Celem pracy było określenie możliwości recyklingu ścieków z manioku, trocin i odpadowych materiałów papierniczych w celu ich szerszego wykorzystania. Nitki z makulatury gazetowej (WNP), nitki z makulatury z papieru do pisania (WWP) i nitki z makulatury z kartonu (WCP) zostały przygotowane, a następnie użyte osobno do wytworzenia paneli kompozytowych z dodatkiem trocin (SDP) przy udziale masowym 0%, 25%, 50 %, 75% i 100%. Zastosowanym spoiwem była przygotowana z odcieku zawiesina skrobi z manioku. Dla przygotowanych próbek określono gęstość nasypową, nasiąkliwość, przewodność cieplną, ciepło właściwe, dyfuzyjność cieplną, zdolność do wbijania gwoździ i wytrzymałość na zginanie. Na podstawie uzyskanych wyników stwierdzono, że próbki miały małą gęstość objętościową, a ich właściwości termoizolacyjne poprawiały się wraz ze wzrostem udziału trocin (SDP). Chociaż próbki zawierające WCP wykazywały najlepsze właściwości, stwierdzono,

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że z wszystkich badanych próbek można wytworzyć sufity o lepszych właściwościach w porównaniu z podobnymi opisanymi w literaturze. Z naukowo-ekonomicznego punktu widzenia zastosowanie wyżej wymienionych odpadów, jak opisano w tym artykule, może pomóc w ochronie środowiska, a także w uzyskaniu bardziej ciepłochronnych stropów, a co za tym idzie przyczyni się do rozwoju bardziej zrównoważonego budownictwa, zwłaszcza w obszarach tropikalnych.

Słowa kluczowe: ścieki z manioku, strop, wytrzymałość na zginanie, zdolność do przybijania gwoździ, przewodność cieplna, absorpcja wody

1.INTRODUCTION

In recent years, there has been a rapid increase in the engineering applications of hybrid composites. This is because hybridization enables such composites to exhibit versatile properties (like high strength, low weight, ease of manufacturing, and so on) that none of the components possesses. In such undertaking, synthetic fibers are frequently utilized. Nevertheless, some factors including high density, non-biodegradability, non-recyclability and increase in cost [1] raise serious concerns about the use of synthetic fibres as reinforcers for development of hybrid composites for various engineering applications. According to Mahir et al [2], natural fibers have been proven alternative to synthetic fiber in transportation such as automobiles, railway coaches and aerospace, military, building, packaging, consumer products, and construction industries for ceiling paneling, partition boards, etc. Since natural fibers are promising enough to address the mentioned challenges and are also cheaply available and sustainable, there is an urgent need to shift attention to their utilization with the aim of replacing synthetic ones. On the strength of this consideration, recycling natural fiber into hybrid composites could help to improve the economy of a country while becoming a safe technique of managing the wastes in order to ensure sustainable development.

Wastes may be defined as the by-products of human activities regarded to have become useless and as such, remain unwanted and desperately crying for immediate disposal. Sanandiya et al [3] posited that urban residents generate wastes four times greater in quantity than their rural counterparts. These wastes emanate from various sources/sectors and are made up of different kinds of materials. For instance, between 25% and 40% of municipal solid wastes generated worldwide consist of paper and paper products [4]. Also, in wood working sectors, sawdust is constantly produced as waste during wood processing [5] and every 1,000 kilos of wood processed generates almost 40% to more than 52% of sawdust [6]. In Nigeria, about 1.8 million tons of sawdust are produced annually [7]. Not only that, in 2017, Food and Agriculture Organization Statistics (FAOSTAT) showed that among the 100 countries that collectively produced 291,992,646 tons of cassava (*Manihot esculenta*) in the world, Nigeria was the largest producer with capacity of 59,485,947 tons. More so, a moderate growth in production is a recurring trend in subsequent economic years. Processing of cassava into assorted useful items (like garri, flour, fufu, tapioca, etc for consumption) usually generates some solid and liquid wastes, among which the most prominent is the effluent (wastewater). Between 6 tons and 8 tons of cassava tubers supplied daily, 3 m^3 to 6 $m^3$of the effluent could be generated during cassava processing [8].

Findings from some studies have revealed that the aforementioned wastes could be used for certain beneficial purposes. For example, starch derived from waste generated during cassava processing is a promising raw material for preparation of binders that are suitable for use as coating materials [9, 10] and in tablet formulations [11, 12]. Slurry prepared from cassava effluent can be utilized in recycling of periwinkle shells, Clam shells and Oyster shells into disc-shaped compacts for electrical/electronic applications [13-16]. In their study, Okeyinka and Idowu [17] reported that ceiling boards produced from a mixture of waste paper and $CaCO_3$ compare well with asbestos ceilings. Aside that, briquettes [18], wood-plastic composites [19, 20], wood-cement composites [21] and reinforced epoxy composites [22, 23] produced with sawdust exhibit satisfactory performance tendencies.

It has been observed that wastes generation is an intrinsic part of human existence and its rate is a function of growth in urbanization. As noted by Kaza et al [24], the World Bank estimated a drastic increase in the amount of global municipal solid waste generation from today's 2.01 billion tons to 3.40 billion tons by 2050. From a careful consideration of the present situation, there is no doubt that the said wastes volume may continue to accelerate throughout this century. In Nigeria and other developing countries, waste management system is ineffective and so, the prevalent habit of getting rid of the wastes in question

is by burning in an open space or indiscriminately discharging them into water ways. These practices are detrimental to environment and public health in diverse ways. For example, diseases can be spread from dumpsites, atmosphere can be polluted with large amount of greenhouse gas and soil productivity can be affected through release of phenol compound into the soil. Since wastes can become eco-toxic if not handled properly, this work focuses on tailoring sawdust with some types of waste paper materials into green hybrid composites using cassava starch slurry (derived from effluent) as binder. In order to determine the suitability of the new materials for engineering applications, their heat transfer and strength properties will be investigated. Interestingly, this paper will be the first to provide scientific information on such attempt so as to address the dearth in the literature of studies on uses of the wastes.

2. EXPERIMENTAL DESIGN

2.1. Materials collection and Description

In this study, cassava effluent, newspapers, writing papers, cartons and sawdust discarded as waste materials were utilized. The cassava effluent was collected from local cassava processing units whereas the sawdust (heterogeneous) was obtained from sawmills. Also, the newspapers, writing papers, and cartons were picked from dumpsites in markets and schools. These materials were sourced in large quantities within Uyo Metropolis, Akwa Ibom State, Nigeria.

2.2. Processing of the materials

The cassava effluent was put in a plastic bucket and allowed to remain undisturbed for 24 hours before the residue (starch) was recovered by decantation. After that, the starch was sun-dried until it became powdery and moisture-free. Also, the waste newspapers, writing papers, and cartons were segregated and then cleaned with brush to ensure that they were free from any accompanying impurities. Each of them was cut into tiny pieces by means of scissors. The pieces obtained in each case were soaked separately in warm water for 24 hours. On removal, the soaked materials were strained to remove excess water from them before they were pound into paste, one at a time, using Agate mortar and pestle. The paste of each material was subjected to continuous sun-drying and weighing until no further reduction in mass was observed. More so, the as-collected sawdust was soaked in water at 24^{o}C for 20 seconds in order to remove sand and other unwanted materials from it. This was followed by complete sun-drying of the sawdust before it was communited. Figure 1 shows the dumpsite as well as dry forms of the processed materials.

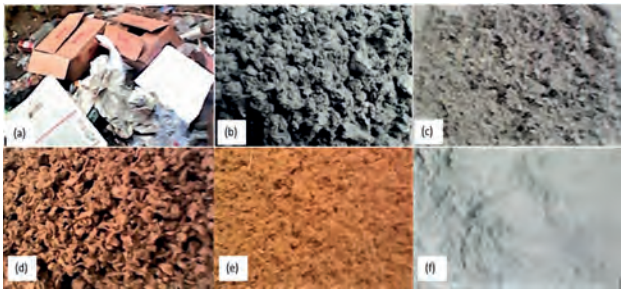

Fig. 1. A dumpsite (a) Waste newspaper paste (b) Waste writing-paper paste (c) Waste carton paste (d) Sawdust particle (e) Cassava starch (f)

2.3. Analysis of the processed materials

For the purpose of evaluating flowability of the as-prepared cassava starch, its Carr's compressibility index was determined as per the standard protocol outlined in [25] and its static angle of repose was measured using fixed funnel method [26]. Sieve analysis was carried out [27] to determine the particle size distribution of the sawdust and the quantity that passed through 2.36 mm openings was utilized in this work. The sieved sawdust and each of the prepared pastes were divided into two portions. In each case, one portion was analyzed for quantification of lignocellulosic components by adopting gravimetric method [28]. Each analysis was performed three times before the mean value and standard error in the results were computed.

2.4.Composites fabrication

The remaining portion of each material was used to fabricate various composites by hand lay-up technique. Each paste was used separately to form composites with various loadings of the sawdust particles. The same loading fractions were applied in all the cases and cassava starch slurry was used as binding agent. This was prepared by continuously stirring and heating a 14% solution of the starch until it became gummy, after which it was allowed to cool completely. Throughout the formulation processes, 1:1 weight ratio of the binder to composite mix was maintained. While the composites meant for flexural strength and nailability tests were cast in a mold measuring 100 mm x 30 mm x 10 mm, those meant for other tests were formed in a circular mold of diameter 110 mm and thickness 9 mm. Compaction was performed by means of a laboratory-

made compacting machine maintained at 5 kN for 24 hours. The composites were prepared in triplicates per formulation. Prior to properties investigation, the developed composites were allowed to dry completely in air before they were subjected to the tests intended for them in this study.

2.5. Property tests

2.5.1. Thermal conductivity

This transport property of a material was examined for each of the test samples by using Modified Lee-Charlton's Disc Apparatus Technique as described in details elsewhere [29]. The experimental set-up used consisted of two identical discs (made from nickel, each measuring 110 mm in diameter and having thickness of 10 mm) and a cylindrical aluminum block [30]. In this study, an electric hotplate (Model Lloytron E4102WH) was used as the heat source. The control dial of the hotplate was adjusted to ensure that the temperature of the disc that supplied heat to the sample was maintained at 98°C. Until steady state was reached, temperature monitoring and measurement were done by means of two digital thermometers (Model 305, properly calibrated) each equipped with type-K probe. Temperature – time models were developed using Microsoft Excel Curve Fitting and with coefficient of determination of at least 0.9998. In each case, the rate of cooling was determined by application of differentiation and then used to compute the corresponding value of thermal conductivity in accordance with Fourier's law equation for one-dimensional heat conduction as:

$$k = \left(\frac{M_d C_d x}{A \Delta \theta} \right) \frac{dT}{dt} \tag{1}$$

where: k – thermal conductivity, M_d – mass of the upper disc, C_d – specific heat capacity of the disc, x – of the sample, A – cross-sectional area of the sample, $\Delta\theta$ – temperature difference across the sample's thickness, $\frac{dT}{dt}$ – rate of cooling of the disc.

After that, the circular samples were cut into reasonable sizes and shapes required in other tests for which they were prepared.

2.5.2. Bulk density and Water absorption

For bulk density determination, Modified water displacement method was applied [31] to obtain the bulk volume of each sample. The bulk density, ρ was obtained for each sample by computation using the mass, M and bulk volume, V based on the relation [32, 33]

$$\rho = \frac{M}{V} \tag{2}$$

Regarding water absorption determination, immersion method was used. The masses of the samples were measured before they were completely immersed in cold water. After 4 hours, the samples were removed from the water and allowed to surface-dry before their masses were measured again. The mass of water absorbed in each case was determined as the difference between the mass before and that after the immersion. From the data gathered, the water absorption of each sample was calculated as:

$$WA = \left(\frac{M_a}{M} \right) 100\% \tag{3}$$

where: WA – water absorption, M_a – mass of water absorbed.

2.5.3. Specific heat capacity and Thermal diffusivity

In the case of specific heat capacity determination, SEUR'S apparatus [34] was designed and used. Aside each of the samples, accessories for heat exchange were aluminum plate of thickness 8 mm and plywood plate of the same thickness. The masses of the accessories were measured using a digital balance (S. METTLER – 600 g). A square cavity measuring 60 mm x 60 mm was centrally provided inside each half for heat exchange. When thermal balance was established, the amount of heat lost or gained (as the case may be) was determined for each plate as the product of mass, specific heat capacity and change in temperature. With assumption of negligible heat losses to the surroundings, the data obtained were then used to calculate the specific heat capacity of sample thus:

$$c = \frac{(Q - q)}{M \Delta T} \tag{4}$$

where: c – specific heat capacity of the sample, Q – total quantity of heat lost by the aluminum plate during heat exchange, q – total quantity of heat gained by the plywood plate during heat exchange, M – of the sample, ΔT – change in temperature of the sample.

The values of thermal conductivity, bulk density and specific heat capacity obtained for each sample representative were used to compute the corresponding thermal diffusivity, λ as [35-38]:

$$\lambda = \frac{k}{\rho c} \tag{5}$$

2.5.4. Flexural strength and Nailability

A universal testing machine (Model H10KT) was used for determination of flexural strength based on three-point bending technique as stated in [39]. During each test schedule, a load of 10 kN was applied and a test speed of 1 mm/min was maintained until fracture occurred. At that instant, the maximum load, *P* applied, span length, *L*. width, *b* and thickness, *x* of the sample were used to compute the flexural strength, according to the relation:

$$\sigma = \frac{3PL}{2bx^2} \quad (6)$$

The samples were then subjected to nailability test in order to assess their ability to withstand nailing. This test was performed by means of a nail gun named Finish Nailer (Model D51257K, manufactured by Dewalt). In the design of this electric hammer, a motor rotates two drive axles and the hammering force is generated by ordinary springs. Each hammering operation was performed slowly and methodically with a 2" – nail fired through the thickness of a sample until either a tiny visible crack was noticed or the nail tip appeared on the opposite side of the sample. In any case the crack was observed, the nailing was discontinued and the nail penetration depth was determined as the difference between the overall length of the nail and the length of the nail's portion remaining. But if the nail penetrated without causing any visible crack, the penetration depth was considered to be the same as thickness of the sample under test. In either case, nailability was obtained using the formula:

$$n_b = \left(\frac{D}{x}\right)100\% \quad (7)$$

where: n_b – nailability, D – penetration depth of the nail.

All the tests/measurements in this work were carried out at (24.0 ±1.0)°C and 53.0% relative humidity. The mean and corresponding standard error values were calculated for each formulation of the developed composite panels.

3. RESULTS AND DISCUSSION

The results of the analysis carried out on the processed material are presented in Table 1. Table 2 shows the results of tests performed on the fabricated samples in order to determine their heat transfer and strength properties.

From Table 1, it can be seen that the WCP contains the highest proportion of cellulose but lowest percentage of lignin compared to the WNP, WWP and SDP. Also, the WNP contains fractions of cellulose and hemicelluloses that are slightly greater than those contained in the WWP. Among the lignocelluloses, cellulose is highly hydrophilic having a very strong hydrogen bonding which enables it to absorb water readily, hemicelluloses acts like a semi-soluble polyelectrolyte and binder whereas lignin is a highly randomized condensed polymer full of chemically resistant cross-links of various types. Thus, the results show that the WNP, WWP, WCP and SDP cannot have the same chemical behavior. From the grading curve illustrated in Figure 2, it can be deciphered that the sawdust particles finer (in diameter) than 0.6 mm are less in quantity than the fine ones. This is a pointer to the fact that many void spaces exist in the developed samples as the SDP loading increases. Since the Carr's compressibility index of value below 15% and static angle of repose value between 31° and 35° generally indicate good flowability [40, 41], it can be averred that the starch utilized in this study has flow characteristics that make it suitable for manufacturing purposes.

Table 1. Particulars of the processed materials

Parameters	Values obtained per material				
	WNP	WWP	WCP	SDP	CST
Lignocellulosic constituents					
Cellulose (%)	43.4 ±0.1	42.8 ±0.2	47.6 ±0.2	41.8 ±0.2	–
Hemicelluloses (%)	27.0 ±0.1	26.7 ±0.1	26.5 ±0.2	26.4 ±0.1	–
Lignin (%)	20.1 ±0.2	20.8 ±0.1	19.7 ±0.2	22.3 ±0.2	–
Flowability					
Carr's compressibility index (%)	–	–	–	–	–
Static angle of repose (°)	–	–	–	–	–

WNP – Waste Newspaper Paste, WWP – Waste Writing-paper Paste, WCP – Waste Carton Paste, SDP – Sawdust Particle, CST – Cassava Starch

Table 2. Results of property tests performed on the test samples

Composite mix	Mix ratio (%)	Measured values per property						
		WA (%)	ρ (kgm^{-3})	k ($Wm^{-1}K^{-1}$)	c ($Jkg^{-1}K^{-1}$)	λ ($10^{-7} m^2s^{-1}$)	n_b (%)	σ (N/mm^2)
WNP:SDP	100:0	86.34 ±0.01	390.84 ±1.03	0.0879 ±0.0004	1342.76 ±0.02	1.67 ±0.01	100.0 ±0.0	1.048 ±0.001
	75:25	91.21 ±0.02	352.43 ±1.11	0.0793 ±0.0003	1482.63 ±0.01	1.52 ±0.01	100.0 ±0.0	0.841 ±0.002
	50:50	97.22 ±0.02	316.27 ±1.09	0.0722 ±0.0004	1597.88 ±0.02	1.43 ±0.02	98.8 ±0.2	0.682 ±0.002
	25:75	102.18 ±0.01	280.06 ±1.07	0.0631 ±0.0003	1722.91 ±0.02	1.31 ±0.01	96.4 ±0.2	0.476 ±0.001
	0:100	106.24 ±0.03	245.21 ±1.01	0.0543 ±0.0003	1866.08 ±0.01	1.19 ±0.02	86.7 ±0.1	0.306 ±0.001
WWP:SDP	100:0	85.10 ±0.02	394.77 ±1.08	0.0886 ±0.0005	1339.35 ±0.01	1.68 ±0.01	100.0 ±0.0	1.050 ±0.002
	75:25	89.21 ±0.02	358.18 ±1.05	0.0810 ±0.0003	1482.07 ±0.03	1.53 ±0.02	100.0 ±0.0	0.867 ±0.002
	50:50	94.03 ±0.01	318.06 ±1.12	0.0724 ±0.0002	1581.24 ±0.02	1.44 ±0.02	99.5 ±0.2	0.689 ±0.001
	25:75	100.78 ±0.01	280.91 ±1.10	0.0633 ±0.0003	1710.09 ±0.02	1.32 ±0.01	96.9 ±0.1	0.497 ±0.002
	0:100	106.24 ±0.03	245.21 ±1.01	0.0543 ±0.0003	1866.08 ±0.01	1.19 ±0.02	86.7 ±0.1	0.306 ±0.001
WCP:SDP	100:0	89.73 ±0.02	268.77 ±1.00	0.0742 ±0.0002	1681.84 ±0.01	1.64 ±0.01	100.0 ±0.0	1.151 ±0.001
	75:25	94.27 ±0.01	264.49 ±1.04	0.0686 ±0.0004	1728.99 ±0.01	1.50 ±0.01	100.0 ±0.0	0.943 ±0.001
	50:50	99,48 ±0.01	257.71 ±1.07	0.0646 ±0.0002	1776.36 ±0.03	1.41 ±0.01	100.0 ±0.0	0.736 ±0.002
	25:75	104.33 ±0.02	252.05 ±1.05	0.0595 ±0.0004	1836.42 ±0.02	1.29 ±0.01	98.9 ±0.2	0.527 ±0.002
	0:100	106.24 ±0.03	245.21 ±1.01	0.0543 ±0.0003	1866.08 ±0.01	1.19 ±0.02	86.7 ±0.1	0.306 ±0.001

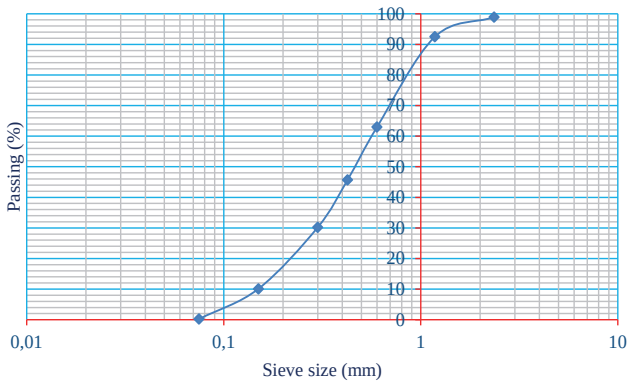

Fig. 2. Grading curve of the processed sawdust

Every porous material that contains lignocellulosic constituents is prone to attack by water during its service life as a partition element or ceiling panel in buildings. It can be seen from Table 2 that water absorption value is the highest in the case of sample developed with 100% content of the SDP, followed orderly by those similarly produced but with the WCP, WNP and WWP. With the use of pastes at 100% level, the sample containing the WNP possesses water absorption capability that is 1.24% greater than its counterpart containing the WWP but 3.39% less when compared to the sample developed with the WCP. This could be understood to be as a result of the differences in the proportions of their lignocelluloses. That is to say, the greater the cellulose content and lower the lignin fraction in a paste, the more affinity the sample developed with it has. Thus, by containing 4.2% and 4.8% cellulose fractions in excess and being deficient by 0.4% and 1.4% in terms of lignin proportions compared to the percentages of such lignocellulosic constituents in the WNP and WWP respectively, the WCP obviously possesses the highest tendency for hydrophilicity. In the case of the sample fabricated with the SDP alone, the porous nature of the fiber plays a major influencing role for its water uptake. Since all the samples are completely dry and porous, the voids in them serve as reservoirs for water accommodation. This insinuates that though cellulose-based materials are naturally hydrophilic, the more porous a material is, the more water it is capable of absorbing under defined conditions. So, due to refractory nature of the SDP, more voids exist in it than in any of the pastes (WNP, WWP and WCP), thus causing the sample fabricated with 100% of it (the SDP) to absorb the highest quantity of water. Consequently, by increasing the SDP content in any of the composite mixes, the water absorption of the resulting sample increases. For instance, utilization of the SDP at 25%, 50% and 75% with the WNP

increases water absorption by about 4.87%, 10.88%, and 15.84% respectively. Also, at similar SDP loadings, the samples produced with the WWP show increase in water absorption by about l4.11%, 8.93% and 15.68% respectively. Again, water absorption increases by 4.54%, 9.75% and 14.60% respectively in the case of composites similarly developed but with the WCP as component. However, the sample made using 25% of the SDP with 75% of the WCP has almost the same ability to take up water as the composite fabricated with the SDP and WWP at 50% levels. Although considerable variations are observed in the results of the water absorption test, the use of one-way analysis of variance (ANOVA) at 0.05 reveals that the water absorption values obtained for the samples developed using various proportions of the WNP are not significantly different from those obtained for their counterparts produced with either the WWP or WCP as component. Comparatively, it is found that the water absorption values of the studied samples are less than the minimum value of 121.06% reported by Akinyemi et al [42] for composite boards developed using corn cob and sawdust and also recommended for indoor uses in buildings.

Bulk density expresses how large the mass of a porous material is in relation to the material's bulk volume. In this study, it is found that increase in proportion of the SDP results in decrease in bulk density of the composites notwithstanding the paste (WNP, WWP or WCP) used. Also, the composites made with various percentages of the SDP and WWP have greater bulk density values than their counterparts containing the WNP while those similarly produced but with the WCP has the least bulk density values. Since the fabrication procedures and conditions adopted in this work remained unchanged, this simply indicates that the SDP is the lightest whereas the WWP is the densest and the WWP is denser than the WCP. The lightness of the pastes and fiber is attributable to the interstices/voids in them. Between the samples developed using the WNP as component and those similarly prepared using the WWP, the largest difference in mean bulk density values is 5.75 kgm^{-3} and this is yielded when utilizing the SDP at 25% level. Also, incorporating up to 75% of the SDP leads to the smallest difference (0.85 kgm^{-3}) between their bulk density values. With respect to the bulk density values obtained for the samples containing 100%, 75%, 50% and 25% of the WCP, the bulk density of counterpart samples with the WNP content increases by about 45.42%, 33.25%, 22.72% and 11.11% whereas the increase in the case of samples containing fractions of the WWP at similar levels is about 46.88%, 35.42%, 23.42% and 11.45% respectively. Due to their closeness in bulk density values, it appears that if used in building design, the sample with 25% content of the WNP would contribute the same weight like the one fabricated with the WWP at similar level. Statistically, application of the ANOVA at $p < 0.05$ reveals a significant difference only when comparing the bulk density values obtained for samples that contain the WCP with the values obtained for their counterparts developed with the WNP or WWP. Based on the standard criteria stipulated in [43], it suffices to remark that all the studied samples may be regarded as low-density panels.

In order to characterize a material's ability to allow transfer of heat as a result of temperature difference around it, the knowledge of its thermal conductivity is a necessity. At 100% content level, the sample made with the SDP has the least mean thermal conductivity value whereas the sample developed with the WWP has the highest value of thermal conductivity. Also, the sample containing 100% of the WNP has a higher thermal conductivity than the sample made with the WCP alone. Since thermal conductivity of a porous material depends on the ratio of pore free path for zero-porosity, the observed trend in this case is possible. Meanwhile, the void spaces in the samples are filled with air, which is well-known to be one of the best thermal insulants. Also, the volume of air correlates positively with the extent of interstices/void spaces in the samples. Thus, being that the SDP is the lightest, followed by the WCP, WNP and then WWP, the air volume in them increases in that order and causes decrease in thermal conductivity accordingly. On the whole, utilization of the SDP with any of the pastes enhances reduction in thermal conductivity of the resulting composite samples. For instance, making use of the SDP at 25%, 50% and 75% content levels reduces the mean thermal conductivity value by 28.21% for the sample containing the WNP. Also, a reduction by 28.56% is noticed in the case of sample made with the WWP content while it reduces thermal conductivity by 19.81% for sample developed with the WCP content. On comparison of the samples fabricated with the SDP at 0%, 25%, 50% and 75%, the thermal conductivity values of those containing the WWP are greater by 0.80%, 2.14%, 0.28% and 0.32% respectively than the values obtained for their counterparts produced with fractions of the WNP. When compared to the thermal conductivity values of the samples similarly fabricated with the

WCP as a component, the increase is found to be by 19.41%, 18.08%, 12.07% and 6.39% respectively. This implies that if all the composites are applied under same thermal conditions, those that contain the WCP will exhibit the best insulation performance and their counterparts with the WNP content will likely be effective and efficient for restriction of heat transmission as the ones similarly developed using the WWP. Nevertheless, the samples investigated in this work have thermal conductivity values that are within the recommended range given as 0.023 $Wm^{-1}K^{-1}$ to 2.900 $Wm^{-1}K^{-1}$ [44] for heat-insulating and construction materials. In terms of thermal resistivity (reciprocal of thermal conductivity), it can be inferred that the most thermally-conductive sample in this study has thermal resistivity of 11.29 $W^{-1}mK$ against the value of 0.34 $W^{-1}mK$ that associates with the least suitable heat-insulating material. This gives 96.99% difference, showing that the said sample is far better than the least possible material that could be applied for the purpose of thermal insulation in a system.

For samples developed with the WNP and SDP other than at 0% loading level of either of them, proportioning the materials (WNP and SDP) at 75% and 25% respectively yields a sample with mean specific heat capacity value that gives maximum marginal increment (139.87 $Jkg^{-1}K^{-1}$). In the case of those that contain the WWP and similar SDP loadings, the same is applicable at 25% of the SDP content in which case the maximum marginal increment is found to be 142.72 $JkgK^{-1}$. As for the use of the WCP instead of the WNP or WWP, the marginal change in the mean specific heat capacity (60.06 $Jkg^{-1}K^{-1}$) is maximum when the SDP content is 75%. Between samples containing the WNP and those produced at similar mix ratios using the WWP as a component, the specific heat capacity values are very close and are also less than the values obtained for their counterparts containing fractions of the WCP. This indicates that incorporation of the WCP can improve thermal insulation efficiency over utilization of either the WNP or WWP at similar levels for development of composite panels. Stating differently, specific heat capacity of the composite constituents has significant influence on the thermal insulation performance of the developed samples. As all the samples contain the SDP as reinforcer, it can be asserted that the use of the WCP makes the resulting composites require more energy in order to change the temperature of their unit mass by one Kelvin compared to their counterparts containing either the WNP or WWP. The graphical illustration in Figure 3 depicts that specific heat capacity of the studied samples increases with increasing SDP loadings in all the cases. This is, plausibly, due to the fact that the SDP has the highest specific heat capacity value compared to the WNP, WWP and WCP.

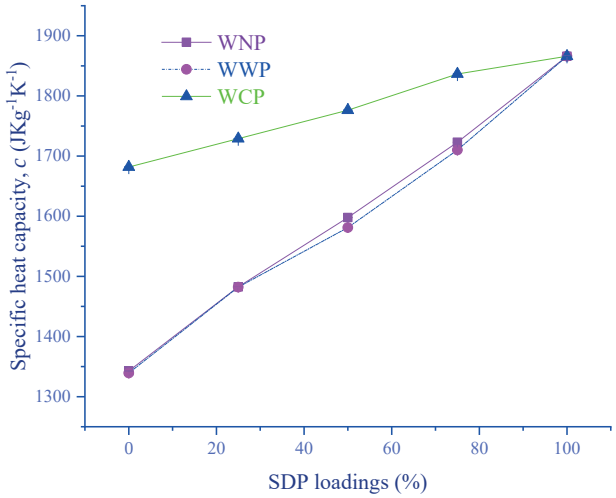

Fig. 3. Variation of specific heat capacity with sawdust proportion

In a situation the samples are photothermally heated during service, high specific heat capacity or bulk density and low thermal conductivity favor low thermal diffusivity in order to prolong thermal equilibrium duration of the thermal environment. By considering this fact based on the support of the empirical relationship expressed as eq. (5) in this work, the implication of the results obtained is that if all the samples fabricated with 25%, 50%, or 75% loadings of the SDP are subjected to the same thermal disturbance, those containing the WCP will enhance the slowest rate of temperature propagation for heat diffusion within them. Because heat-diffusing tendency of the SDP is less than that of the WCP, WWP or WNP, sluggishness in the spread of heat within the samples is observed to improve as the SDP proportion increases. The response of the samples to thermal waves could also be explained in terms of thermal resistance (ratio of thickness to thermal conductivity), keeping in mind that all the samples prepared in this work for investigation of heat transfer properties have the same thickness (9.0 mm). From the obtained results, it can be deduced that at 100% loading level, samples developed using the WNP, WWP, WCP and SDP have mean thermal resistance values of 0.102, 0.102, 0.121 and 0.166 (all in $W^{-1}m^2K$) respectively. This portrays that when exposed to thermal front, the highest opposition to heat transmission would be offered by the sample

with 100% content of the SDP while the least resistance to such oscillatory heat flow would be provided by the sample containing 100% of the WNP or WWP. For the studied samples, the highest thermal diffusivity value ($1.68 \cdot 10^{-7}$ m^2s^{-1}) is 29.54% less than the value of $2.38 \cdot 10^{-7}$ m^2s^{-1} reported by Gesa et al [45] for a conventional ceiling panel called Isorel. It therefore means that all the samples examined in this work could perform better than Isorel as far as their application for actualization of thermal management by restriction of heat propagation is a priority.

When joining of the samples to a suitable material by nailing is needed, it is clear from the results of nailability test that sample developed with the SDP at 100% content level cannot withstand such operation. This observation could be argued in the light of refractory nature of the SDP with respect to the concentration of the binder used in fabricating the samples. That is to say, using slurry of cassava starch that is more viscous/gummy than the one utilized in this work could enhance adhesion to ensure successful nailability of a sample made with the SDP alone. Evidence in support of the effect of sawdust nature on nailability of the samples is in the cases involving the use of the paper pastes. Understandably, the WNP, WWP and WCP are known to be less refractory compared to the SDP. As expected, utilizing at least 75% of the WNP or WWP as a component or by using at least 50% of the WCP fraction yields a composite panel that is nailable. Below the afore-stated limits, adhesion effect is reduced with increasing SDP content and consequently weakens the internal bond strength between the constituents in the composite matrix. When decline in the nailability value occurs, the use of the WWP ensures the least difference (0.5%). At 75% level of the SDP incorporation, the use of the WCP produces the smallest difference (1.1%) compared to 3.1% obtained in the case of the WWP and 3.6% due to utilization of the WNP. The refractory nature of the SDP also influences the flexural strength of the samples. As can be seen from Figure 4, the bending stress the samples can withstand before they fracture varies negatively with the SDP proportions. This shows that the pastes utilized in this study are less fragile than the sawdust. Even as it is, the maximum flexural strength (0.1 N/mm^2) reported for Agro-waste composite ceiling boards [46] is found to be 67.32% less than the minimum mean value (0.306 N/mm^2) obtained in this work for the studied samples.

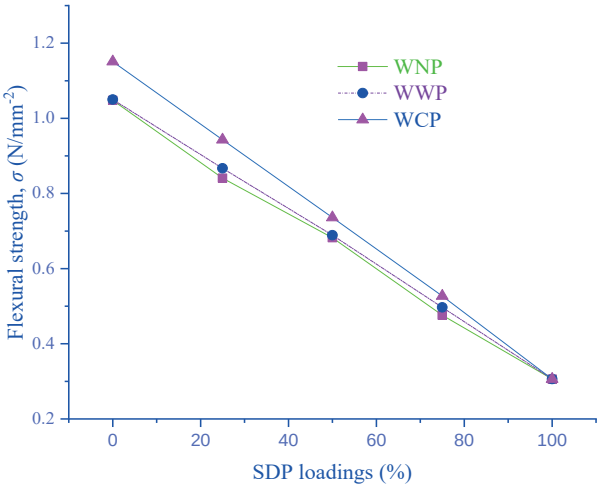

Fig. 4. Variation of flexural strength with sawdust proportion

4. CONCLUSION

From the results of the tests performed on the samples developed in this work, it was found that composites fabricated using sawdust particle (SDP) and waste newspaper paste (WNP) have almost similar property values when compared to their counterparts containing waste writing-paper paste (WWP) as a component. For samples made with either the WNP or WWP content, decline in nailability from 100% was observed when utilizing at least 50% of the SDP in the composite mix whereas in the case involving the WCP, a similar phenomenon occurred when making use of at least 75% of the SDP. All the studied samples showed heat-insulating and strength tendencies that are better than those reported in the literature for some known ceiling panels. However, it was found that composites fabricated with the WCP and SDP contents could exhibit the best performance in terms of thermal insulation, absorption of dead loads and energy saving in buildings. It can therefore be adjudged that cassava effluent, sawdust and waste paper products (such as discarded newspapers, writing papers and cartons) are promising alternative raw materials for production of thermal insulation panels that are suitable for indoor application as ceilings especially in tropical areas. Valorization of the wastes as described in this study is an important step to protect the environment while ensuring availability of economically-sustainable and environmentally-friendly insulation ceilings for building design.

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EXPERIMENTAL STUDY ON THERMAL COMFORT AT UNIVERSITY BUILDINGS IN SLOVAKIA

EKSPERYMENTALNE BADANIE KOMFORTU CIEPLNEGO W BUDYNKACH UNIWERSYTECKICH NA SŁOWACJI

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Abstract

The paper discusses the issue of thermal comfort expressed by the students of the University of Žilina in anonymous questionnaires. The volunteers rated their thermal sensations, preferences as well as lighting conditions in the autumn season. The students were in favour of the prevailing thermal conditions – almost 88% of the volunteers expressed positive opinions about their environment. The comparison of the test results for a computer laboratory with the Fanger model calculation results was also made and indicated differences between the experimental data and values determined with the model.

Streszczenie

W artykule omówiono zagadnienie komfortu cieplnego studentów Uniwersytetu w Żylinie w oparciu o anonimowe ankiety. Ochotnicy oceniali swoje odczucia termiczne, preferencje oraz warunki oświetleniowe w okresie jesiennym. Studenci wyrazili się pozytywnie w zakresie panujących warunków termicznych – blisko 88% odpowiedzi. W pracy dokonano również porównania wyników badań w laboratorium komputerowym z wynikami obliczeń wg modelu Fangera i wykazano różnice między danymi eksperymentalnymi a wartościami wyznaczonymi modelem.

TRAFFIC ZONES ACCESSIBLE FOR ALL USERS. DESIGN SOLUTIONS AND MATERIAL RECOMMENDATIONS FOR OUTDOOR TRAFFIC ZONE PAVEMENTS

PRZESTRZEŃ KOMUNIKACJI DOSTĘPNA DLA WSZYSTKICH. ROZWIĄZANIA PROJEKTOWE I WYTYCZNE MATERIAŁOWE NAWIERZCHNI CIĄGÓW KOMUNIKACYJNYCH ZEWNĘTRZNYCH

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Abstract

This article discusses the aspects of designing the pavements of pedestrian zones, shared spaces, city squares and other public spaces in terms of the selection of their parameters, colour and texture, which can significantly improve their comfort of use and, in a wider context, improve the accessibility of public spaces and buildings. When we think about a friendly city, we aim to create urban spaces free from any barriers that could exclude some people from the social life. Urban space can be defined as friendly from the perspective of an end user who moves around on foot, or uses crutches or a wheelchair, but also in the context of fully fit people, who are nevertheless limited in their movement because they are pushing a pram, carrying a baby or heavy luggage, etc. It has been proven that a well-designed pavement can significantly improve access to an area, reducing therefore the stigmatisation of elderly, disabled, blind, visually impaired people, etc. Solutions described in this article go well beyond the applicable legal acts in the context of the building law and therefore significantly improve the accessibility of public spaces and buildings and help to create spaces that are friendly to all users - i.e. spaces that are safe and free of any risks connected with disorientation, psychological security or the possibility of collision due to the existing barriers

Streszczenie

Artykuł porusza aspekt projektowania nawierzchni ciągów pieszych, pieszo-jezdnych, placów miejskich i innych przestrzeni publicznych pod kątem doboru ich parametrów, kolorystyki oraz faktury, które w znacznym stopniu poprawiają komfort ich użytkowania, a w szerszym kontekście, zwiększają dostępność przestrzeni i obiektów publicznych. Myśląc o mieście przyjaznym, należy wziąć za cel kształtowanie przestrzeni miejskich bez barier wykluczających z życia społecznego. Należy wspomnieć, iż o przyjaznej przestrzeni możemy mówić w kontekście bezpośredniego użytkownika poruszającego się przede wszystkim pieszo lub za pomocą kul i na wózku inwalidzkim, ale również osób w pełni sprawnych, lecz ograniczonych przez np. przemieszczanie się z wózkiem dziecięcym, dzieckiem na rękach czy ciężkim bagażem itp. Wykazano, że odpowiednio zaprojektowana nawierzchnia znacząco wpływa na dostępność przestrzeni, a tym samym na zmniejszenie wykluczania osób starszych, osób z niepełnosprawnościami, niewidomych, niedowidzących itp. Przedstawione w artykule rozwiązania szeroko wykraczają poza obowiązujące akty prawne w świetle prawa budowlanego, tym samym znacząco wpływają na dostępność przestrzeni i budynków publicznych oraz kreują przestrzeń przyjazną każdemu użytkownikowi, czyli bezpieczną i niestwarzającą zagrożeń związanych z dezorientacją, bezpieczeństwem psychicznym i ewentualnymi kontuzjami na skutek istniejących barier.

AL HERITAGE OF UKRAINE AND WAYS OF THEIR RECREATION LOST MONUMENTS OF THE CULTUR

UTRACONE ZABYTKI DZIEDZICTWA KULTUROWEGO UKRAINY I SPOSOBY ICH ODTWORZENIA

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Abstract

The article deals with scientific and practical issues of solving the problem of lost cultural monuments in Ukraine. It highlights the loss of Ukrainian cultural heritage sites as a result of war crimes of the Russian Federation and considers possible ways of recreating them, taking into account existing practice, which will serve as a useful example for the subsequent incarnations of the lost architectural monuments. The questions of the legitimacy of the reconstruction of various objects of cultural heritage in accordance with domestic and international standards are discussed. Some financial and economic aspects of restoring the cultural heritage of Ukraine are considered.

The purpose of this study is to highlight the problems of destruction and damage of Ukrainian cultural heritage sites' after full-scale Russian aggression and directions of their recreation considering domestic and foreign experience.

Streszczenie

Artykuł dotyczy naukowych i praktycznych zagadnień rozwiązania problemu zaginionych zabytków kultury na Ukrainie. Zwraca uwagę na utratę obiektów dziedzictwa kulturowego Ukrainy w wyniku zbrodni wojennych popełnionych przez Federację Rosyjską i rozważa możliwe sposoby ich przywrócenia z uwzględnieniem istniejącej praktyki, co posłuży jako użyteczny przykład dla kolejnych wcieleń utraconych zabytków architektury. Omówiono kwestie zasadności odbudowy różnych obiektów dziedzictwa kulturowego zgodnie ze standardami krajowymi i międzynarodowymi. Rozważono niektóre finansowe i ekonomiczne aspekty przywracania dziedzictwa kulturowego Ukrainy.

"AN ACCESSIBLE CITY" – A LOOK FROM THE PERSPECTIVE OF THE '60+' GENERATION

„DOSTĘPNE MIASTO" – PRÓBA SPOJRZENIA Z PERSPEKTYWY POKOLENIA „60+"

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Abstract

This paper presents the results of workshop experiments aimed at realising the concept of the accessible city and identifies key considerations for enabling seniors to function better in the city's public space, based on the real needs of an ageing population. The study used field research (in situ), functional-spatial analysis (case studies) and data synthesis. The latest available data from the Statistics Poland on the demographic situation of senior citizens, government programmes and current legislation – depicting the current and projected situation in Poland were analysed. Faced with alarming data indicating that Poland's population will continue to grow older until 2050, with the number of people aged 60+ reaching 40.4% of our country's total population, field research was carried out into the accessibility of selected urban spaces and a set of architectural and urban planning recommendations were presented to address the most important needs and better functioning of the 60+ generation. As the Świętokrzyskie Voivodeship is currently home to the largest total population of senior citizens, the region's capital, Kielce, was chosen as the location for the analysis.

Streszczenie

W artykule przedstawiono wyniki eksperymentów warsztatowych ukierunkowanych na realizację koncepcji miasta dostępnego oraz wyłoniono najważniejsze przesłanki umożliwiające lepsze funkcjonowanie seniorów w przestrzeni publicznej miasta, opierając się na rzeczywistych potrzebach starzejącego się społeczeństwa. W pracy posłużono się badaniami terenowymi (in situ), analizą funkcjonalno-przestrzenną (case studies) oraz syntezą danych. Przeanalizowano dostępne najnowsze dane GUS w zakresie sytuacji demograficznej seniorów, programy rządowe i obowiązujące przepisy – obrazujące obecną i prognozowaną sytuację w Polsce. W obliczu niepokojących danych wskazujących, że do 2050 r. populacja Polski wciąż będzie stawała się coraz starsza, a liczba osób w wieku 60 lat i więcej osiągnie 40,4% ogółu ludności naszego kraju, przeprowadzono badania terenowe pod kątem dostępności wybranych przestrzeni miejskich oraz przedstawiono zestaw zaleceń architektoniczno-urbanistycznych uwzględniających najważniejsze potrzeby i lepsze funkcjonowanie pokolenia „60+". W związku z faktem, że obecnie najwyższa liczba osób w wieku senioralnym zamieszkuje w województwie świętokrzyskim, na miejsce analiz wybrano stolicę regionu – Kielce.

PAPER – SAWDUST COMPOSITES: FABRICATION AND COMPARISON IN TERMS OF HEAT TRANSFER AND STRENGTH PROPERTIES

KOMPOZYTY PAPIEROWO-TROCINOWE: WYTWARZANIE I PORÓWNANIE WŁAŚCIWOŚCI CIEPLNYCH I WYTRZYMAŁOŚCIOWYCH

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Abstract

This study was designed to examine the feasibility of recycling cassava effluent, sawdust, and unused paper products to enhance their utilization for beneficial purpose. Waste newspaper paste (WNP), Waste writing – paper paste (WWP), and Waste carton paper paste (WCP) were prepared and then used separately to similarly fabricate composite panels with Sawdust particle (SDP) proportioned at 0%, 25%, 50%, 75%, and 100% by weight. The binder used was cassava starch slurry prepared from the effluent. Bulk density, water absorption, thermal conductivity, specific heat capacity, thermal diffusivity, nailability, and flexural strength were determined for the developed samples. From the results obtained, the samples were found to be light-weight and their thermal insulation performance improved with increasing proportions of the SDP. Though samples containing the WCP exhibited the best satisfactory performance, it was found that all the studied samples could perform more effectively and efficiently as ceilings compared to some of those reported in the literature. From scientific-economic viewpoint, valorizing the above-mentioned wastes as described in this paper could help to protect the environment and also yield value-added insulation ceilings for enhancement of sustainable building construction especially in tropical areas.

Streszczenie

Celem pracy było określenie możliwości recyklingu ścieków z manioku, trocin i odpadowych materiałów papierniczych w celu ich szerszego wykorzystania. Nitki z makulatury gazetowej (WNP), nitki z makulatury z papieru do pisania (WWP) i nitki z makulatury z kartonu (WCP) zostały przygotowane, a następnie użyte osobno do wytworzenia paneli kompozytowych z dodatkiem trocin (SDP) przy udziale masowym 0%, 25%, 50 %, 75% i 100%. Zastosowanym spoiwem była przygotowana z odcieku zawiesina skrobi z manioku. Dla przygotowanych próbek określono gęstość nasypową, nasiąkliwość, przewodność cieplną, ciepło właściwe, dyfuzyjność cieplną, zdolność do wbijania gwoździ i wytrzymałość na zginanie. Na podstawie uzyskanych wyników stwierdzono, że próbki miały małą gęstość objętościową, a ich właściwości termoizolacyjne poprawiały się wraz ze wzrostem udziału trocin (SDP). Chociaż próbki zawierające WCP wykazywały najlepsze właściwości, stwierdzono, że z wszystkich badanych próbek można wytworzyć sufity o lepszych właściwościach w porównaniu z podobnymi opisanymi w literaturze. Z naukowo-ekonomicznego punktu widzenia zastosowanie wyżej wymienionych odpadów, jak opisano w tym artykule, może pomóc w ochronie środowiska, a także w uzyskaniu bardziej ciepłochronnych stropów, a co za tym idzie przyczyni się do rozwoju bardziej zrównoważonego budownictwa, zwłaszcza w obszarach tropikalnych.

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