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SPIS TREŚCI

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The Borobudur temple: the Buddhist architecture in Indonesia. History, structure, symbolism and conservation. Influence on the contemporary Indonesian culture.

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Abstract: The article presents the current state of knowledge about the Borobudur temple, a valuable representative of Buddhist architecture, located in Java, Indonesia. The author presents the genesis of the temple, the facts concerning its rediscovery after centuries of oblivion, and Buddhist cosmology embodied in the form of a three-dimensional mandala on which the architectural form of Borobudur is based. The author studies Buddhist symbolism of the architectural form, reliefs and sculptures created on the basis of regional patterns and local Javanese culture of everyday life. This temple is one of the most perfect examples of translation of Buddhist cosmology and symbolism into an architectural form. At the same time, it constitutes an intercultural and timeless masterpiece of architecture and sculpture which requires particular protection, also due to the influence it exerts on the life of local Buddhist religious minorities.
Keywords: Buddhist architecture, Borobudur Temple, Buddhist cosmology, Buddhist symbolism, three-dimensional mandala

1. Introduction

The present publication systematises today's knowledge about the history of the architecture of the Borobudur temple, a building of enormous historical, architectural and symbolic value.

As part of the Erasmus+ program, the author visited many Buddhist temples on the island of Java in September 2018 in order to make a photographic documentation[1] of architectural objects and to obtain data from the most up-to-date and direct sources.

As Buddhism in Asia is disappearing or transforming from a religion of experience into a religion of faith, especially in Islamic countries, once impressive Buddhist communities are turning into local religious minorities forgetting their roots, monuments and traditions.

It is all the more important to keep track of how much the symbolic value of architectural sacred objects affects the local Buddhist and non-Buddhist community, or whether it falls into oblivion, only being available to researchers of architectural history. The author investigates how far advanced the process of forgetting is in such traditionally

[1] Photographs taken by the author on 17/09/2018 with a Canon Digital IXUS 80 IS camera. 311 photos of the structure of the temple at all the levels of the building; details of the reliefs. The photos selected for the article are those that best present the objects described in the text. Normal technique, colour photos, horizontal resolution: 180 dpi, vertical resolution: 180 dpi, non-metric, without specifying the scale and size of objects, without flash.

Buddhist countries as Indonesia, and what aspects of this culture are still alive. The vitality of the Buddhist culture can be assessed on the basis of how often and how extensively this community uses the heritage and symbolism of their architecture, based on the existing tissue of Buddhist sacred monuments, or whether they create new sacred objects with an original symbolic layer.

The universality of the symbolism of Buddhist architectural objects clearly emerges from the history of Buddhist architecture in the East, together with their ease in adapting to local culture in their form of expression, which is close to contextualism, basing on local patterns of aesthetics [1]. This publication also aims to analyse the layout of the Buddhist temple in a non-European cultural circle of Southeast Asia.

There are huge numbers of Buddhist monuments in Java [2]. Many of them are devastated [3]. After regaining independence after World War II (1950), Indonesia invested a lot of energy and financial resources in the renovation of "pusaka", as special architectural objects of worship are called in Indonesia - buildings whose history dates back to ancestors' most distant memories [4]. Another name for temples or places of worship from pre-Islamic times is "chandi." Their origins are often unknown, but the memory of their significance is passed down from generation to generation [5].

Since 1970, over 200 "pusaka" have been restored. The most famous of them, restored and well-preserved, is the Borobudur Temple. It is the largest Buddhist temple in island Southeast Asia. Together with Angkor Wat in Cambodia and Pagan in Burma, they make up the pantheon of the most impressive Buddhist monuments in this region [6].

Borobudur has all the features of a stupa, but it significantly goes beyond and refines its symbolic structure of a three-dimensional mandala, depicting the Buddhist scheme of the structure of the universe [7]. It is an example of a purely Buddhist architectural order with specific elements of Javanese tradition [8]. Borobudur is important for many reasons: as a work of art, as an architectural miracle, as a significant place of religious worship, as a "pusaka" or heritage of the past, defining Indonesia's identity [10].

Although many actions have already been taken to protect and popularise the pre-Islamic (Hindu and Buddhist) period of Indonesian culture, the radicalisation of the political scene raises questions about the future of monuments of non-Islamic origins.

2. The history of Borobudur

Indonesia was a strong Buddhist cultural centre from the 7th to the 15th century AD. In the areas of present-day Indonesia and Malaysia, the Srivijaya kingdom flourished from the 7th century AD, combining Hindu and Buddhist cultural traditions without conflict [11]. This culture originated on the island of Java, from where it spread to Sumatra and other surrounding islands. In the 12th century, the Srivijaya kingdom began to decline, and in 1377 it was conquered by another Buddhist dynasty, Majapahit. From the beginning of the 15th century, Islamisation of the region led to the disappearance of the Buddhist culture [10].

On the basis of comparisons with the surrounding archaeological sites and their documentation, the Borobudur temple is dated to 870-920 AD, to the period of the rule of the Sailendra dynasty [12], although new theories about more accurate dating are emerging [13]. To this day, the architects of this building are unknown, although the great expert on the history of Southeast Asian architecture, Hiram Woodward Jr., published an article in 2009 which presented an interesting hypothesis saying that the Javanese monk Bian-hong, who studied Tantric Buddhism in China in the 8th century, returned to Java and played a significant role in the Borobudur project [14]. The interpretation of the short inscriptions carved on the hidden foot of Borobudur - the Karmawibhangga relief - also provided a certain lead. The inscriptions have a similar lettering style to the Karang Tengah inscription, dated to 824 AD, and the Cri Kahulunan inscription, dated to 842 AD. According to Casparis [15], basing on the interpretation of Karang Tengah and Cri Kahulunan, the founder of the Borobudur Temple was Samaratungga, who ruled in 782-812 AD during the reign of the Sailendra dynasty. The Borobudur temple was built to worship Mahayana Buddha [10], whose cult was adopted at that time. In addition to the lettering and language used, these two inscriptions evoke words that are considered to refer to the Borobudur temple [10].

The name Borobudur has not been fully explained and there are many interpretations; according to some, it means "the hill of Buddha", according to others - ancient Boro (a village nearby), or “a high place”, or is a shortened version of the word Bhumisambhara, which means: “merit and wisdom achieved gradually” [16]. These stages are symbolically achieved by climbing higher and higher levels of the temple.

Borobudur was first discovered by Western civilization in 1814, when General Thomas Stanford Raffles – the British Lieutenant-Governor of Java - heard information about it from the local community during meetings in Semarang. Residents said that in the Kedu region, near the village of Bumisegoro, there was a carved stone structure overgrown with trees and thickets. Raffles delegated engineer H.C. Cornelius (a Danish officer) to explore the area and to order the site to be cleaned up. For two months, Cornelius with 200 men cut down trees and jungle thickets, burned grass and unearthed the hidden monument from under volcanic ashes from the explosion of Mount Merapi volcano [10], but the excavation of all galleries could not be continued for fear of the structure collapsing. Reports on his work were also provided in the form of drawings. The works were then continued by the governor of the Kedu region, Hartmann, until 1835, when they were completed. According to Hartmann, the main stupa at the top of the building was empty after opening. Due to the fact that Hartmann did not write any reports of his work, there were suspicions that he had found there, without telling anyone, a great Buddha statue. In spite of the fact that in 1842 Hartmann conducted an official investigation into the contents of the main stupa, it was not documented, and the stupa remains empty [10]. The excavation site served for some time as a source of artefacts for "souvenir hunters" and income for thieves [17]. As there were no written reports on the reconstruction of the temple, most of the monument's structure was still shrouded in mystery. And when Isaac Groneman, the first president of the Archaeological Union, accidentally discovered the hidden structure of carvings under the base of the temple in 1885 (Fig. 7), new unanswered questions emerged [10]. The Karmavibhangga relief had been hidden for over 1000 years at the bottom of the temple base (its open platform). It consists of 160 bas-reliefs and was covered by over 12,000 stone blocks [10]. The reason why the carvings had been hidden is still a mystery. Some suggest that this was due to the technical instability of the temple during the construction phase, or a faulty design of the reliefs; others believe it was for religious reasons [8]. The reliefs were studied thanks to photographs taken by Kassian Cephas, an Indonesian photographer, when they were temporarily uncovered in 1888-1891. After the documentation was prepared, some panels were left visible and uncovered in the south-east corner, thanks to which we can see today fragments of reliefs [17].

In the years 1907-1911, the first professional conservation works took place, carried out by Theodor van Erp from the government of the Dutch East Indies. Their object was the Arupadhatu level (the highest level of the temple), which contains perforated stupas on circular terraces and the highest stupa on the top. Basing on van Erp's photos from the first conservation and photos taken 10 years later, it was assessed that mechanical damage by vandalism and the process of stone degradation by natural factors were progressing again [10]. In the years 1973-1983, a second conservation was carried out by the Indonesian government in cooperation with UNESCO. Because Arupadhatu was still in good condition, only the lower levels were renovated, cleaned and rearranged to reflect their original set-up [10].

Many famous researchers studied the building; among them Wilhelm von Humboldt, who wrote about it in his linguistic study *On the Kai Language* published in 1836 [18], as well as Paul Mus, who wrote about Borobudur in 1935 [19].

3. The structure and symbolism of Borobudur

The monument resembles a miniature Mount Meru[2]. The Borobudur Temple was built at the top of a hill. Since a pile of stones was laid on a mound of soil as a base, it is not a structure entirely made of stone. It is built of andesites, volcanic rocks, with a total volume of 55,000 m^3 and made of two million stone blocks. The building has no internal rooms (except for the top stupa) [20]; it is intended for kora (a Buddhist meditation performed by ritual clockwise circling) [10].

This structure is a harmonious combination of the ideas of a stupa, a temple and a sacred mountain; a masterpiece of Buddhist architecture and monumental art (Fig. 1). From the outside, the structure of the temple looks like a stupa, but from the inside it imitates the form of *prasada*, an archetypal form consisting of a stepped pyramid, such as Lohapasada in Anuradhapura, Sri Lanka, [6].

Fig. 1. Borobudur Temple, Indonesia; a photo taken from the level of the base encasement of the temple, source: author's archive, 2018

In Buddhist cosmology it is believed that the universe is divided into three spheres: Kamadhatu, Rupadhatu, and Arupadhatu [8]. These three spheres are reflected in the multi-level (3 parts, 10 levels) design of the temple itself [9], which is a physical reflection of the Buddhist view on the stages of achieving enlightenment, symbolised by the terraced mandala (Fig. 6) [10].

The Borobudur Temple, 121.38 m wide, 121.66 m long and 35.4 m high, has four symmetrical flights of stairs. The stepped, uncovered pyramid consists of ten superimposing

[2] A mythical mountain in the middle of the universe according to Buddhist and Hindu traditions [6]

platforms, crowned with the main stupa (a large, bell-like dome) on the top, referring to the ten steps that a bodhisattva must reach to attain Buddhahood. The levels I-VII have a square shape, while the levels VIII-X have the shape of circular platforms [10].

Kamadhatu (the base) consists of an open platform and stairways. The Rupadhatu (the body) consists of five galleries, which are formed by four terraces crossed by four flights of stairs. Arupadhatu (the top) consists of three rows of stupas, of which there are 72 in total, surrounding the main stupa at the top (Fig. 3). Stairways point to the four cardinal directions, with the eastern stairway at the main entrance [21]. Pradaksina begins in the east. It is associated with reading the reliefs, which also begin from the east. On the five four-sided lower terraces there are reliefs depicting scenes from the life of Buddha and the Jatakas (stories of Buddha's previous incarnations) with a total length of about 6 km (Fig. 2). There are over 2,000 reliefs (Fig. 2). The reliefs cover 2,500 m2 of gallery walls [10].

Fig. 2. Examples of reliefs in Borobudur in galleries on 5 lower square terraces, Indonesia; source: author's archive, 2018

Originally, the temple contained 504 Buddha statues, hidden in the gallery niches (Rupadhatu) or in bell-shaped openwork stupas arranged in circles (Fig. 3 and 4) on the higher terraces (Arupadhatu). Today, there are only 475 statues, 247 of which are damaged (mainly without heads), but 228 statues are intact, 29 statues are missing in the temple structure.

The Buddha statues in the Borobudur temple depict five "dhyani-buddhas." The location of the statues also presents five directions of the world according to the Mahayana school; they are placed on platforms III to VI, counting from the base [10].

Fig. 3. Transparent stupas in Borobudur on circular terraces of the Arupadhatu level, Indonesia; source: author's archive, 2018

The body of the temple (Rupadhatu - the middle part) has five levels of square terraces. On the first level, there are 104 Buddha statues, on the second - 104 statues, on the third - 88 statues, on the fourth - 72 statues; the fifth level has 64 statues (Fig. 5).

At the first, second, third and fourth level, all Buddhas on each side of the world have their hands in the same mudra. However, at the highest, fifth square level, Buddhas have different hand gestures (mudras) from analogous Buddhas on the terraces below; they all have the same mudras in each of the parts of the world [10]. Each hand gesture (mudra) has a specific meaning.

On the eastern side of the terraces I, II, III, IV, there are statues of Dhyani Buddha Akshobhya with a hand gesture called the Bhumisparsha mudra, which means calling the Earth to witness. On the southern side of terraces I, II, III, IV, there are Dhyani Buddhas Ratnasambhava with a gesture of the Vara mudra, which means giving a blessing. On the western side of terraces I, II, III, IV, there are statues of sitting figures of Dhyani Buddhas of Amitabha, with a gesture of the Dhyana mudra, which means calmness, meditation. From the north, terraces I, II, III, IV are decorated with statues of Dhyani Buddha Amoghasiddhi with the Abhaya mudra gesture, which means fearlessness in the face of danger. On terrace V, there are statues of Dhyani Buddha Vairocana with a gesture of the Vitarka mudra, i.e. teaching or speaking.

In Arupadhatu (circular terraces VI, VII, VIII), there are 72 Buddhas inside the openwork stupas:

- Terrace VI: 32 Buddha statues,
- Terrace VII: 24 Buddha statues,
- Terrace VIII: 16 Buddha statues.

All statues are images of Dhyani Buddha Vajrasattva with a gesture of the Dharmachakra mudra, which means turning of the wheel of dharma [6]. In the Borobudur museum, there is a Buddha statue described as "the statue that was not finished" and has many imperfections (an ugly face, one arm shorter than the other). It was found buried under a walnut tree in the temple's garden. According to most experts, the statue comes from the inside of the stupa at the top of the temple and is a proper representation of the Adi-Buddha, or the Most Perfect Buddha, whose perfection lies beyond all imagination; hence the representation of his imperfections [10].

Fig. 4. The exposed Buddha statue from the perforated stupa in Borobudur, Indonesia; source: author's archive, 2018

The location of hidden panels with Karmawibhangga carvings (Fig. 6 and 7) below the base of the temple represents the sphere of desire (Kamadhatu) of the Buddhist cosmology, the lowest level on the way to Nirvana. Rupadhatu (the sphere in which we reject our desires, but we are still attached to names and forms) is represented by the body of the temple in the form of five square platforms (Fig. 6).

Fig. 5. Buddha statues from the levels of square terraces of Rupadhatu and circular terraces of Arupadhatu in Borobudur, Indonesia; source: author's archive, 2018

Arupadhatu (the formless sphere) is represented by the "super structure", consisting of three round platforms and a large stupa crowning it [10].

The design and significance of the Borobudur temple were influenced by the Mahayana and Tantrayana Buddhism [6]. Tantrayana developed in Bengal, India in the 8th century AD. This type of Buddhism emphasises the importance of living life as if one was already enlightened (the so-called Bodhisattva way).

Mahayana Buddhists live through the idea of Upaya (skill in means), a doctrine that emphasises the possibility of release from suffering and the cycle of rebirth, called Samsara.

Good karma born from good "karmic seeds" shapes the path to enlightenment and the escape from the suffering of rebirth [6]. Borobudur is richly decorated with reliefs with images and descriptions to explain the law of karma, or the law of cause and effect, which governs the cycle of rebirth.

Kamadhatu is represented by hidden reliefs in the foot of the temple (Fig. 6 and 7). Some of the images have short descriptions that probably contain instructions concerning the meaning of the carved scenes. Karmawibhangga, a bas-relief hidden for hundreds of years, illustrates the Buddhist belief in the law of cause and effect, otherwise known as karma. The panels present examples of good and bad actions, and karma that results from them. The relief also offers fascinating insights into history, religious ceremonies, social structures, fashion, tools used, local flora and fauna. One panel usually consists of two or three scenes, which are graphically separated by a bas-relief with the image of a tree, the symbol of the law of cause and effect: what seeds will be sown, such a tree will grow out of them. This first group of bas-reliefs presents examples of the law of cause and effect in specific life situations. Good actions will lead to good results, bad actions to bad results. Impersonal compassion, loving kindness and wisdom towards others will bring good karma.

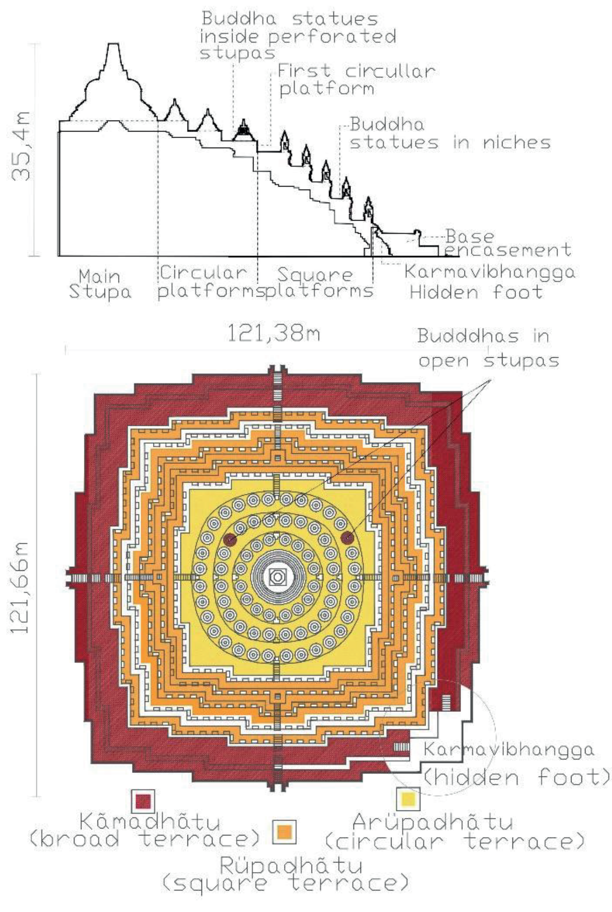

Fig. 6. Cross section and plan of the building, Borobudur, Indonesia; based on: Gunawan artapranata, https://commons.Wikimedia.org/wiki/File: Borobudur_Cross_Section_en.svg, accessed 14.10.2018

Fig. 7. A part of Karmawibhangga reliefs, hidden under the base of the Borobudur temple, Indonesia; source: author's archive, 2018

The relief illustrates how the Buddhist teachings were adapted in the Javanese cultural context. The way of reading the Karmawibhangga bas-relief is consists in walking around the temple, starting from the eastern side of the southern stairs and finishing at the eastern side of the northern stairs.

The bas-reliefs of the Borobudur temple can be read like a book. They present a story that was supposed to inspire people to do the right thing and to be transferred into their own life experience.

The orientation of the gates of ancient Buddhist stupas usually follows the movement of the sun, from the east through the zenith, to the west and nadir. The path of the sun also symbolises how Buddha illuminates the relative reality of this world with his teaching. The eastern gate symbolises his birth (Buddha-jati), the southern - his enlightenment (Sambodhi), the western - his teaching doctrine (Dharmacakrapravarttana), and the northern - his ultimate liberation (Parinirvana) [10].

4. The significance of Borobudur for the contemporary culture of Indonesia

Borobudur is a masterpiece of Buddhist architecture and sculpture. It presents the in-depth knowledge and technical skills of the people who created the temple. More than 55,000 m^3 of andesite were collected from nearby areas to build this masterpiece. Rocks were cut, transported to the construction site, and laid without mortar. When the building was completed, specialised craftsmen carved reliefs on the walls and galleries of the temple.

Every part of the Borobudur temple structure was built in accordance with a detailed and meticulous design, with an awareness of functionality, aesthetics and religious meanings, making this temple one of the greatest Buddhist monuments ever constructed [22].

All its walls are decorated with carvings depicting scenes from the well-known text of Mahayana, Gandavyuha Sutra, as well as the Jataka tales about previous incarnations and the life of the historical Shakyamuni Buddha (Fig. 2). Above five square terraces, there are three circular platforms with a single large stupa on top. These three elements: the square foundation, the circular central levels and the top stupa symbolise the universe with its constituent elements of the earth, gods' worlds and the realm of pure lands, symbolising Sunyata. This figurative geography makes the whole structure a huge mandala, through which pilgrims symbolically travel.

Despite the fact that today Indonesia is a mostly Muslim country, Borobudur continues to be a major attraction as a cultural and historical tourist destination (on average 2.5 million visitors per year, but this number is still growing: 3.8 million tourists in 2016) [23]) and, increasingly, a place of Buddhist pilgrimage [24]. Minister Rizal Ramli (2015) believes that the Borobudur temple can become a Buddhist religious object comparable to Mecca for Muslims. However, local tourists still outnumber foreigners [25].

Borobudur is not only a unique example of Indonesian art and architecture; the temple is also the main venue for the celebration of Vesak, held every year in Indonesia. It commemorates the birth, enlightenment and death of Shakyamuni Buddha and is the most important holiday for Buddhists. The first national celebration of Vesak was a symbol of a renaissance of Buddhism in Indonesia and took place on May 23, 1953. The celebrations were organised by Anagarika The Boan An, later known as Ashin Jinarakkitha [25].

In Borobudur, Vesak is celebrated with the ritual of collecting holy water from the Jumprit spring (Temanggung) on the slope of Mt Sindoro [26] and the natural eternal flame of Mrapen, near the village of Manggarmas, created through the leaking of natural gas from the ground [27]. It does not go out even during tropical monsoon rains or winds. It is maintained at the nearby Mendut Temple to be carried around and used during the ceremony in Borobudur. Pilgrims go together from the Mendut monastery to Borobudur, carrying a flame of the eternal fire, holy water and Buddhist symbols that are presented to pilgrims in the courtyard in front of Borobudur.

Integral elements of the rituals are burning candles and chanting mantras while pilgrims meditate, followed by the blessings of Mahathavir Bhikshu and Mahetra Bhikkhu, Buddhist teachers, marking the end of the series of Vesak rituals. Over 1,000 offering lanterns are released into the sky, symbolising the wishes for enlightenment for all beings, the entire universe [28].

5. Borobudur conservation and protection

Borobudur Temple was listed as a UNESCO World Heritage Site in 1991 [29]. It is one of eight World Heritage Sites in Indonesia [30], [31].

"The condition for a cultural site to be added to the World Heritage List is recognition of its exceptional universal value based on at least one of the five criteria listed below, with criterion VI only being used as a complementary criterion [32]."

Borobudur, joining this unique list, managed to meet the criteria of as many as four of the following points:

"I. to represent a masterpiece of human creative genius;

II. to exhibit an important interchange of values, over a span of time, or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning, or landscape design;

III. (…)

IV. to be an outstanding example of a type of building, architectural, or technological ensemble or landscape which illustrates a significant stage(s) in human history;

V. (…)

VI. to be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance (…)" [10].

Professor Dr Soekmono, the first Indonesian archaeologist, was involved in the first project of conservation of the temple under UNESCO auspices (1975-1982), being the project manager as early as in 1971, up to 1983. During this time, Borobudur underwent various conservation treatments. The Ministry of Education and Culture of the Republic of Indonesia carried out many important conservation activities to protect the site of the Borobudur temple. Through careful analysis, using all the most modern conservation techniques, the Borobudur Conservation Office cooperated with UNESCO and international experts, from e.g. Germany, Japan and Italy, to implement many modern methods and scientific discoveries to ensure the safety of the stone carvings for hundreds of years [10]. To support these efforts, since 2011 the German government has been providing a generous financial contribution through UNESCO to the research and implementation of conservation methods in protecting the Borobudur temple [10].

The UNESCO Committee has been involved in the protection of Borobudur since 1968. The second phase of Borobudur's conservation efforts began in 2003. It was possible thanks to the cooperation between UNESCO and the Ministry of Culture and Tourism of the Indonesian Government, with the financial support of UNESCO and Japan. Currently, the project focuses mainly on discovering cultural significance and on building relationships. UNESCO and the Ministry work with the local community seeking opportunities to restore the value of Borobudur both in terms of understanding its cultural and religious heritage, and in terms of sources of income and entrepreneurship for the local community.

Conservation of Borobudur is a complicated undertaking: for over a thousand years, the monument had to resist earthquakes [33], volcanic eruptions, heavy rainfall during the wet season; was exposed to great temperature changes throughout the year and was covered several times with a thick layer of volcanic dust during volcanic eruptions. The Marapi volcano last exploded with great force in 2010, and the Kelud volcano in 2014 [10]. The temple was once again covered with a thin layer of ash during a small eruption of the Marapi volcano in 2018 [34].

The type of adequate technology selected for the conservation of a work of architecture depends on three conditions: the degree of advancement of the degradation of the building, the available archaeological documentation and the policy of the relevant government. The degradation of Borobudur was so advanced that it was difficult to find a clear diagnosis of the problem. However, careful analyses of the reasons for the destruction of the monument led to the conclusion that the primary reason is the leakage of rainwater into the core of the stone structure and into the soil hill below it, causing a series of destructive processes such as stone deterioration through physico-chemical and biological processes resulting from residual moisture in the deeper layer of soil, leading to soil particles being washed away from the layer under the stone structure and to high moisture content in these stone layers. Therefore, any solution must confront the conditions in the soil under the temple; it must also take into account possible earthquakes.

The conservation project aims to restore the proper walls of the building as well as the sliding elements of the structure to the vertical orientation, to level out the sloping floors of the platforms, and to provide foundations that guarantee permanent stability of the structure in the face of earthquakes and sliding of the building. The project must prevent the uncontrolled flow of rainwater by ensuring its drainage through a complicated drainage system and save time that works to the detriment of the building. In 1969, Netherlands Engineering Consultants (NEDECO) proposed a conservation programme that met these criteria. Conservation plan was divided into four subsequent phases, corresponding to the division of the building structure into four symmetrical parts. The project faced various adversities (inflation, political unrest caused by the activities of communist parties, lack of funds, lack of experts and modern equipment, extreme humidity and lack of air circulation). The proposed solutions were to implement the project in a minimum period of time using more employees; to intensify training for more experts; to introduce solutions from international discussion panels faster and more efficiently. The project is still being carried out [10].

The Borobudur Temple is exposed to other dangers. On May 21, 1985, nine stupas of the Borobudur temple were blown up. In 1991, a blind Muslim preacher, Husein Ali Al Habsyie, was sentenced to life imprisonment for masterminding the bombings and an attack on the temple in the mid-1980s, for which two more members of the Islamist terrorist group were sentenced to 20 years in prison in 1986, while another defendant received a 13-year prison sentence [35].

With the radicalisation of Islamic communities and the emergence of ISIS, extreme Wahhabi influence of politicians sponsored by Saudi Arabia began to penetrate into the so far moderate current of Indonesian Islam.

In August 2014, the Indonesian police and security forces strengthened security around Borobudur and the adjacent areas as a means of prevention in the face of threats posted on social media by the local ISIS cell, declaring that terrorists plan to destroy Borobudur and other statues of Buddhist art in Indonesia. This jihadist group follows a restrictive interpretation of Islam, which condemns any anthropomorphic representations, such as sculptures of the human body, seeing them as idolatry [35].

In the face of such threats, it is particularly important to promote the value of such a masterpiece of architecture and art as Borobudur in order to be able to protect and preserve this object for future generations thanks to the support of the international community [36]. There is a danger that it may share the fate of masterpieces of Buddhist culture in Afghanistan – (the Buddhas of Bamyan from the 4th century AD, 54.86 m high and 35 m high, the largest statues of Buddhas in the world) - blown up in 2001 [37]. In Swat Valley in Pakistan, the face, feet and fragments of the shoulders of the legendary Jehanabad Buddha were blown up [38].

6. Conclusions

The Borobudur temple is a unique work of art, an architectural miracle, a significant place of religious worship for Buddhists in a Muslim country, and a "pusaka" or heritage of the past, defining the identity of Indonesia, where nowadays very few remember its Hindu and Buddhist roots.

Borobudur is a masterpiece of Buddhist architecture and monumental art because it is an original, unique and harmonious combination of the ideas of a stupa, a temple and a sacred mountain. It symbolises the universe with its constituent elements of the earth, gods' worlds and the realm of pure lands, which makes this construction a huge mandala, through which pilgrims symbolically travel. Every part of the Borobudur temple structure was built over 1000 years ago in accordance with a detailed and meticulous design, with an awareness of functionality, aesthetics and religious meanings, making this temple one of the greatest Buddhist monuments ever constructed.

Borobudur continues to be a major attraction as a cultural and historical tourist destination despite the fact that today Indonesia is a country that is 87% Muslim. Although once impressive Buddhist communities have turned into local religious minorities losing the awareness of their cultural roots (Buddhists constitute only 0.7% of the population of Indonesia), the temple is the venue for the celebration of Vesak, the most important religious holiday for Buddhists.

Indonesia has allocated a lot of financial resources to protect and popularise the Borobudur temple. It is one of eight UNESCO World Heritage Sites in Indonesia. International experts, from e.g. Germany, Japan and Italy, together with the Borobudur Conservation Office and UNESCO, have invested a lot of work and effort to implement many modern methods and scientific discoveries to ensure the safety of the valuable carvings as a heritage for future generations. Currently, UNESCO and the Indonesian Ministry of Culture and Tourism are seeking opportunities to restore the symbolic value of the Borobudur temple in the eyes of the local community both in terms of understanding its cultural and religious heritage and as a potential source of development of entrepreneurship for the local community.

However, the radicalisation of the political scene raises questions about the future of monuments of non-Islamic origins. It is particularly important to promote the value of such a masterpiece of architecture and art as Borobudur in order to protect and preserve this object for hundreds of years in the best condition possible thanks to the support of the international community.

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References

[1] Kastawan, I. W.,A Study on the Hindu-Buddhist Candi Architecture in the Java and Bali Islands, Nagoya: Ph.D. thesis, Nagoya Institute of Technology, (2009).

[2] Dumarçay, J., “Histoire de l’architecture de Java.” École Française d’Extrême-Orient, Mémoires Archéologiques 19, Paris, (1993).

[3] Tiffin, S., “Java’s Ruined Candis and the British Picturesque Ideal”, in: Bulletin of the School of Oriental and African Studies, University of London, 72, 1, Cambridge University Press, Cambridge, (2009).

[4] Degroot, V., Klokke, M., “Interrelationships Among Central Javanese Temples: The Example of Asu, Lumbung, and Pendem”, in: Archipel (80), Paris, (2010).

[5] Dumarçay, J., “Architectural Composition in Java from the Eighth to Fourteenth Centuries”, in: The Journal of the Siam Society, Bangkok, 77 (2), (1989).

[6] Irons, E.A., Encyclopedia of Buddhism, Facts On File, Inc., New York, pp. 56-57, 387-388, 528-529, 576-577, (2008).

[7] Atmadi, P., Some architectural design principles of temples in Java: a study through the buildings projection on the reliefs of Borobudur temple, Gadjah Mada University Press, Yogakarta, (1994).

[8] Susetyo, G., The Ancient Puzzles of Borobudur, http://indonesiaexpat.biz/travel/history-culture/the-ancient-puzzles-of-borobudur/, [accessed 1.11.2018], (2013).

[9] Giessenbacher, K., Der Candi - Wesen einer Kultur: die Symbolik der traditionellen Steinarchitektur von Zentraljava im Synkretismus der Religionen, diploma thesis, TU Wien, (2016).

[10] Soekmono, R., The Restoration of Borobudur, The UNESCO Publishing, Paris, pp. 21- 22, 29-34, 38, 41, 43, 45-48, 51, 60, 116-118., (2005).

[11] Miksic, J., “The Buddhist-Hindu Divide in Premodern Southeast Asia”, in: Nalanda-Sriwijaya Centre Working Paper No. 1 (March 2010), Nalanda- Sriwijaya Centre of the Institute of Southeast Asian Studies, Singapore, (2010).

[12] Jordaan, R.E., “Why the Sailendras were not a Javanese dynasty”, Paper, Symposium, Non-Javanese, Not Yet Javanese, and Un-Javanese: Encounters and Fissures in a Civilization, Leiden, 23-25 March, (2004).

[13] Sundberg, J.R., “Considerations on the dating of the Barabudur stūpa: introduction to the problem”, Journal of the Humanities and Social Sciences of Southeast Asia, E.J. Brill, Leiden-New York-Köln, (2008).

[14] Woodward, H.W. Jr., “Bian-hong, Mastermind of Borobudur?”, Pacific World: Journal of the Institute of Buddhist Studies (Third Series) 11, Berkley, pp. 25-60, (2009).

[15] Dumarcay, J., De Casparis, J.G., Soekmono, R., Borobudur Prayer in Stone, Archipelago Press, NY, (1990).

[16] Soekmono, R., The Javanise Candi, function and meaning, E.J. Brill, Leiden-New York-Köln, (1995).

[17] Rooseboom, H., http://indonesiaexpat.biz/travel/history-culture/javas-first-photographer-kassian-cephas-1845-1912/, [accessed 1.11.2018], (2014).

[18] Humboldt, W., Über die Kawi-sprache auf der Insel Java, Cambridge University Press, Cambridge, (2011).

[19] Mus, P., Barabuḍur: sketch of a history of Buddhism based on archaeological criticism of the texts, Indira Gandhi National Centre for the Art: Sterling Publishers, New Delhi, (1998).

[20] Woodward, H.W. Jr., “On Borobudur`s upper terraces”, Oriental Art Magazine, Surrey, England, pp. 34-43, (1999).

[21] Cirtek, P., Borobudur. Appearance of a Universe, Monsun Verlag, Hamburg, (2016).

[22] Degroot, V., Candi, space and landscape: a study on the distribution, orientation and spatial organization of central Javanese temple remains, Leiden: Ph.D. dissertation Universiteit Leiden, (2009).

[23] Citrinot, L., Close to Four Million Visitors at Borobudur Temple in 2016, http://asean.travel/2016/12/23/close-to-four-million-visitors-at-borobudur-temple-in-2016/, [accessed 17.06.2019], (2016)

[24] Woodward, H.W. Jr., “Southeast Asian traces of the Buddhist pilgrims”, Muse: Annual of the Museum of Art and Archaeology, University of Missouri-Columbia 22: pp. 75-91, (1988).

[25] Budi, H., Ubud, S., Fatchur, R., Mintarti, R., “Borobudur Temple as Buddhist Pilgrimage Destination in Indonesia: an Analysis of Factors that Affect Visit Intention”, 98: Journal of International Buddhist Studies, JIBS, Vol. 7, No. 2., pp. 98-110, (2016).

[26] Suyitno, H., Puluhan biksu ambil air berkah di Umbul Jumprit jelang Waisak, https://www.antaranews.com/berita/499051/puluhan-biksu-ambil-air-berkah-di-umbul-jumprit-jelang-waisak, [accessed 26.06.2019], (2015).

[27] Pusparani, I.G., The Mysterious History of Mrapen ‘Eternal Flame’ Used in Asian Games 2018, https://seasia.co/2018/07/23/the-mysterious-history-of-mrapen-eternal-flame-used-in-asian-games-2018, [accessed 1.11.2018], (2018).

[28] Swearer, D.K., Buddhism and Society in Southeast Asia, Pa.: Anima, Chambersburg, (1993).

[29] ICOMOS , World Heritage List no. 592, http://whc.unesco.org/en/list/592/documents/, [accessed 18.06.2019], (1991).

[30] UNESCO/WHC, https://whc.unesco.org/en/list/592/, [accessed 1.11.2018], (2012).

[31] Gomez, L.O., Woodward, H.W. Jr., “Reflections on the theory of Barabudur as a mandala”, in: Barabudur: History and Significance of a Buddhist Monument, Asian Humanities Press, Berkeley, California, (1981).

[32] Polski Komitet ds. UNESCO (The Polish National Commission for UNESCO), http://www.unesco.pl/kultura/dziedzictwo-kulturowe/swiatowe-dziedzictwo/, [accessed 18.06.2019], (1972).

[33] Ambraseys, N.N., Review of the Seismic Stability of the Borobudur Temple, Indonesia, ‘Pelita Borobudur’ Series, Vol CC 3, Proyek PELITA Pemugaran Candi Borobudur, Jakarta: Departemen Pendidikan dan Kebudayaan, pp. 80–128, (1974).

[34] The Jakarta Post, Mount Merapi ash hits Borobudur temple, https://www.thejakartapost.com/travel/2018/05/24/mount-merapi-ash-hits-borobudur-temple.html, [accessed 18.06.2019], (2018).

[35] The Staits Times, Indonesia's police on alert over apparent ISIS terror threat to Borobudur Temple, https://www.straitstimes.com/asia/se-asia/indonesias-police-on-alert-over-apparent-isis-terror-threat-to-borobudur-temple, [accessed 1.11.2018], (2014).

[36] Pearson, N., Tourism, terrorism and other threats: preserving the cultural legacy of Java's temples. Asian Studies Association of Australia (ASAA), Australian National University, Canberra, (2016).

[37] Harvey, I., Taliban blowing up 4th-century statues of Buddha leads to caves filled with 5th-century artwork, (2018), https://www.thevintagenews.com/2018/02/27/statues-of-buddha/, [accessed 1.11.2018], (2018).

[38] Littlefair, S., Destroyed by Taliban nine years ago, iconic "Jahanabad Buddha" is reborn, https://www.lionsroar.com/pakistani-buddha-statue-destroyed-by-taliban-restored/, [accessed 1.11.2018], (2016).

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Comparative analysis of the inventory process using manual measurements and laser scanning

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Abstract: Laser scanning allows the acquiring of spatial data about existing objects. It is used as a modern inventory technique, most often in the creation of archival or conservation documentation. It gives the opportunity to obtain a very large amount of spatial data of the facility thus helping to improve operations in the field of conservation but also reduces the margin of error in the inventory and then design documentation. It is useful due to the growing BIM technology, through which three-dimensional models of existing objects of various scales are obtained. This article presents research comparing the traditional measurement method and the modern one with the use of a laser scanner. The research is a compilation of the duration of architectural inventory techniques as well as the accuracy of the measurements made and of the following architectural drawings. The result of the research is a relative percentage ratio showing the acceleration of inventory works with a simple construction object using modern assistive techniques compared to the traditional method.

Keywords: Architectural inventory, historic objects, laser scanning, point cloud, measurement methods

1. Introduction

Architectural inventory of existing facilities is a key element in the preparation of comprehensive project documentation. The inventory process itself concerns both measurements in the object as a whole as well as specific dimensioning of architectural details [1]. Computer support in the inventory process is a helpful tool that greatly speeds up the work [2]. The specificity and accuracy of the inventory depends on its subsequent use but also on the measured object itself. Classical inventory methods most often presented the study in the form of paper 2D plans (projections, sections, views and photo plans) [3]. The development of computer technology results in additional capabilities for documenting objects measured in numerical form of CAD [4]. The currently growing measurement technology, most often used in the study of historic objects focuses on creating a three-dimensional computer model. With the use of the right software, BIM technology in which we obtain an inventory model can be extremely useful for planning conservation work (renovation works, incorporation of new elements into historical fabric or even for virtual reconstruction of the object) [5]. The results of BIM measurements can also be presented in the form of a 3D model printout or a virtual walk [6]. Creating documentation in the form of a point cloud not only results in better measurement capabilities but also creates a documentation of sorts allowing the improvement of other research methods on existing objects [7].

In this article, two measurement methods will be compared. One method is traditional measurement using a measuring tape and a laser rangefinder. The other method is a measurement through scanning the building with a laser scanner. The duration of the entire process as well as the accuracy of the results of the part related to the in-situ test and the processing of the acquired data up to obtaining the final architectural documentation will be verified. Laser scanning is a modern measurement method and currently the most popular method of inventory [8]. The measurement accuracy depends on the type of device, but also on the material being measured or the distance from the measured component [9]. If the collected data in the form of a point cloud provide sufficient material, laser scanning can be treated as a direct measurement method [10]. In this study, however, laser scanning functions as an inventory note and is therefore regarded as an indirect measurement method. This method involves the collection of spatial data describing the geometry of the measured object and the assignment of its radiometric values. The so-called point cloud forming the three-dimensional object model created with this kind of measurement serves as an inventory note in the further development of drawing documentation in AutoCad software.

A small and simple construction object was selected for the study. It was important for the studied building to be a small and two-story object - with emphasis on the importance of the measurement problem most often created by wooden staircases due to its irregularity in the dimensions of individual elements - with visible damages in the structure of external and internal partitions. During the inventory using both traditional and laser techniques, each stage of measurements was described, and measured over time. Then, after obtaining drawings in the form of CAD files, the accuracy of the measurement and the duration allocated to individual elements were compared.

2. General characteristics of the studied object

The object undergoing inventory works is a residential building located on the premises of the palace and park in Snopków in the commune of Jastków (Fig. 1). It has a simple body with a gabled roof, two symmetrically located northern entrances, windows on each external wall and additionally two roof windows on the south side. Small ventilation openings to the basement from the front, located symmetrically at ground level. It is a two-story building made of solid brick with wooden window and door joinery, with no visible decorations, both outside and inside the building.

There was no information or conclusive traces of any interference (repairs, renovations, reconstructions) in the facility over the years. The building, owing to its simple architectural form and significant degradation, is an interesting research element.

Features of the object relevant to the experiment:

- A simple geometric form in the outline
- Small cubature
- Gabled roof
- Deformation of the geometry of both the internal and external partitions
- Numerous defects and damage in the body of the building
- Wooden staircase with irregular steps.

Fig. 1. Building covered by the study, Snopków 102 - photo by the author

3. Description of research

Basic available equipment used during architectural inventory was used for research on the site. In the traditional method, a laser rangefinder and measuring tape were used (Fig. 2). In the case of laser technology, the Leica C10 laser scanner was used (Fig. 3) [11]. The research method focused on the basic measurements carried out on this type of buildings in traditional and laser inventory (Table 1). The aim was to create a comprehensive measurement documentation taking into account the dimensioning of the building's facade, indoor enclosures, roof truss, staircase and finally marking the damage in the object’s structure.

a) 

b) 

Fig. 2. Measuring instruments a) laser rangefinder b) measuring tape - photo by author

Fig. 3. Leica C10 laser – photo by author

Table 1. List of materials and measurement techniques - compilation by author

Details	Traditional measurement	Laser measurement
Stage 1 preparing measuring equipment		
Laser scanner	-	X
Laser rangefinder	X	-
Measuring tape	X	-
Papers	X	X
Pens	X	X
Photo camera	X	X
Stage 2 in situ research		
Sketch of building plan	X	X
Facade sketch	X	-
Facade measurement	X	X
Enclosure outline measurement	X	X
Enclosure height measurement	X	-
Stairs measurement	X	-
Attic slants measurement	X	-
Roof truss measurement	X	-
Window opening measurement	X	-
External partition thickness measurement	X	-
Roof slope angle measurement	X	-
Supporting photographic documentation	X	-
Stage 3 measurement digitalisation		
Placing posts in a point cloud	-	X
Redrawing measurements to CAD format	X	X
Additional measurements of missing data	X	-
Correcting measurement errors	X	-

- ## Traditional technique:

In the traditional technique, after preliminary preparation of foundations illustrating the schematic layout of the rooms and the façades of the measured building, detailed measurements were implemented. Two people participated in the measurement (one performing the measurement, the other noting the dimensions onto sheets of paper). Laser rangefinder and measuring tape were used for this task. The building heights and total as well as detailed lengths of the walls were checked. Door and window openings as well as their joinery were measured separately. The next stage was the documentation of internal rooms including window and door carpentry, room heights in at least 3 places (due to the likelihood of ceiling deflection). Subsequently, measurements were made of two wooden staircases. It was necessary to check the differences between each of the stair steps in detail, because they showed significant deviations from each other. After reaching the habitable attic, the procedure was repeated, and supplemented with additional measuring aspects related to the slants present in each floor space. Subsequently, the plumbing installations, ventilation openings, manholes for the basement and the unused attic were marked.

After applying of all inventory information to the drawing pad (Fig. 4), the researchers proceeded to describing the structure of the building partitions.

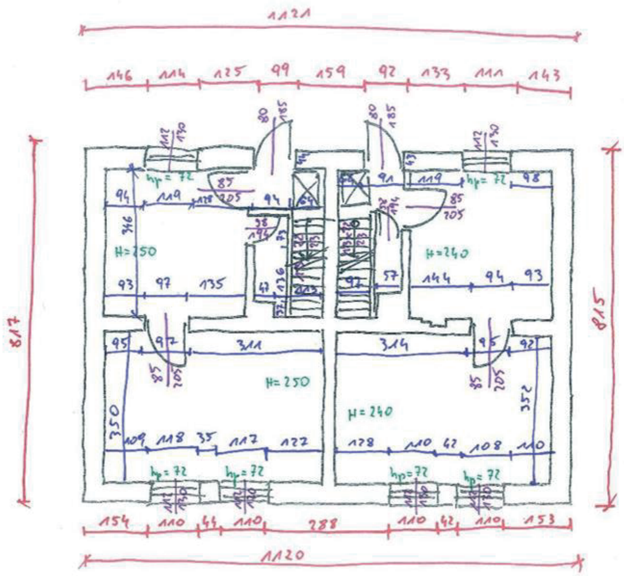

Fig. 4. An example of a manual sketch layout with dimensions

- ## Laser technique:

After preparing a schematic (and simplified compared to the one used in the traditional technique) functional system of individual storeys of the object, as the measuring proceeded, only an approximate location of the placement of the scanning device was applied (Fig. 5.). Photographic documentation was then made, the duration of which was 30 minutes. The measurement was carried out by two people due to the need to carry measuring equipment and a tripod. For each measurement, the scanner was placed on a tripod. The device was then leveled manually and the scan was started. The first stage of the measurement was the placing of the scanner in each of the 9 stands outside the studied object for the inventory of the elevation. The number of stands resulted from the necessity of interlocking of the consecutive planes of external walls. Subsequently, the places where the scanner was placed were transferred on plan.

The average time of equipment transfer, tripod setting and leveling was 7 minutes. The average duration of one scan was 7 minutes. 20 individual workstations were set up during work on the site. The entire duration of the scanner operation was a total of 280 minutes. To the measured time, an additional 20 minutes were added which accounted for the first start of the scanner and a manual sketch of the object layout needed to apply scanning spots. The total duration of in-situ work was 330 minutes.

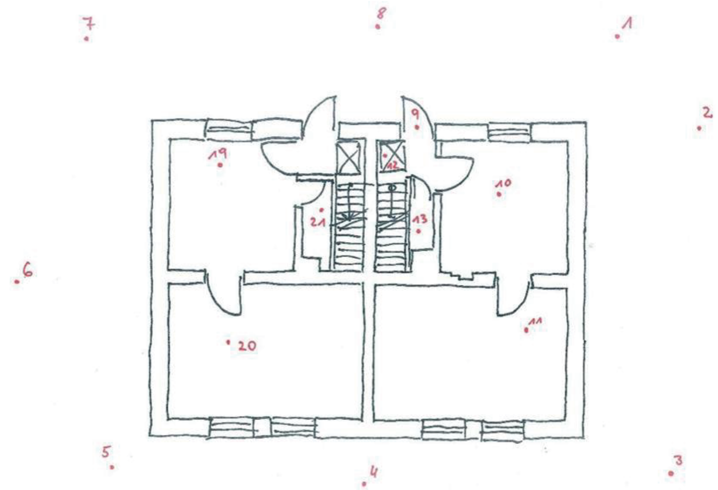

Fig. 5. An example of a manual layout sketch with marked points

4. Result summary

The detailed measurement procedure and processing of the obtained data in both developed techniques are presented below (Tab.2.). The time measurement was given in minutes.

A summary of data comparing each stage in detail with regard to the duration of carrying out inventory activities is shown in Fig. 6. A comparison of the duration of the measurement with the time of its digitalisation is shown in Fig. 7.

After the measurement processes were concluded, two drawings were made in the AutoCad software in order to compare the measurement accuracy. Below are the drawings of the conducted inventory in both measuring techniques. (Fig. 8.) (Fig. 9) The difference in wall plastics is already visible in the drawing showing the basement. The result of manual (traditional) measurement was the simplification the geometry of external and internal walls, while the measurement using a laser scanner allowed to map out the exact geometry of the walls. The significance of the measurement differences is also noticeable when tracing wooden staircases which have been distorted over the years and each of the stair steps differs significantly from the previous one.

Table 2. List of performed measurement activities - compilation by author

Performed action	**Description of performed action**	
	Traditional method	**Laser method**
Preliminary drawing note	Schematic drawings needed for dimensioning walls, window and door openings, functional layout, building elevations, staircase	Schematic drawings of story plans on which laser location positions are marked (not required)
Duration: minutes	**36**	**20**
Photography	Drawing up a diagram of the functional system on which the locations of taking pictures of the object were marked	Drawing up a diagram of the functional system on which the locations of taking pictures of the object were marked
Duration: minutes	**30**	**30**
Measurement stage 1	The length and width of the object, the rooms inside, the width of the partitions, the height of the window sills, the width and height of the door and window joinery, dimensioning of stairs between storeys, room heights, roof slope angle, structural arrangement of the roof truss (Fig. 2)	Placing the laser scanner first around the building and then entering the inside moving in such a way that the performed scans intersect each other.
Duration: minutes	**540**	**360**
Digitalisation of measurements, stage 1	Based on the manual measurements made, preliminary drawing documentation was prepared using AutoCad software	After the measurements made, single stations were connected to obtain a point cloud to generate ready inputs (projections, elevations, cross-sections, etc.) (Fig. 3.)
Duration: minutes	**600**	**120**
Measurement, stage 2	After transferring the measurements to the CAD format, the drawings were printed in order to mark the degraded places in the building on precise inputs (plaster losses, defects in the masonry structure, salinity, moisture, damage of the roof truss and roofing).	Does not apply
Duration: minutes	**300**	**0**
Digitalisation of measurements, stage 2	Marking the damage in the documentation	The tracing of inputs generated from the point cloud in JPG format in the AutoCad software. Visible in the prepared inputs are the losses, damage, moisture and salinity in the structure of the object, which at this stage are applied to the drawings.
Duration: minutes	**300**	**600**
Measurement, stage 3	Applying additional measurements of missing data from stages 1 and 2	Does not apply
Duration: minutes	**300**	**0**
Digitalisation of measurements, stage 3	After the damage measurements are made and additional measurements of missing data is performed, it is drawn onto the earlier inputs using photographic documentation.	Does not apply
Duration: minutes	**300**	**0**
Printout	Ready CAD files are printed	Ready CAD files are printed
Duration: minutes	**60**	**60**

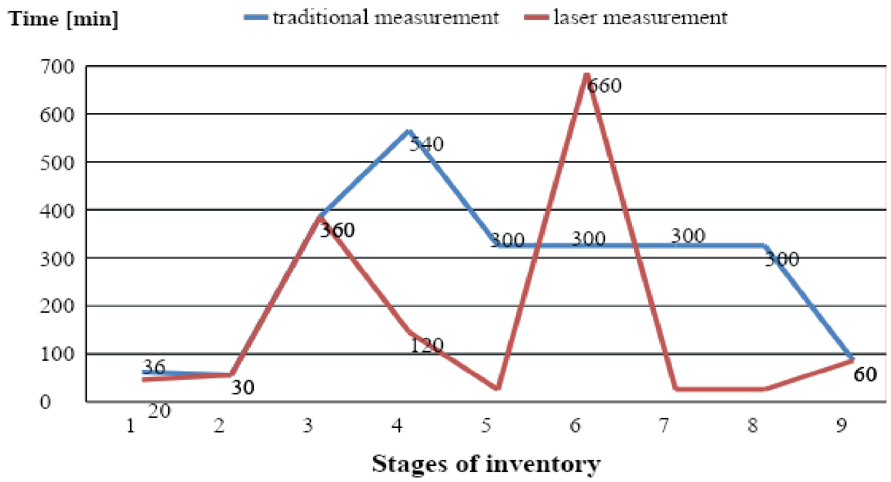

Fig. 6. Diagram of the comparison of the duration of measurements of individual stages - compilation by the author

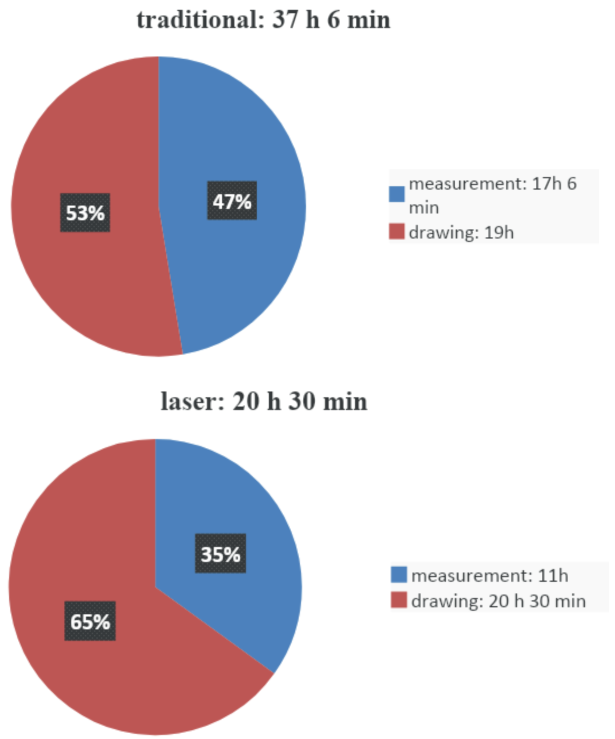

Fig. 7. Percentage comparison of measurement duration with drawing duration - compilation by the author

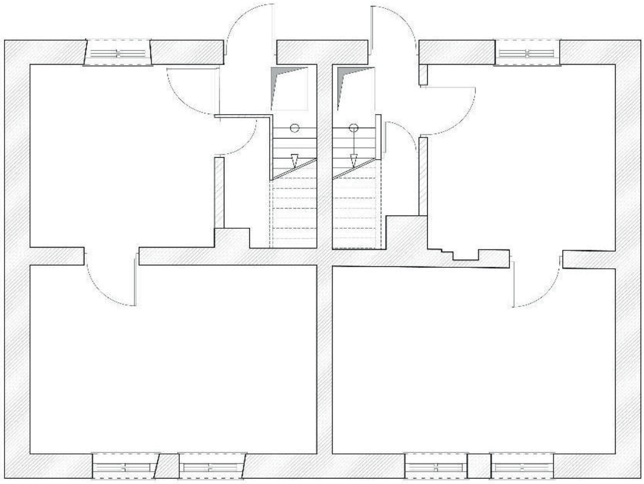

Fig. 8. Object outline based on manual measurement - compilation by author

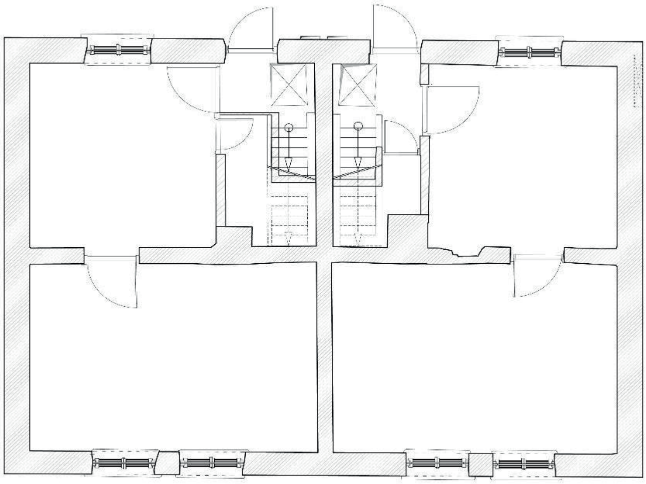

Fig. 9. Object outline based on scanning- compilation by author

5. Conclusions

During laser measurements, a decrease in the time at the measurement and offset stages as well as a shorter time of digitalisation of the measurement data can be noted. This is due to the fact that a single measurement using a 3D scanner allows to obtain the maximum amount of data needed to prepare later documentation in the 2D version. The research on a specific construction object presented in this paper clearly illustrates the advantage of laser inventory over the traditional one. Experience has shown that the difference between the two methods is twice as fast in favor of laser technology. Moreover, the inventories made differ considerably in terms of accuracy. The traditional method produces a much larger measurement error, and thus the accuracy of the drawings is significantly varied. The laser measurement technique allows to obtain a measurement representing the actual state [12], whereas the traditional technique contains a substantial measurement error.

References

[1] Uchański J., Falkowski P., Sörensen L., "The problem of standardization of terrestrial laserscanning techniques for architecture inventory purposes", Archiwum Fotogrametrii, Kartografii i Teledetekcji, vol. 18, 2008, pp. 633-641

[2] Chodorowski F., "Inwentaryzacja architektoniczna od Villarda de Honnecourt do komputerowego wspomagania", in Zeszyty Naukowe Politechniki Białostockiej. Architektura, 1999, Tom Z. 18, p. 79

[3] Boroń A., Borowiec M., Wróbel A., „Rozwój cyfrowej technologii inwentaryzacji obiektów zabytkowych na przykładzie doświadczeń zakładu fotogrametrii i informatyki teledetekcyjnej agh" / „The development of digital technology concerning surveys of heritage objects based on experiences of agh department of photogrammetry and remote sensing informatics", in Archiwum Fotogrametrii, Kartografii i Teledetekcji, Vol. 19, 2009, p. 13

[4] Boroń A., Rzonca A., Wróbel A., „Metody fotogrametrii cyfrowej i skanowania laserowego w inwentaryzacji zabytków" / „The digital photogrammetry and laser scanning methods used for heritage documentation" in Polskie Towarzystwo Informacji Przestrzennej, Roczniki Geomatyki 2007, tom V, zeszyt 8, p.129

[5] Sztwiertnia D., Ochałek A., Tama A. & Lewińska P., "BIM (Heritage Building Information Modell) of The Wang Stave Church in Karpacz (Poland)" – case study, International Journal of Architectural Heritage, 2019. https://doi.org/10.1080/15583058.2019.1645238

[6] Kulig A., Nassery F., Filipowski Sz., Zieliński R., "Wykorzystanie technologii BIM w nowoczesnej inwentaryzacji i analizie zabytków architektury" / "The use of BIM technology in modern methods of inventory and anlysis of architectural monuments", Wiadomości Konserwatorskie (Journal of Heritage Conservation) vol. 42/2015, pp. 39-42.

[7] Gleń P., Krupa K., "The use of secondary build-up in historical fabric based on the donjon of Kłodzko Fortress", E3S Web of Conferences 49, 00031 (2018), Solina 2018, p. 3

[8] Głowienka E., Jankowicz B., Kwoczyńska B., Kuras P., Michałowska K., Mikrut S., Moskal A., Piech I., Strach M., Sroka J., „Fotogrametria i skaning laserowy w modelowaniu 3D" pod redakcją Sławomira Mikruta i Ewy Głowienki, Rzeszów 2015, p. 73

[9] Boroń A., Rzonca A., Wróbel A., „Metody fotogrametrii cyfrowej i skanowania laserowego w inwentaryzacji zabytków" / „The digital photogrammetry and laser scanning methods used for heritage documentation" in Polskie Towarzystwo Informacji Przestrzennej, Roczniki Geomatyki 2007, tom V, zeszyt 8, p. 133.

[10] Filipowski Sz., „Skaning laserowy w inwentaryzacji architektonicznej – stosowane rozwiązania i propozycja udoskonalenia" / „Laser scanning in architectural surveying – popular solutions and proposal for improvement", PUA 1/2018, p. 97.

[11] Lewińska P., Zagórski P., "Creating a 3D database of Svalbard's historical sites: 3D inventory and virtual reconstruction of a mining building at Camp Asbestos", Wedel Jarlsberg Land, Svalbard, Polar Research; ISSN 0800-0395. — 2018 vol. 37 art. no. 1485416, pp. 1-9. https://doi.org/10.1080/17518369.2018.1485416

[12] Remondio F., "Heritage Recording and 3D Modeling with Photogrammetry and 3D Scanning", Remote Sensing, 2011, vol. 3(6), pp. 1104-1138. https://doi.org/10.3390/rs3061104

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Municipal gardens as the synergic element of the structure of selected towns of Lublin region

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Abstract: Planning of municipal gardens as the integral part of urban landscape in the Lublin region was typified by the activity of the outstanding garden planners: engineer Feliks Bieczyński and Walerian Kronenberg. This movement to create public, municipal green areas commenced in 19th century and continued with success during the inter-war period. This process took place in the big cities of Lublin, Zamość or Lubartów. Newly established public gardens were usually located on the outskirts of the city as for example, Park Saski (1837), Ogród Bronowicki (the Bronowicki Garden) – formerly called the Foksal Park in Lublin, or Park Miejski im. Jana Kanclerza Zamoyskiego (the Zamoyski Municipal Park – 1926) located in the former fortification area in Zamość. The situation in smaller cities such as Lubartów, Radzyń Podlaski (1755, planner: Jakub Fontana) and Kock (planner: Szymon Bogumił Zug) was slightly different. The former garden complex adjacent to the magnate residence served a key role in the urban structure of the settlement (thus, determining its development) was later adapted to the function of a municipal park.

The article describes three selected garden complexes. The spatial relations of the parks in the context of their urban structure are analysed. The article takes into account their contemporary use and the state of preservation of their historic elements as presented in the original composition as presented in historic images and maps.

Keywords: municipal park, garden architecture, the 19th/20th century, the Lublin region

1. Introduction

The development of municipal parks in Poland started in the 19th century due in an effort to organize and regulate the cities. Public greenery gained then an autonomous function, becoming an important element for spatial and urban planning of the developing cities of Lublin region [1]. Some of the new garden complexes were located on the city outskirts, often near tollbooths or entry gates, often in demanding and difficult areas due to the terrain, remnants of ancient fortifications, or problematic infrastructure issues in and arounds areas designated for the public parks.

Municipal parks were considered to be the opportunity for improving the sanitary and hygienic conditions of the city and for increasing aesthetics qualities, for the developing parts of the city. Creating city parks from existing older gardens of palaces, manors, and monasteries had its own challenges. These parks are most often located near the market squares located in the very centre of the towns. By making them public, they became an important green area for the entire urban layout and determined the street layout [2].

2. The state of research

The subject of municipal parks in Lublin Voivodship have not been fully investigated. The principles of the design of calligraphy parks, the work of Walerian Kronenberg were described by V. Kulus [3]. The monograph devoted to the planner presented the main doctrines of his workshop in creating urban parks. P. Baster (2011) analysed the garden complexes of Kronenberg with particular emphasis on the manored and palace parks [4]. The history the municipal park in Zamość was described by B. Sawa [5]. The analysis of dendroflora and state of preservation of the park in Czesławice by Walerian Kronenberg was carried out by K. Pudelska and K. Rojek [6].

The establishment of the palace park complex in Lubartów and its transformations was the subject of the articles by M. Kseniak [7] and E. Przesmycka [8]. The architecture of the greenhouse/hothouse in this complex was described by, among the others, Grytczuk, Kuźmicz [9] and K. Boguszewska [10], [11]. The municipal park in Lublin called the Ogród Saski was the subject of research and articles of J. Niedźwiedź [12] and N. Przesmycka [13].

3. The purpose and scope of work

The article shall present three municipal parks of the Lublin region, specifically the parks of Lublin, Lubartów and Zamość. The common denominator of these public spaces is the function they fulfil today. The article analyses the changes in the form and function of the historic structure of three parks, approaches to their restoration and the nature of their complementary infrastructure, including hothouse and greenhouse as the nodal architectural elements.

4. History of establishing of municipal gardens

The first public gardens were mostly complexes accompanying palaces and monasteries. Examples of this include the gardens of Warsaw: Ogród Saski (palace park) – 1727, Ogród Krasińskich (palace park) – 1768, Ogród ks. Podkomorzego – 1780 (manor garden), and Łazienki Królewskie (palace park). In the 19-th century these were opened for the residents of Warsaw.

The first municipal parks in the Congress Poland were established in Kalisz (converted former Jesuit garden) and Łęczyca at the end of the 18th century. Later, parks were created in: Kielce in 1815 (former bishop's garden), Sieradz in 1825, Konin in 1825, Częstochowa in 1826, Janów Lubelski in 1830, Radom in 1834, Suwałki in 1832, Płock, Sandomierz in 1859 and Lublin in 1837 [14].

In 1892, Edmund Jankowski described the state of public gardens in the Congress Poland. In his article *"On public gardens in provincial cities"* (original title: *„O Ogrodach publicznych w miastach prowincjonalnych") *he stated: *"In truth, a few larger cities like Lublin, Kielce, Sandomierz or Płock finally have good public gardens, but these complexes are also flawed when viewed by an expert. Lack of views, roads led without a reasonable need, common planting material, and above all, not watered, hence poor lawns. This is all too noticeable. You clearly see the lack of a good plan of the complexes, inappropriate management at the execution, and in many cases, inability to maintain gardens, and, without doubt, everywhere, the meagreness of funds to maintain gardens designated for municipalities*" [15]. This brief description presents the problems that the institutions responsible for establishing and maintaining public gardens at the turn of the 20th century were facing. E. Jankowski in his paper encourages *"provincial cities"* to take care of the greenery in the centre and to plant trees along the streets; he emphasizes the advantages and benefits of an extensive greenery system in the urban structure from *"hygienic benefits"* to *"social life nodes"*.

Particular emphasis was placed on the method of financing of the so-called "Plantations". E. Jankowski argued that the basis is a good *"plan (...), which then has to be performed in stages, even for a dozen or so years, but it needs to be done to the letter, with iron perseverance"*. He also notices that after having analysed the plans of public parks of cities and towns, it can be seen that *"almost none of them had an original plan, made by competent, well-educated and experienced gardeners – artists"* [15].

At the turn of the 20th century, the establishment of municipal parks became exceptionally popular. At that time, there were many prominent planners and garden planners called landscape architects. It's especially worth mentioning Walerian Kronenberg, the creator of over 300 parks in the period 1880-1905, Teodor Charzyński, Stanisław Celichowski, Edmund Jankowski, and Franciszek Szanior- among the others the creator of new parks in Warsaw (Sakryszewski Park and Ujazdowski Park) [14]. These newly established parks included a complementary infrastructure, in the form of gazebos and pavilions, sport infrastructure (the influence of game parks of dr. Jordan), and various types of greenhouses and palm houses. Admittedly, these were not as impressive in shape and size as greenhouses of Great Britain or Germany. The latest constructional solutions were also not used. However, an important example of such buildings in Poland are the greenhouses in the Botanical Garden in Wrocław (1861), the hothouse in Kraków (1872) and the palm house in Lubiechów (1911-1914) [16]. One example of the greenhouse – palm house, also known as the "great iron greenhouse" in the Saski Garden in Warsaw were erected in 1854, in its south-western part of the garden, near the square behind the iron gate. A representative parterre preceded the greenhouse. It had a rectangular plan with a design influenced by the humble Anglo-Saxon greenhouses glazed with Polish flat rolled glass, hot water heating systems, and a cast iron structure [17]. The main body of the orangery was accentuated by a centrally placed break, which defined the entrance detailed as a Moorish arch. The single volume interior was rearranged in 1912, when artificial caves and rocks were added to create a backdrop for exotic vegetation stored in the building. The greenhouse was wrecked during the Warsaw Uprising and torn down by the retreating Germans.

In the Lublin region, municipal parks started to be created from the first half of the 19th century. Herein, we will investigate three municipal parks of the Lublin region: the first public gardens in Lublin, Lubartów and Zamość and the function they fulfil presently.

The municipal park in Lubartów

The palace - park complex in Lubartów is one of the best preserved and reconstructed after the Second World War. The garden exemplifies the baroque composition of the *entre cour et jardin*[1]. The eight-hectare park, converted to a municipal park in 1935, is one of the most important green areas of this district town of nearly 23 thousand residents. Currently, it functions as a leisure spot for the town residents and accommodates a football field.

Lubartów, originally called Lewartów, was founded by Piotr Firlej from Dąbrowica, who obtained permission for the location its 1543 from the King Sigismund I the Old. The town was founded on the basis of Magdeburg laws "*in cruda radice*". The centre of the town was the Market Square with a wooden town hall. In the northern part there is a wooden church

[1] A garden composition, called "between the courtyard and the garden" (*entre cour et jardin)*, characteristic for the Baroque period, subject to the rigorous rules of the composition.

dedicated to St. Peter, the Apostle. After the fire its name was changed to the church of St. Anne [8]. At that time, a magnate's residence was surrounded by an Italian garden. The Lubartów Palace, along with a park of 18.5 hectares, was called the Lubartów castle.

In the eighteenth-century plan of Hendesfeld, a baroque composition of the entire palace – park complex is visible. It is worth comparing this plan with the description of the garden complex from the 1747 Inventory of Lubartów estates [18]. The main compositional axis of the complex ran through the centre of the palace. It was extended by an alley flanked with lime trees (now road number 20) leading to the palace complex of Kozłówka. In front of the palace there was the main courtyard (cour d'honneur), square in plan, surrounded by annexes built of brick (separating the space from the north and south side) and the main entrance gate at the west. The symmetrical division of the garden by the main avenue, from which the secondary alleys divided, was further emphasized by a circular area with a lawn and two rectangular canals which closed the magnate garden of the east (from the side of the Wieprz river). Interestingly, an empty square is visible on the plan. It has been described in the inventory as follows: *"the other half of the garden lanes planted with hornbeams (...) and at the end of the garden, the square where trees froze and died".* The water of the "Sadzawka Pańska" pond came from two encased sources located under the bridge near the main courtyard. In the centre there was a round square with a circular lawn. The plan also included buildings accompanying the whole complex, including the hothouse - "orange house of three storeys" (Fig. 1). The park in Lubartów was transformed into an English style gardening 1830, thanks to the new owner, Klementyna Małachowska. This intervention included the demolition of the main entrance gate with the keep and the annexes surrounding the square [7].

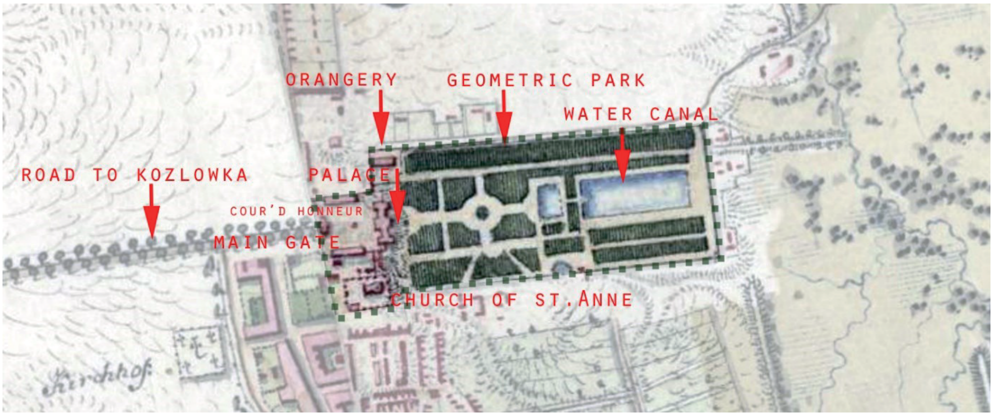

Fig. 1. A part of the plan from the end of the 18th century which shows the most important elements of the complex, author's own elaboration on the basis of fragment Carte von West-Gallizien...,1804, Kriegsarchiv, Wien source mapire.eu, access: 08.05.2019

In 1949, thanks to Gerard Ciołek the restoration of the complex according to his designs was partially executed. The baroque park composition layout was reinstated. Until now, there is a historic area covering the space of the first complex. The historical substance of the park in the form of specimen trees dating back to the times of the Firlej and Sanguszko family is represented by individual trees located near the palace and in the northern part of the park by one of the alleys (which in the past was one of the compositional axes). Most of the historic stand of trees is dated to 1840-1934 and is located in the southern part of the park and in the vicinity of the pond.

The park and its spatial structure in its present state is the result of the restoration carried out in the 1950-1975 according to the plan of Gerard Ciołek and later Anna Obrębska [19]. The project of restoration of the garden complex according to Gerard Ciołek was developed in the 1950s, at a time when various "social functions" were often imposed on historical parks thereby severely damaging then the historical nature and disturbing their historic spatial compositions. This was often of a building – a manor house or a palace and its historical plantings. Gerard Ciołek attempted the reconstruction of the French baroque garden in the immediate vicinity of the palace in order to recreate a kind of garden salon.

The nineteenth-century part in the English style remained largely unchanged, apart from small interventions - like the creation of island in the pond. The northern part of the establishment was to be a garden theatre in the form of cabinets stretching along the baroque water channel (Fig. 2). It was complemented with a complex of sport fields and a representative garden emphasizing the building of the Baroque-Classicist hothouse. These plans were only partially implemented - the garden salon was reconstructed next to the palace, while in the northern part, a sports stadium was built together with back-office buildings and an amphitheatre in the place of the planned complex of sports fields [7]. We can say that the historical park in Lubartów shared the fate of many other garden complexes transformed into municipal parks. It lacks the proper maintenance and care for the historical stands resulted in the blurring of the perspective axes that were landscape connections with the Wieprz River and riverside meadows.

Currently, the city of Lubartów is one of the five municipalities involved in the partnership project called "Zielony LOF" (the Green Lublin Functional Area). This project is co-financed by the European Regional Development Fund as a part of the Regional Operational Program of the Lublin Voivodeship for the period of 2014-2020. The project is focused on increasing the biodiversity of the covered areas by improving the quality of green areas along with their management and limiting the impact on the areas. One of the tasks of the project is *"modernization of the municipal park and supplementing the infrastructure to enhance tourist attractiveness of Lubartów"*. Within the framework of this mission, the arrangement of the entire park, included the introduction of new functions (areas of activity for children and adults) together with the necessary infrastructure, pond cleaning and adaptations [20].

Fig. 2. Park in Lubartów, current state, photo by author

The hothouse as a node element of the park in Lubartów.

One of the most important facilities complementing the infrastructure of the park was the greenhouse building located in the north-west part of the complex. It is one of the largest hothouses accompanying a mansion complex in the Lublin Voivodeship. The building was built in the Classicial style and is first mentioned in 1703. The hothouse is a one-storey block with a two-storey part at the east, made in the shape of L. Orangery had a 23-bays on the south façade. It is a brick building covered with a hipped roof covered in ceramic roof tiles (Fig. 3). This building was originally used to keep orange trees during the winter season. Later, during the interwar period, it was adapted to residential function. It was used for this purpose until the 1960s. In 2000, its structural condition was catastrophic. In 2005, the building was sold, and in 2010, only the southern wall and a fragment of the eastern wall remained from the building of the former greenhouse [10]. If we analyse the history of the similar buildings, one might have expected that the Lubartów hothouse would disappear from neglect. However, the building was purchased by a private investor who has been rebuilding it over numerous years. The architectural detail of the building and the divisions of window joinery have been respected and reproduced with a great accuracy. This object is to be used for hotel and restaurant function [21] (Fig. 4).

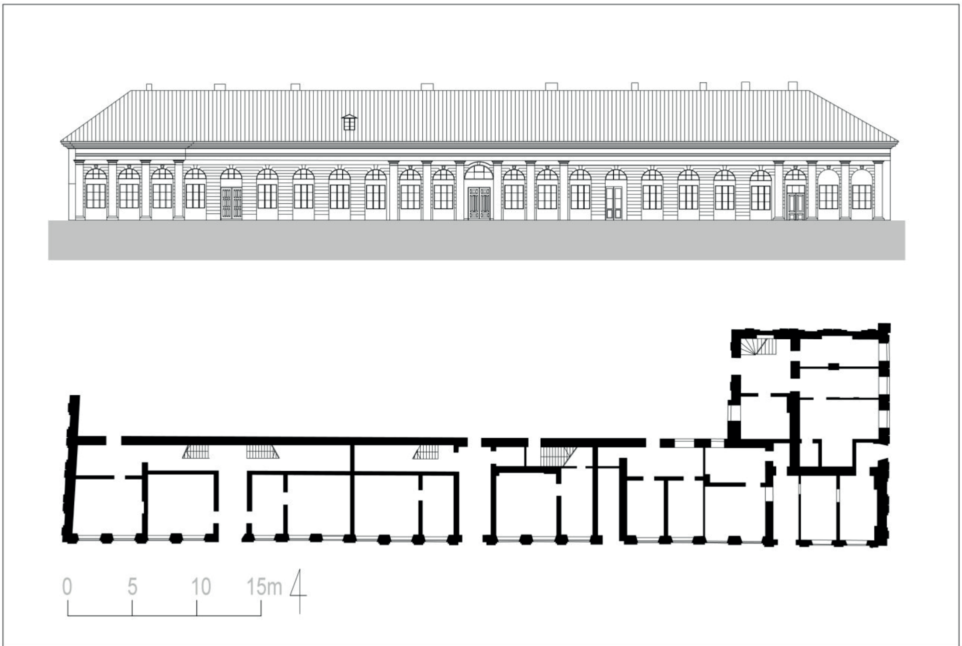

Fig. 3. The schematic plan and façade of the hothouse in Lubartów, author's own elaboration

Fig. 4. The hothouse in Lubartów in 2005 and 2018, photo: author

The Saski Garden (Ogród Saski) in Lublin

The establishment of the Saski Garden (1837) in Lublin is connected with the work of the gubernatorial engineer Feliks Bieczyński, originator and planner of the nineteenth-century municipal parks of Lublin: a park in the area of the Jewish city, Bronowice park (1869) "located in the area of the city between the Czerniejówka river and the suburbs of Piaski" or unrealized concept of a housing estate and park from 1860.

The Saski Garden was located "by the paved road to Warsaw" on the former Dominican properties [22]. The choice of the plot for the future municipal park was made due to the advantageous ownership and economic situation of the plot, the improvement of the quality of the "wretched city of Wieniawa" adjacent to the future investment, varied topography and relief, "vast views" and "proximity of the city" [23]. The park was made in a landscape style; the organic layout of communication routes has been composed as an element that was binding individual landscape interiors. The elements of landscape architecture were complementing the layout of the park. Bieczyński designed among the others a well, an entrance gates to the park, a guardhouse, or an unaccomplished adaptation of the building of the old powder-magazine for the function of gardener's house (Fig. 5).

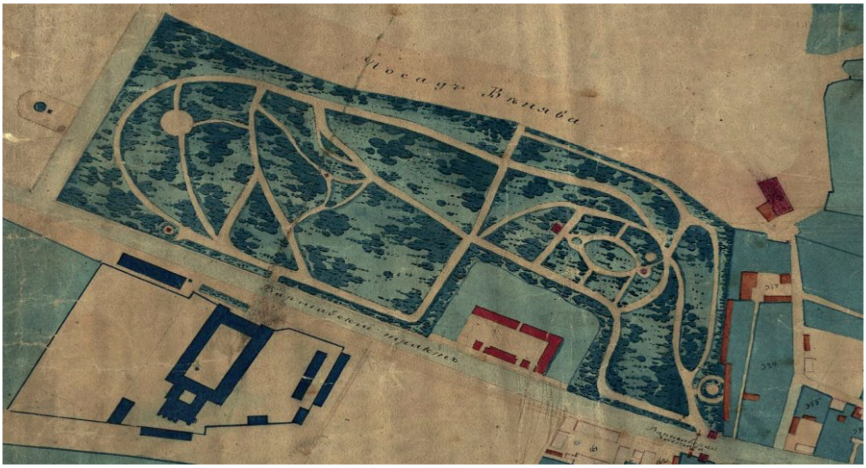

Fig. 5. Archival plans of the Saski Garden in Lublin, fragment План города Люблина 1870, source: State Archives, s. 5, План города Люблина, 1870, Piotr Cegliński, Lubelskie Archiwum Cyfrowe

An unexecuted plan for the Hothouse Pavilion

At the end of the 1950s, there were plans to locate the palm house in the Saski Garden. The opinion of an expert was commissioned for the needs of the local plan "*in which basic requirements were defined and the significance of this type of garden architecture was characterized as: educational, didactic and tourist"*. Therefore, the study underlines that this type of facility should be located in municipal parks, and the most representative and well located in terms of communication was the oldest municipal park of Lublin called the Saski Garden (Ogród Saski). The area devoted for the construction of a new building was a rectangular, flat square created after repurposing of an agricultural farm. It bordered on two sides with the old-growth trees of the municipal garden, and on the other side with the building formerly called the House of Party, currently housing the Rector's Office of the Medical University. Placing of such an important architectural building necessitated the plans to change the main entrance to the park, whereas the palm house was to "stand on the background of the old-growth trees of the park as far as possible from Racławicka street, and the entire flat area was to be transformed into a representative flower garden, separated from the street with a belt of trees and bushes" (Fig. 6) [24].

Fig. 6. The Saski Garden in Lublin, current state, photo by Wojciech Pawlak

The municipal park in Zamość

In 1924, an exhibition of plans of parks and gardens was organized in Warsaw by the Planners' Club of the Warsaw Horticultural Society. Its main goal was to popularize the art of landscape planning. Twenty planners associated in the Planners' Club together with the different institutions took part in the event lasting nearly a week. About 100 plans were presented at the exhibition. One of them was sent by the city of Zamość and *"presented the plan of the park on the fortress ramparts, developed and perfectly adapted to the conditions by Mr. Walerjan Kronenberg, a well-known planner"* [25].

The residents of Zamość made efforts to create a municipal park date back to 1903 when the first steps were taken in this direction. However, only after World War I, in 1917, after the consultations with the Warsaw Horticultural Society, the city of Zamość announced a two-stage architectural competition for the concept of municipal park development. The work of Walerian Kronenberg, a renowned garden planner specializing in establishing garden complexes at parks and manors, the author of city parks in Warsaw (1903-1904) - (Agrykola), Łódź (1904-1910), was selected for this task. The planner's works also include projects of spa parks in Nałęczów (recomposition and enlargement of the park), Konstancin Jeziorna or municipal parks in Białystok and Spała. The works on the park lasted for 8 years and were supervised by the designer himself.

The municipal park in Zamość represents the early modernism. It was made in the form of landscape and geometric park (Fig. 7). The complex designed by Walerian Kronenberg differed significantly in terms of the composition and style from the calligraphic parks designed before by the planner. It is an example of an innovative approach to the *"devastated fortress landscape"*, which determined the ultimate character of the complex through its topography, thus showing the identity of this place. The functional - spatial composition of the park was closely related to the remains of the seventeenth-century bastion fortification left after demolition. The park was founded in the area of three fortresses: *Bastion IV, the counterguard of the same bastion and ravelin in front of the curtain between Bastion IV and V* [26].

The way of shaping the communication routes and the water system (the pond and the island highlighting the former counterguard of the bastion) emphasized the historical outline of the fortifications and made them legible in the composition of the whole complex[2]. Bastion IV is currently not an *"orderly relic"* but an example of the original architectural creation of the old fortress. As a result of the program *"Zamość, a city of UNESCO, the Monument of the History of the Republic of Poland, as a tourist product of the Polish economy"*, the bastion was opened to the public and is a great view point for the modernist garden complex, just like the over-bulwark, from which the panorama of the city of Zamość can be admired [26]. The other part of the park (on its eastern side) is a highly geometricized, representative part consisting of two garden interiors intersecting at a right angle with a centrally placed fountain [3] – the whole is inscribed in the former ravelin in front of the main gate and the bridge stretched over the system of fortifications. Currently, this space is used by go-carts that are a tourist attraction of the park (Fig. 8).

[2] *„The introduced new elements serve to visually link the bastion with the circumference of the fortifications. The readability (integration) of earth elements and the correction of greenery on Bastion IV with plantings in the background of the bastion (outfield), the use of defence devices around the pen, and the appointment of the area (information boards) were made. Casemates of Bastion IV were intended for tourist functions".* http://twierdza.zamosc.pl/pl/places/222/park-miejski-bastion-iv-sloniczolo-przed-bastionem.html, access: 19.12.2018

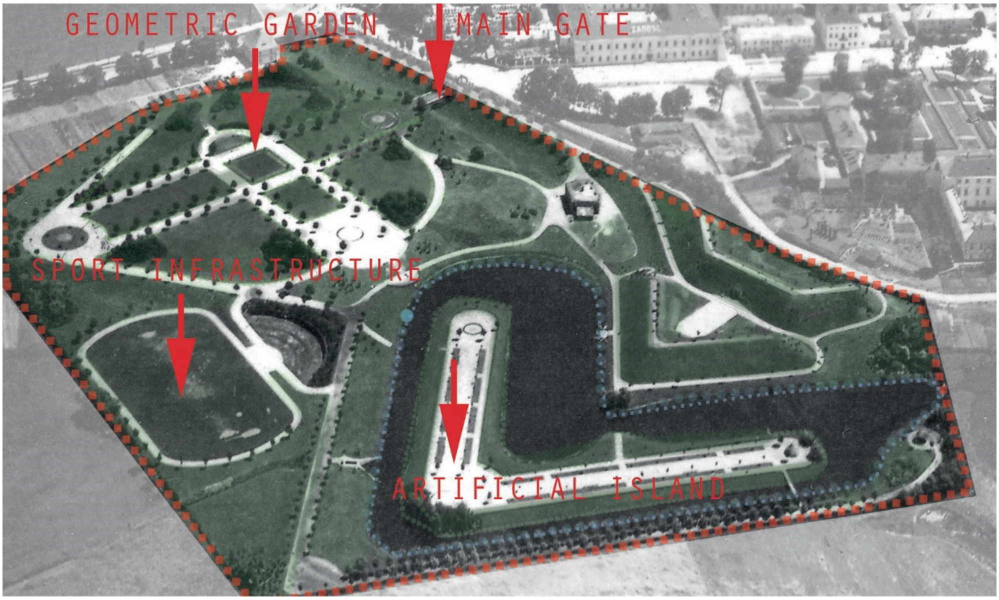

Fig. 7. Schematic plan of park in Zamość, author's own elaboration on the basis of the photo in archive of Instytut Sztuki PAN in Warsaw, nr 18373 (1927)

Fig. 8. The municipal park in Zamość, current state, photo by author

In terms of functionality, the municipal park in Zamość is analogic to the functional program of the Palmgarten park in Frankfurt designed by F. H. Siesmayer in 1868-1887, when Valerian Kronenberg had his apprenticeship there (in the 1870s). Just like in the German public garden, the "Great Garden Salon" decorated with floral patterns ("Wielki Staw" – the Big Pond) was designed in Zamość. There was also garden architecture in the form of cafés, gazebos, three bridges leading to the island and other decorative elements like compositions of flower parterres or lapidarium in the form of the boulders near the pond.

A very important element of the public gardens of the early 20th century was the sport infrastructure represented in the garden in Zamość by a square of 4.5 thousand m^2 with an audience and running track, a tennis court and a playground for children. The trend of designing new forms of recreation in the open space has been gaining more and more popularity since the end of the 19th century due to the game parks of dr. Jordan [3].

The greenhouse

The building of the former greenhouse is currently used for a florist's shop. It was built in the 1930s and was based on the modest greenhouses accompanying manor gardens. The building built on the circular plan is in the form of a rotunda with the vestibule in front of the entrance. The building had a surface of 290 m^2 and its height was four meters. The building material and cast iron windows arranged symmetrically in the facade were obtained from the demolition of the "Unia" factory located at Lwowska street. There was a chimney in the central part of the greenhouse. Smoke channel in the external walls was used to heat the greenhouse [5] (Fig. 9).

Fig. 9. The building of the former greenhouse and now the florist's shop, current state, photo. author

5. Summary

The gardens listed in the table below (Tab. 1) are undeniably among of the most important green areas of the above-mentioned cities. They are the tourist gem and the place for leisure of their residents. The area of these urban gardens is quite significant - they range from 8 to 11 hectares (Tab. 1). Nowadays, they are an important element of the city centre (Lublin, Lubartów) or they border directly with the Old Town (Zamość). They were created at very different periods of time (Tab. 1) and in a different way, starting from the magnate foundation (Lubartów), through the planned action of greening of the city (Lublin), to an architectural competition project (Zamość). However, they have one thing in common – the areas for their location were interesting in terms of landscape and located outside of then borders of the city centre. An exception here is the park in Zamość, which was designed to respect the existing fortifications system adapting it to new functions. Only this park has still documentation of the plan by Walerian Kronenberg. For the other sites in Lublin and Lubartów, we know the landscape plans of the parks only from later city development plans.

Noteworthy is the fact that the parks in Lublin and Zamość had a very rich functional program as opposed to the park in Lubartów, which originally was supposed to be a garden accompanying the palace. Especially the garden in Zamość, which based its plan on German models and was created almost the same time as the game parks of dr. Jordan of the early twentieth century, was characterized by a large sport area in the form of: a sports square of 4.5 thousand m^2 with a running track, a tennis court, kayaks and an ice rink in the winter at the pond (Tab.1).

In observing the degree of preservation of these historical compositions - currently two parks have been restored (Lublin, Zamość) and their spatial composition has been preserved in nearly unchanged. The garden in Lubartów is currently classified as one of the better reconstructed (1950s and 1960s) Baroque complexes *Entre Cour et Jardin* in the Lublin region, although the later character of landscape park from the nineteenth century is mostly visible from the eastern part by the pond. This park, however, did not escape the devastation, influenced on manor complexes in the aftermath of "pro-social" decisions of the 1950s (a sport stadium was located within the borders of the park).

Currently, there are a few significant changes in the area of the parks. They are more accessible due to better space organization and they give more sense of security thanks to the implementation of monitoring (Lublin, Zamość). The historical functions of the park are currently being recreated. For instance in Zamość, by the end of 2019 the construction of a park cafe will be completed (such building once existed in the area of the park). Whereas in Lubartów, the hothouse was rebuilt.

Table 1. The transformations in the functional and spatial use of the analysed parks, author's elaboration based on literature, archives and internet sources

The name of the complex	**Palace – park complex in Lubartów**	**The municipal park in Lublin „ Ogród Saski" – Saski Garden**	**The municipal garden in Zamość**
The current style of the garden, the form transformation and function, the time of establishment	The first half of 18th century. Baroque palace park / later landscape park, in the 50's and 60's restored by G. Ciołek	1837, landscape public park, (municipal)	1919 – 1926, Modernist, public garden taking into account and exhibiting in its topography and architectural forms elements of the former fortifications of the city of Zamość

Planner / founder	Sanguszko family Palace – park complex transformed into municipal park in 1935	Eng. Feliks Bieczyński Lublin city	Walerian Kronenberg/ Zamość city, park developed as a result of an architectural competition
Surface The time of restoration	8 hectares, pond: 3,54 hectares, 2017 – end of 2018	12 hectares, 2009 - 2013	11 hectares
Original functional program of the park	Baroque residential garden – the kind of entre cour et jardin. The main courtyard, a palace with brick annexes, a baroque garden salon, a hothouse, and a water channel.	Fenced landscape municipal park with a pond and a cascade, a neo-gothic guardhouse, pavilions – a gazebo – a patisserie, a circular gazebo, two fountains (19th- and 20th-century), a sundial, a baroque sculpture erected on a mound during the war by the Germans, Tyrolean tavern	Garden salon consisting of two garden parterres with fountains, a representative main gate Café, Big pond available to residents (in summer, there is a boat, in winter - an ice rink). Three garden bridges leading to the island. A lock in the shape of a mushroom, lapidarium at the pond. A sports square of 4.5 thousand m2 with a running track. Auxiliary garden with greenhouses and a nursery. Children's Playground, Building and pavilion for the orchestra, tennis court
Current functional program of the municipal park	A walking park, in the palace there is currently the Lubartów Town Office, the pond is unused (fishing with a permission), a baroque salon next to the palace, the hothouse in the private hands in the middle of a major overhaul to adapt the building for restaurant and hotel function, the restoration project of the complex is ready.	Fenced park, surface was replaced, renovated water system, (construction of a new pond), an aviary, an amphitheatre, renovation of a neo-gothic guardhouse	Walking park, garden salon (go-cards, bicycles), sport area, a pond accessible for the residents (kayaks), the plans to build a cafe, a bastion open for tourists, a former hothouse functioning as a florist.
The cost of restoration plan	PLN 10 million as part of the Zielona LOF partnership project planned for 2016-2020	PLN 12.7 million, co-financing in the amount of PLN 7.3 million from the European Regional Development Fund	PLN 11 million project

References

[1] Majdecki L., „Historia Ogrodów od XVIII wieku do współczesności", Wydawnictwo Naukowe PWN, Warszawa 2008, p. 359

[2] Przesmycka N., Boguszewska K., „Kształtowanie terenów zieleni w układzie urbanistycznym śródmieścia Lublina", 2018, typescript

[3] Kulus V., Kronenberg W., „Materiały do słownika twórców architektury krajobrazu w Polsce, T1", Wydawnictwo SGGW, 1990, pp. 36, 61-62

[4] Baster P. „Polskie parki kaligraficzne", Wydawnictwo AGH, Kraków 2011

[5] Sawa B., „Dzieje zamojskiego parku", *Zamojski Kwartalnik Kulturalny,* no. 1-2 (78-79) 2004, Zamość, Zamojski Dom Kultury, 2004, pp.96-97

[6] Pudelska K., Rojek K., „Zmiany w strukturze drzewostanu w XIX wiecznym parku w Czesławicach", *Teka Komisji Architektury, Urbanistyki i Studiów Krajobrazowych*, OL PAN 2013, IX/3, pp. 56-63

[7] Kseniak M., „Parki i ogrody dworskie w województwie Lubelskim", 1983, Lublin, pp. 34, 36-38

[8] Przesmycka E., „Przeobrażenia zabudowy i krajobrazu miasteczek Lubelszczyzny", Wydawnictwo Politechnika Lubelska, 2001, p. 168

[9] Grytczuk R., Kuźmicz M., „Projekt rewaloryzacji zespołu pałacowo-parkowego w Lubartowie z adaptacją oranżerii na cele współczesne", praca magisterska, Politechnika Lubelska, Lublin 2001, pp.85, 110,

[10] Przesmycka E., Boguszewska K., „Losy Oranżerii w Lubartowie", *Teka Komisji Architektury, Urbanistyki i Studiów Krajobrazowych*, OL PAN 2011, pp. 126-131

[11] Boguszewska K., „Oranżerie województwa lubelskiego w świetle polskich wzorników sztuki ogrodowej z XIX i XX wieku", *Annales Universitatis Mariae Curie-Skłodowska. Sectio L, Artes*, vol. 11, 1 (2013), pp. 9-25. https://doi.org/10.2478/umcsart-2013-0007

[12] Niedźwiedź J., „Ogrody Lublina w planistycznej twórczości Feliksa Bieczyńskiego", Czasopismo Techniczne. Architektura, R. 104, z. 5-A, 2007

[13] Przesmycka N., „Przeobrażenia historycznych terenów zielonych Lublina do 1939 roku", *Teka Komisji Architektury, Urbanistyki i Studiów Krajobrazowych*, OL PAN, 2005, pp. 157-167

[14] Ciołek G., „Ogrody polskie", Wydawnictwo Arkady, Warszawa 1978, p. 180

[15] Jankowski E., „Ogrody publiczne w miastach prowincjonalnych", Warszawa 1892, pp. 554, 555

[16] Gronostajska B., „Historia powstania oranżerii" , *Architectus*, vol. 1(11) 2002, pp.112-113

[17] Kraushar A., „1727-1927 w dwuchsetną rocznicę oddania Ogrodu Saskiego do użytku publicznego", Warszawa "WUZET", 1927, p.15

[18] „Inwentarz dóbr lubartowskich jaśnie oświeconych na Białym Kowalu, Smolanach i Rakowie, Zasławiu i Ostrogu książąt ichmościów Sanguszków, na Wiśniczu, Jarosławiu i Tarnowie Hrabiów, marszałków wielkich Wielkiego Księstwa Litewskiego, krzemienieckich i czerkaskich starostów, spisany na gruncie z pomiarem in anno 1747", Archiwum Narodowe w Krakowie, Archiwum Sanguszków, sign. 581, 5-327, za: Za: M. Kseniak Parki i ogrody dworskie w województwie Lubelskim, 1983, Lublin, p. 36

[19] Cebula A., Kunkel A., Projekt koncepcyjny przebudowy parku miejskiego w Lubartowie działki nr ewidencyjny 218/2 i 223 obręb Lubartów, Warszawa 2017

[20] http://lubartow.pl/projekty_unijne/102709/zielony_lof/, [Access: 15 Dec 2018].

[21] http://przegladlubartowski.pl/informacje/17773/ruszyl-remont-lubartowskiej-oranzerii, [Access: 15 Dec 2018].

[22] Żywicki J., „Urzędnicy: Architekci, Budowniczowie, inżynierowie cywilni..., Ludzie architektury i budownictwa w województwie lubelskim oraz guberni lubelskiej w Królestwie Polskim a latach 1815 – 1915", Wydawnictwo UMCS, Lublin 2010, p.147

[23] Targońska E., „Najstarszy ogród w mieście”, *Apla Biuletyn. Pamiętajcie o ogrodach*, APL, No.2, 2011, p. 2.

[24] Lisiak B., „Ekspertyza techniczna planu zieleni miasta Lublina na etap 1955 – 1965”, Poznań, 1957, Archiwum UM w Lublinie.

[25] Szanior F., „Wystawa planów parków i ogrodów”, *Ogrodnik*, R. 14, no. 13-14, 1-15.07.1924, p.172-173.

[26] http://twierdza.zamosc.pl/pl/places/222/park-miejski-bastion-iv-sloniczolo-przed-bastionem.html, [Access: 19 Dec 2018]

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Technological advances in Japan's high-rise buildings

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Abstract: The architectural and structural analysis of selected high-rise buildings in Japan is presented in this paper. Tokyo, Osaka and Nagoya have the largest share in development of high-rise buildings. Those cities are very densely populated and moreover they are located in one of the most active seismic zones. The combination of these factors has resulted in the creation of sophisticated designs and innovative engineering solutions, especially in the field of design and construction of high-rise buildings. The foreign architectural studios (Jean Nouvel, Kohn Pedesen Associates, Skidmore, Owings & Merrill) which specialize in the designing of skyscrapers, played a major role in the development of technological ideas and architectural forms for such extraordinary engineering structures. Among the projects completed by them, there are examples of high-rise buildings that set precedents for future development. An essential aspect which influences the design of high-rise buildings is the necessity to take into consideration their dynamic reaction to earthquakes and counteracting wind vortices. The need to control motions of these buildings, induced by the force coming from earthquakes and wind, led to the development of various methods and devices for dissipating energy during such phenomena. Currently, Japan is a global leader in seismic technologies which safeguard seismic influence on high-rise structures. Due to these achievements the most modern skyscrapers in Japan are able to withstand earthquakes with a magnitude of over seven degrees at the Richter scale. Applied damping devices applied are of a passive type, which do not require additional power supply or active type which need the input of extra energy. In recent years also hybrid dampers were used, with an additional active element to improve the efficiency of passive damping.

Keywords: Core structure; damping system; high-rise buildings.

1. Introduction

Japan is one of the most densely populated countries in the world, with its capital Tokyo, one of the 47 prefectures, being its largest metropolis. Osaka Prefecture is the third and Aichi Prefecture with capital Nagoya the fourth-most populated. Japan also has one of the most active seismic zones in the world. Geological instability triggers about a thousand earthquakes each year (Fig. 1). The combination of these factors has resulted in the creation of sophisticated designs and innovative engineering solutions, especially of tall buildings. Over 140,000 people died during the Great Kanto earthquake in 1923, which almost completely destroyed Tokyo. The Tohoku earthquake and tsunami of 2011 was the most expensive catastrophe in the world with estimated damage of $235 billion. Until the early 1960s Japan's law on construction standards limited the maximum height of buildings. Frequent earthquakes in Japan mean that strictly defined construction standards are needed that require skyscrapers to implement security infrastructure, such as quake dampers and special deep foundations. The highest skyscrapers in Japan are mostly office and residential buildings. The urban form of Japan and especially Tokyo is largely a consequence of the reconstruction that occurred after the World War II. In comparison to Europe, where historic brick and stone buildings were built, old buildings in Japan were mostly wooden, and very few of them were reconstructed.

Fig. 1. Map of active faults in Japan (based on website of the Headquaters for Earthquake Research Promotion)

Japan's rapid economic growth continued until the first oil crisis in 1973. It had an influence on the development of urban centers around railway stations and the construction of many lines radiating outward from Tokyo. After the crisis, another stage of urbanization took place from 1970-1990. Tokyo's urbanism can be seen in terms of its architecture, with almost the whole city being completely rebuilt after the World War II. This rebuilding is characterized by the fact that many of its original buildings were designed by architects from around the world. The landscape of Tokyo was largely transformed by technological development. It was a transition from its architecture that in the past appreciated the natural landscape to its present architecture that consumes natural resources and intervenes in the natural landscape. In recent years, the trends to preserve natural resources and ecological solutions have become a priority. The panorama of Japanese cities and in particular Tokyo, Osaka and Nagoya includes many high-rise buildings. Currently in Tokyo there are 149 buildings over 150 m, in Osaka 38 and in Nagoya 11 (Fig. 2). Among these high-rise buildings, 8 were selected for further architectural and structural analysis (Fig. 3).

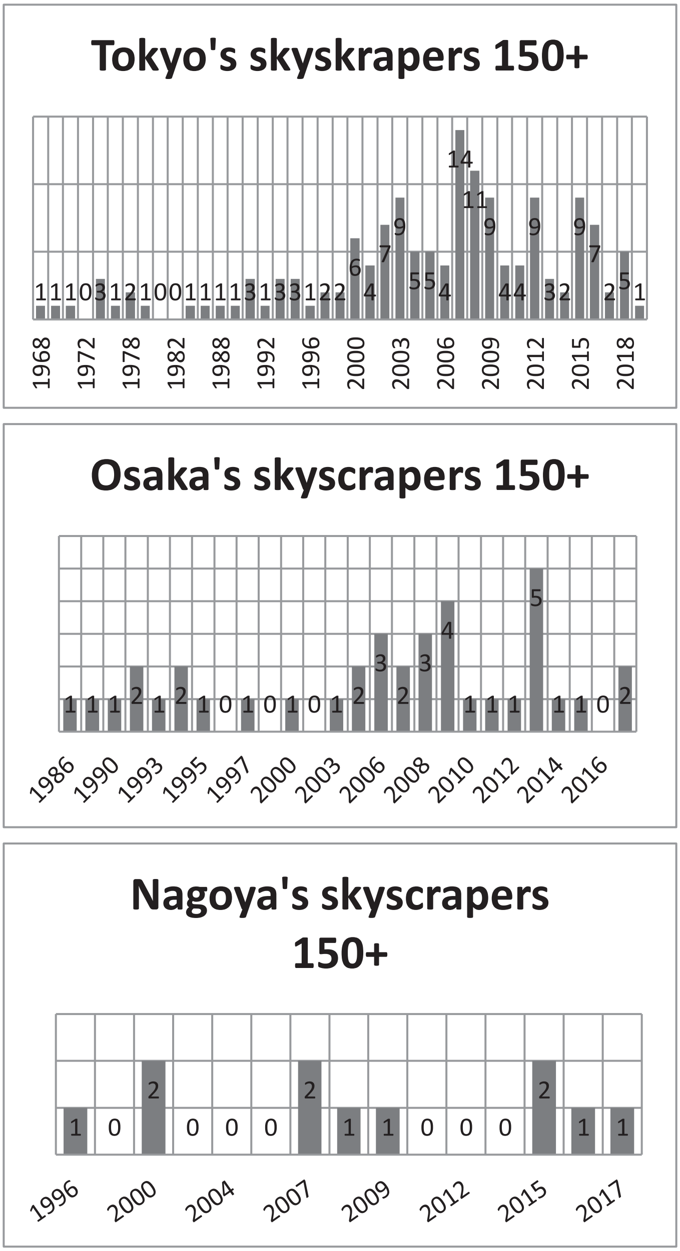

Fig. 2. Building completions timeline (150 m+): Tokyo, Osaka, Nagoya, developed by authors [1]

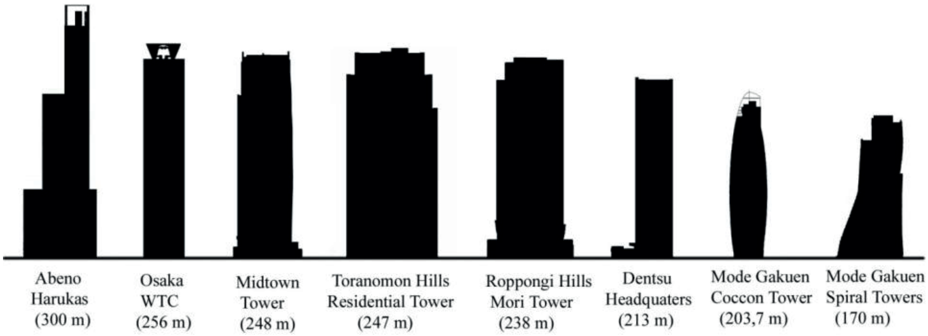

Fig. 3. Selected the tallest high-rise buildings in Japan

2. The history of tall buildings in Japan

Japan ranks third in the world after China and US in terms of the number of tall buildings. Tokyo has played a major role in the architectural history of these buildings in Japan (70% of all buildings above 150 m). Its architecture has also influenced their construction in Osaka (20%), Nagoya (5%) and Yokohama (1%). The first tall building in Japan was built in 1890 and it was known as Ryonkaku (64 m) [2]. This building located in Asakusa district in Tokyo was damaged as a result of Great Kanto earthquake in 1923. The abolition of buildings height limit to 31 m in Japanese Law, which was established in 1961, resulted in erection of the Kasumigaseki building in 1968 with 147 m and 36 floors. It was an opening of the era of skyscrapers in Japan.

In the following years, the height record changed many times. In 1970, the World Trade Center was built in Hamamatsucho with a height of 150 m and 40 floors, and in 1971 the Keio Plaza hotel was built and had a height of over 200 m. Three years later, the Mitsui building with a height of 220 m and 55 floors was erected. The highest skyscraper of the first generation was built in 1978 and was the Sunshine building in Ikebukuro. It was the tallest building in Japan until 1992. In 1993, The Yokohama Landmark Tower was built in Yokohama City with a record height of 296,3 m and 73 floors.

At the beginning of the 21st century, for the first time in history, a significant number of foreign architects with extensive experience in designing of high-rise buildings were invited to cooperate with local architectural studios. Among their projects are examples of tall buildings that set precedents for future development especially in Tokyo . Atago Hill Mori Tower and Forest Mori Tower designed by Cesar Pelli were erected in the Roppongi district in 2001. The corporate center developed by Minoru Mori Roppongi Hills was designed by the New York architectural studio Kohn Pedersen Associates in 2003. In 2007, Tokyo Midtown Tower, designed by Skidmore, Owings and Merrill, was opened.

Since 2014, the tallest building in Japan, Abeno Harukas, has been located in Osaka with a high of 300 m and 60 floors. An interesting example of high-rise building to solve the problem of the still growing number of inhabitants is the project Next Tokyo 2045. The central building of this project is the 1600 m Sky Mile Tower, designed by Kohn Pedersen Associates and Leslie E. Robertson Associates, Fig. 4. The skyscraper will be located on a man-made island near the coast of the Tokyo Bay (Fig. 5). The main challenge for the designers was to protect the building against the threat caused by the occurrence of typhoons and earthquakes. The project used a solution in which sea waves that are dangerous to the construction would be broken up by hexagonal objects arranged around the Sky Mile Tower.

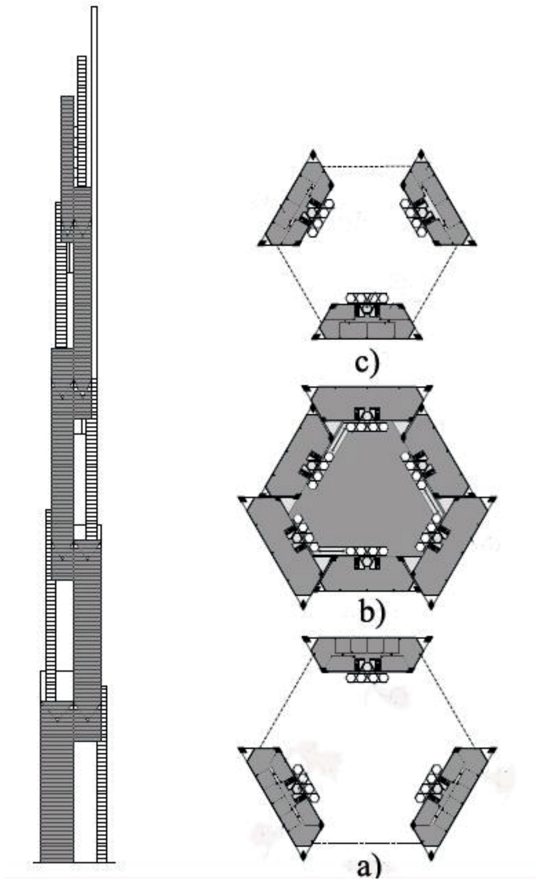

Fig. 4. Sky Mile Tower: floor plans (a) 1-35 floors; b) 36-40 floors; c) 41-75 floors) and section, developed by authors [3]

Currently, Japan is one of the most advanced countries in terms of development of steel structures. This development is a consequence of evolution between research into steel materials and the standard requirements for building structures. Every year, about 25 million tons of steel is consumed in construction, which is 2.5 times more expensive than in the US [4]. As statistics show, about 30% of Japanese buildings (in terms of total area) have a steel structure what results in the share of steel structures in Japan being much higher than in other countries.

Despite the unfavorable geographical location associated with the occurrence of frequent earthquakes, Japan can boast of having such building structures as: Akashi Kaiyko bridge (one of the longest suspension bridges in the world, with longest span of 1991 m, 1998), The Tokyo Skytree (the highest free-standing tower, 634 m, 2012) and skyscraper Abeno Harukas (the highest skyscraper in Japan, 300 m, 2014).

Undoubtedly, the factor that influenced the creation of these structures was the improvement of the efficiency of steel materials, which favored their development. TMCP technology was used to obtain high-strength steel. This technology is a combination of "controlled rolling", which favors the refining of the microstructure by introducing dislocation in the high temperature range and "accelerated cooling", which realizes the quenching effect while suppressing grain growth. With that limited carbon technology high-performance steel materials with excellent weldability and efficiency can be produced.

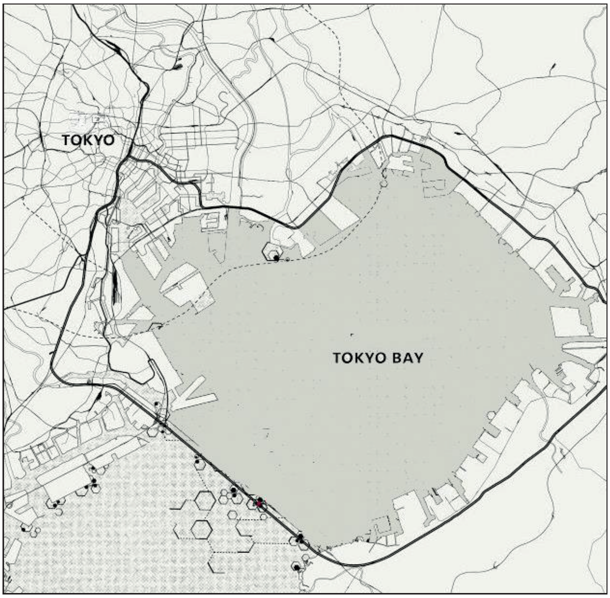

Fig. 5. Site plan of Next Tokyo 2045 [5]

The use of high-strength steel in high-rise buildings was a consequence of their earlier use in bridge constructions. The steel of tensile strength 600 N/mm^2 class was used in Yokohama Land Mark Tower in 1993, and steel of tensile strength 800 N/mm^2 class in Kokura Station in 1998 and Tokyo Skytree in 2012. On the other hand, around 1990, in addition to the tendency to increase the strength of steel, there was a demand for steels with a low yield stress (yield strength 100 N/mm^2 class and yield strength 225 N/mm^2 class), which began to be used for the construction of vibration dampers. Because the plastic deformability of high strength steel is lower than for conventional steels, the performance of entire building is realized by a combined use of dampers.

At present, steel with a tensile strength of over 1200 N/mm^2 is available. This high strength was achieved by the development of a dual-phase steel (DP steel), which has a structure composed of hard and soft material and TRIP steel, in which the plasticity effect of unstable austenite is caused by the martensitic transformation.

3. Vibration damping systems used in high-rise buildings in Japan

Buildings in Japan are designed in such a way that they are resistant to seismic activity. An essential aspect of designing tall buildings is their dynamic reaction to earthquakes and counteracting wind vortices. A stiffer building can be achieved with a proper selection of the structural configuration. Tubes, diagrids, and core-supported outrigger structures could be considered more optimal solutions than others. Moreover, high buildings are sensitive to wind-induced vibrations, and the impact of such vibrations becomes dominant for buildings higher than 200 m. Apart from sway movements, wind has a significant impact on the building when the frequency of vortex shedding approaches the frequency of its vibration. If the vortices induce vibration of the building equal to its resonant frequency, they can generate a great force and cause a disaster. In this case, designers are creating aerodynamic shapes of buildings or very diverse façades, which prevents the overlapping of vortices. Tall buildings shape modifications were widely described in [6]. Various aerodynamic modifications of the structure of a building can be divided into the following groups:

- a cone-shaped cross-section and a shift back in the building line,
- the façade derived from micro-design features, which interweave structural elements, such as bay windows and balconies into one continuous line,
- a funnel shape and extended spirals upwards and outwards,
- modification of corners.

According to Japanese standards, the following three mean wind speeds are considered when analyzing the wind impact, averaged over 10 minutes with return period of 1 year, 100 years and 500 years. Fulfilling the last case ensures that the building's response is almost completely elastic.

While the strength of building materials, such as steel, has doubled in the last few decades, its stiffness has not increased significantly. This has led to an elastic-based approach to design in which lateral deflections and accelerations are the dominant structural constraints for tall buildings. Vibrations can be partially damped by the structure itself. Increasing the stability of the structure causes an increase in the natural frequency. According to the numerical simulation of the construction response to wind, if the natural frequency is greater, the maximum acceleration decreases approximately in proportion to half of the natural frequency.

The light steel structure used in high-rise buildings has low natural damping or natural dissipation of energy and is sensitive to dangerous accelerations in conditions close to resonance. The dynamic reinforcement of load conditions can be reduced by redistributing stiffness in order to avoid resonance, or by the implementation of a damping system in the building. The need for motion control has led to the development of various methods and devices for dissipating energy. Damping devices can be passive, which do not require additional energy supply, or active, which suppress the reaction with input energy, usually through the use of actuators [7]. Passive systems have fixed properties while active systems change their properties based on the load demand and require an external energy source to be activated. Therefore, while more efficient, active systems are less common due to economic and reliability constraints.

Passive damping systems are divided into three categories: hysteretic dampers, viscous dampers, and mass dampers (Fig. 6).

Hysteretic damping uses steel and steel joint dampers (respectively SD, SJD), as well as viscoelastic dampers (VED), lead dampers (LD) and friction dampers, which are used to reinforce material interactions at the FD connections. Steel vibration absorbers dissipate energy through cyclic inelastic deformation of materials. These damping systems are often designed in the form of a triangular plate or are X-shaped. Due to this shape, plastic deformations appear in a much larger area, which leads to a more efficient dissipation of energy. This system was used in the Ohjiseishi Building in Tokyo (1991), Art Hotels Sapporo in Sapporo (1996), and Kobe Fashion Plaza in Kobe (1997).

In friction dampers, energy dissipation occurs as a result of friction between two solids moving in relation to each other. There are two types of friction dampers used in steel framed buildings: rigid frame friction dampers and braced frame friction dampers. For example, friction dampers were used in the Sonic City Office Tower in Ohmiya (1988) and Asahi Beer Tower in Tokyo (1989).

Viscous dampers (VD) and oleo-dynamic dampers (OD) use viscous materials in which the resistance force acting on the body moving in the material is proportional to the speed of the body. In this case, high viscosity chemicals such as silicone oil are used. The thermal effect is also significant. VD are particularly effective in the high frequency range and low vibration levels against moderate earthquakes and strong winds. This type of damper, consisting of steel plates is installed as a part of a diagonal brace, where it can dissipate vibrational energy by the shearing action of VE material.

Viscoelastic dampers were used in the TV-Shizuoka Media City buildings in Tokyo (1967) and the Torishima Riverside Hill Tower in Osaka (1999) to counteract the vibrations caused by extremely large earthquakes.

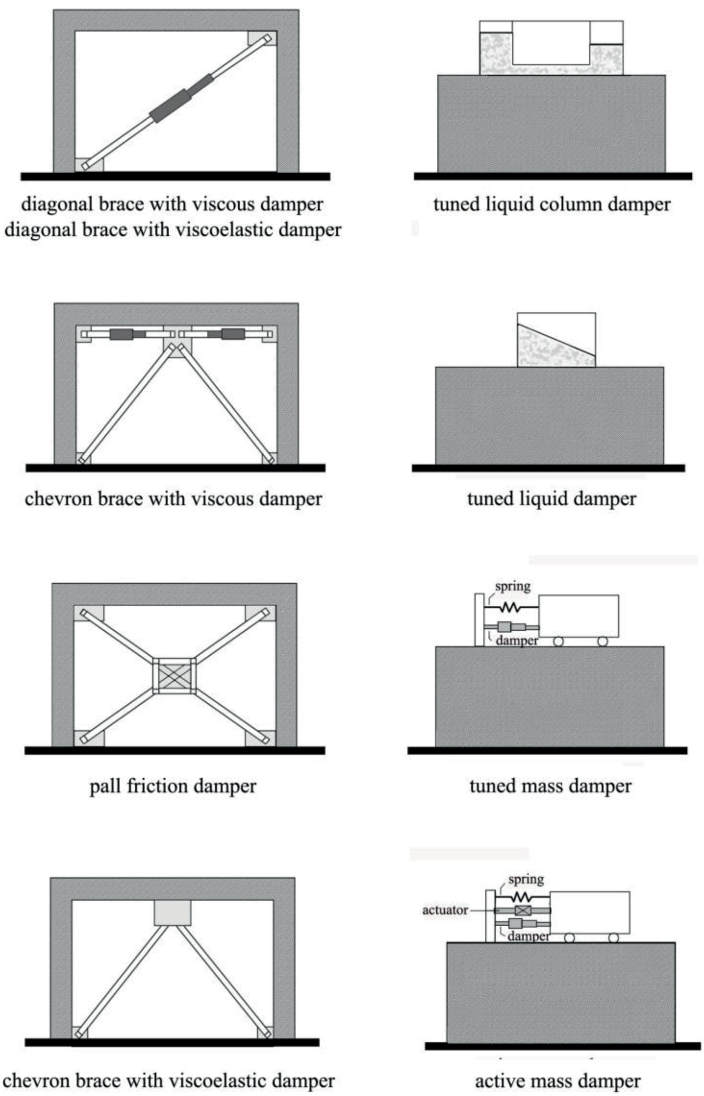

Fig. 6. Vibration damping systems (figure by authors)

When these devices do not provide sufficient energy dissipation, significant damping can be added to the structure through the use of tuned mass dampers (TMD) [8]. A TMD is an additional mass, usually in the order of 2-5% of the total weight of the building, which is attached to the structure by means of springs and dashpots. The inertia force of the mass is damping the reaction of the building. However, TMDs are mostly effective only when they are excited by the resonant frequency for which they have been designed. Sometimes, spacing limitations do not permit traditional TMD system, requiring the installation of alternative configurations including pendulums, hydrostatic bearings and laminated rubber bearings. A TMD damper was used in Fukuoka Tower in Fukuoka (1989), Higashimyama Sky Tower in Nagoya (1989) and Huis Ten Bosch Domtoren in Nagasaki (1992).

Another type of mass damping system is tuned liquid dampers (TLD). This damping system uses the movement of liquids in special containers to absorb the energy of building vibrations. TLD vibration frequency can be controlled by the water depth and the size of the container. TLDs are preferred because of their simplicity, low maintenance price and the possibility of including water for emergency fire protection. The TLCD system was used in the Rokko-Island P & G Building in Kobe (1992), Crystal Tower in Osaka (1992), and Sea Hawk Hotel & Resort in Fukuoka (1998).

In recent years, hybrid dampers have appeared, which are a combination of a mass damper with an additional active element, which aims to improve the efficiency of passive damping. The forces from the active actuator increase the effectiveness of the mass damper and are very effective in the event of changes in the dynamic characteristics of a structure. The active portion of the system is only used under excitation of a high-rise building, otherwise, it behaves passively. The hybrid system was used in the Landmark Tower building in Yokohama (1993), the Ando Nishikicho building in Tokyo (1993) and in Osaka World Trade Center in Osaka (1994).

4. Architectural and structural description of selected high-rise buildings

In this paper the most notable Japan's high-rise buildings located in Tokyo, Osaka and Nagoya were selected for structural and architectural analysis (Fig. 2).

4.1. Abeno Harukas (Osaka, 2014)

Abeno Harukas is a multi-functional skyscraper with a steel structure. This skyscraper is located in Abeno ward on the west side of the Osaka Abenobashi Station [9]. The building is 300 m high and contains 60 floors above-ground level and 5 floors underground (Fig. 7). It is the tallest building in Japan and the third tallest construction following Tokyo Skytree and Tokyo Tower. The skyscraper design was made by the architectural studio Takenaka Corporation. The superstructure is composed of three blocks having setbacks on the north side. The lower block is for the Kintetsu Department Store with Kintetsu Railway platform on the second floor, the middle one for offices and an Art Museum on the 16th floor and the upper one for a hotel with an observation deck which occupies floors 58-60. The upper block has a large atrium in the center.

The building's planes are 71 m x 80 m on the basemen and low-rise floors, 71 m x 59 m on the mid-rise floors and 71 m x 29 m on the high-rise floors. The foundation of the building is a piled raft foundation which consists of a raft foundation with its bottom depth of 30.5 m below the ground surface and cast-in-place concrete piles embedded in a very dense gravel layer below a depth of 70 m.

Fig. 7. Abeno Harukas (photographs by authors)

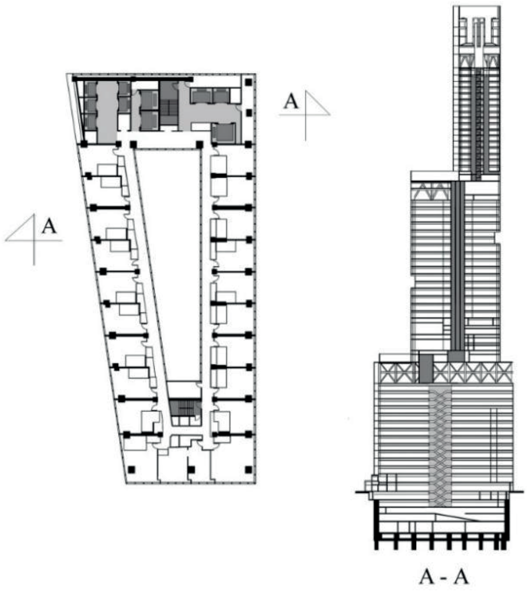

Fig. 8. Abeno Harukas: floor plan of the 53 and section, developed by authors [9]

Abeno Harukas has an outrigger structure (Fig. 8). This system connects through truss floors to the steel core, using steel plate walls and braces, with the peripheral frame made of steel concrete-filled tubes. Located between the blocks and at the top of the upper one are transfer truss floors. In order to enhance horizontal and torsional rigidity against strong earth-quakes and wind excitation, outrigger mega-trusses are placed in the transfer floors and in the middle block. In order to counteract adverse effects there were used four types of dampers, both viscous and hysteresistic which were placed at four corners in the lower block around the central core, in the middle block and around the atrium in the upper block. In addition two kinds of mass dampers (active mass damper - MD and active tuned mass damper ATMD) are installed on the 56th floor.

4.2. Osaka World Trade Center (Osaka, 1995)

Osaka World Trade Center is an office high-rise building with steel structures. The WTC Cosmo Tower is located near the bay area of Osaka. It is a part of an extensive new urban center built on artificial island in Osaka Bay known as Sakishima. The WTC is a major landmark in Cosmo Square. The skyscraper design was made by Nikken Sekkei [10].

The building is 256 m heigh and contains 55 floors above-ground and 3 floors underground (Fig. 9). At the base it widens out in a triangular shape. The low-rise wing includes five storeys high atrium with super-truss structure. The tower houses public space, an auditorium, business support centres and office space (7th to 44th floors). The upper floors house a World Trade Center Museum (45th floor), sky restaurants, Cosmo Hall, and other functional components. The building is capped by the distinctive inverted pyramid where on the 55th floor at a height 252 is located an observation deck.

The WTC tower is designed on a rectangular plan with a central communication shaft (Fig. 10). The underground part of the building is a steel-encased reinforced concrete structure. A firm 13-m-thick diluvial clay layer covers the entire area below 63 m. The pilings were designed to support the building from this layer. Steel tubes with belied bottom sections and filled with cast-in-place concrete were used. Above ground the tower is constructed of structural steel frames assembled from box-section elements. On the short side of the structure there are two external bracing frames and eight rigid internal frames. From the seventh story downward, a super truss was formed by spreading the external and internal columns outward. The footprint of the building was doubled to stabilize the structure against earthquakes and wind action. In the building have been installed two tuned mass dampers to reduce swaying. A 50 t pendulum was installed in opposite corners of the roof, reducing the response acceleration of the building by approximately 50%.

Fig. 9. Osaka World Trade Center (photographs by authors)

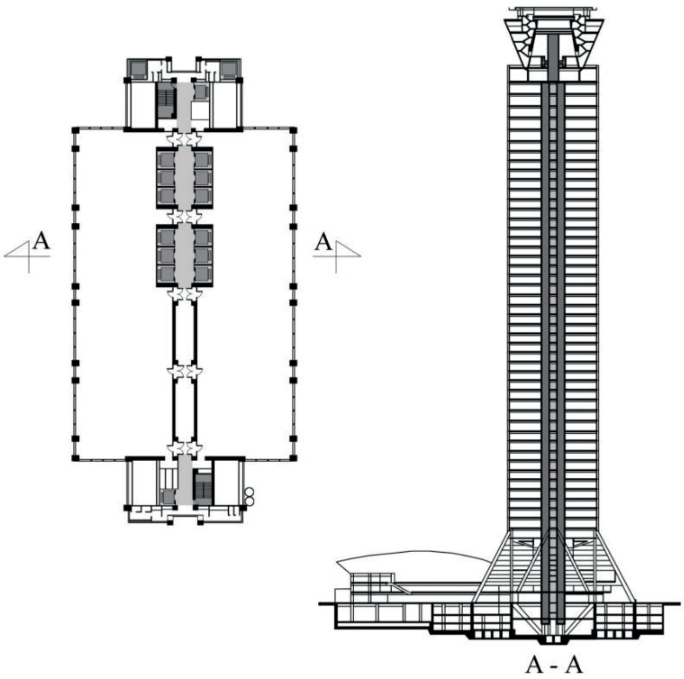

Fig. 10. Osaka World Trade Center: floor plan and section, developed by authors [10]

4.3 Midtown Tower (Tokyo, 2007)

Midtown Tower is a multi-functional skyscraper, the tallest of six buildings in the new Tokyo Midtown urban complex [11]. With the transfer of the headquarters of the Japan Defense Agency to the Ichigaya district, a great project to rebuild the area located in the center of Tokyo, containing an extensive range of greenery with the Hinokicho park, has begun. The project of the skyscraper was made by the architectural studios Nikken Sekkei and Skidmore, and Owings & Merrill.

The building is 248 m tall and contains 54 floors above-ground level and four underground floors (Fig. 11). The Midtown tower is designed on a rectangular plan with a central communication shaft. In the underground part of the building there is a car park, while above-ground there is a shopping center (floors 1-3, conference center (4th floor), Tokyo Midtown Design Hube gallery and design office (floor 5), Medical Center (6th floor), commercial offices (floors 7-44), and the Ritz-Carlton hotel (floors 45-53)). Unlike similar skyscrapers in the area, such as the Roppongi Hills Mori Tower, the top of the 54th floor of the Midtown Tower does not have an observation deck for visitors. Instead, the floor is occupied by a machine room.

Three buildings in the Midtown Tower complex are located on a massive foundation slab with a length of 230 m on each side. The main load-bearing structure of the tower consists of steel frames, steel columns filled with concrete and an internal frame core (Fig. 12). Midtown tower sits on rubber pads. This is a system known as base isolation, where the building is separated from the ground by a layer of rubber or ball-bearings. In order to counteract seismic impacts, buckling stabilizers and viscous oil dampers were used.

Fig. 11. Midtown Tower (photographs by authors)

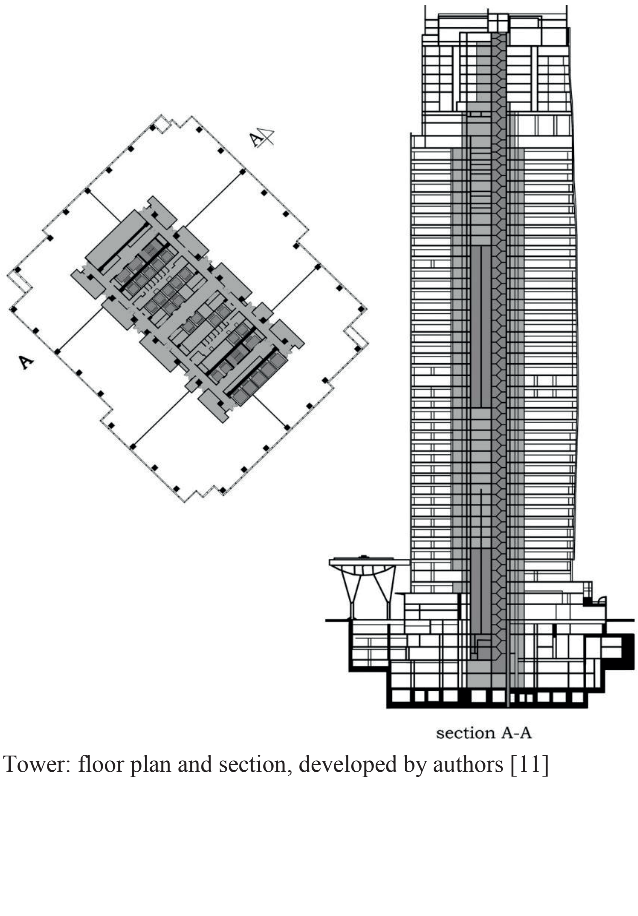

Fig. 12. Midtown Tower: floor plan and section, developed by authors [11]

4.4. Toranomon Hills (Tokyo, 2014)

Toranomon Hills Mori Tower is a multi-functional skyscraper with a steel and reinforced concrete structure designed in the Toranomon Hills complex, the creator of which, as with Roppongi Hills, was Minoru Mori.

The building is 247 m high and contains 52 floors above-ground level and 5 underground floors (Fig. 13). The building was designed, by the architectural studio Nikhen Sekkei, on an elongated hexagon plan with two rounded opposite corners and with a central communication shaft on a rectangular plan. In the underground part there is a car park, on floors 1-3 commercial buildings, floors 4-5 occupy a conference center, floors 6-35 are intended for offices, floor 36 includes a spatial truss structure, floors 37 to 46 occupy the living spaces, and the hotel Andaz occupies the above floors. The skyscraper was designed around the new communication Loop Road 2 connecting Toranomon and Shimbashi as part of the loop around Tokyo. The Loop Road 2 that runs underground connects the eastern side of the building (Fig. 14) with a tunnel at the second underground level [12]. The road runs through a tunnel structure, which was built independently of the building's structure. In order to avoid the impact of road traffic vibrations on the building, the building's structure is isolated from the running structure by the introduction of material damping vibrations. Noise is reduced with the use of a Sylomer mat (polyurethane elastomer).

Fig. 13. Toranomon Hills (photographs by authors)

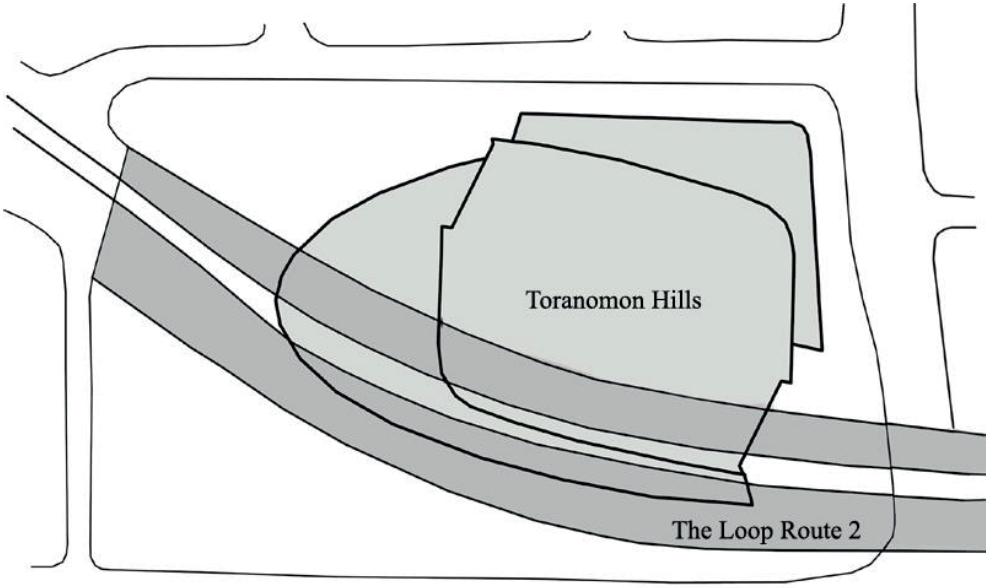

Fig 14. Toranomon Hills: Site Plan, developed by authors [12]

The skyscraper has a raft foundation that cooperates with reinforced concrete piles. The spread foundation of Toranomon Hills is built directly into solid ground called Tokyo Layer. The main load-bearing structure of the above-ground part of the building is a steel frame structure with steel columns filled with concrete and a central reinforced concrete core (Fig. 15). The underground part has a mixed construction consisting of steel and reinforced concrete frames. The podium construction on the Loop Road tunnel consists of prefabricated reinforced concrete slabs with a thickness of 1 m. In the corners of the part of the building that has sharp angles, which are located in the north-west, south-east and south directions on floors 8 to 13, there is a system of inclined two columns, which intersect and pass into one column on the floors below. In the locations of this passage, there is a steel connection with a weight of 20 tons, which allows the load to be transferred from two columns to one. Due to the change of the structural layout in the sector above the 35th floor and the introduction of columns at a distance of 9 m from the outer edge of the building, on the 36th floor, a spatial truss with a height of 1 m was used (Figure 16). The crowning of the skyscraper is a steel structure inclined towards the east-west in the shape of shifted pyramids. In order to transfer forces from the roof to the building, two Keel trusses were used. The longest diagonal roof element has a length of 30 m and is covered with reinforced concrete slabs in order to increase its stiffness in the plane.

The use of a steel mega frame in the construction of the skyscraper effectively counteracts deformations coming from the bending of the entire building. Additionally, viscous oil dampers, buckling stabilizers in the form of diagonal braces and friction dampers as devices controlling shock and vibration reactions were used.

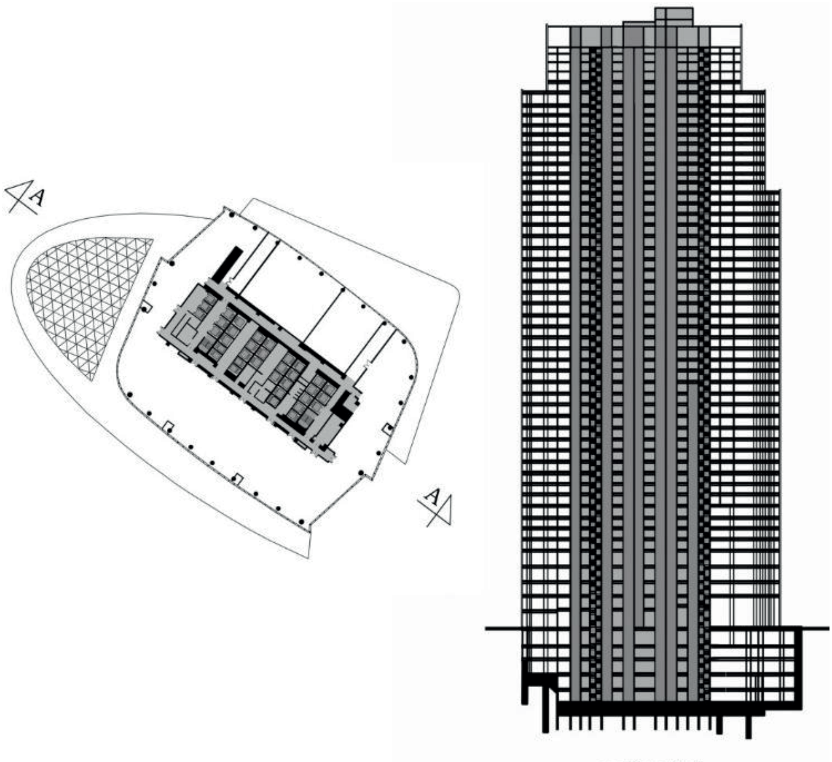

Fig. 15. Toranomon Hills: floor plan and section, developed by authors [12]

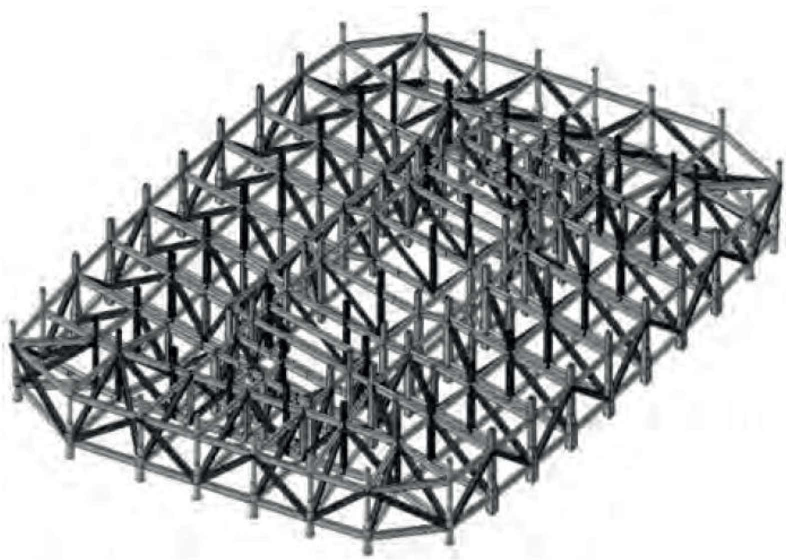

Fig. 16. Toranomon Hills: Structural spatial truss on the 36th floor [12]

4.5. Roppongi Hills Mori Tower (Tokyo, 2003)

Roppongi Hills Mori Tower is a multi-functional skyscraper with a steel and reinforced concrete structure. The structure is the central point in the mega-complex that comprises office buildings, apartments, the Grand Hyatt hotel, the Asahi television studio and an amphitheater. The creator of this complex was the potentate of the building market Minoru Mori, who realized his vision of a global city. It is one of the largest urban complexes in Japan, which has been transformed from small building plots and surrounded by lush greenery that is combined with various urban functions.

Roppongi Hills is 238 m high and contains 54 floors above-ground level and six underground floors (Fig. 17). The building was designed by a team led by Eugen Kohn, William Pedersen and Paul Katz from the architectural studio Kohn Pedersen Fox Architects. The usable area of the skyscraper, when compared to this type of facility, is one of the largest in the world. The building is designed on a concave-convex octagon plan with a central communication shaft on a square plan. On the first six floors, there are shopping facilities and restaurants, floors 7-48 serve as offices of various corporations, and the Mori Art Center is located on floors 49-54. The central element of this center is the Mori Art Museum located on the 53rd floor, which was designed by Gluckman Mayner Architects. The observation terraces were designed on floors 52 and 54. The form of the building was implemented in accordance with traditional Japanese architecture. In the facades, horizontal and diagonal lines have maximized the amount of glass and steel, just like in the folds of a paper origami sculpture.

The skyscraper has a raft foundation that cooperates with reinforced concrete piles. The main load-bearing structure of the building consists of steel frames, steel columns filled with concrete and an internal frame core (Fig. 18). In order to counteract seismic actions, were installed 192 hydraulic oil dampers and braces made of flexible steel with a low yield strength [13], [14].

Fig. 17. Roppongi Hills Mori Tower (photographs by authors)

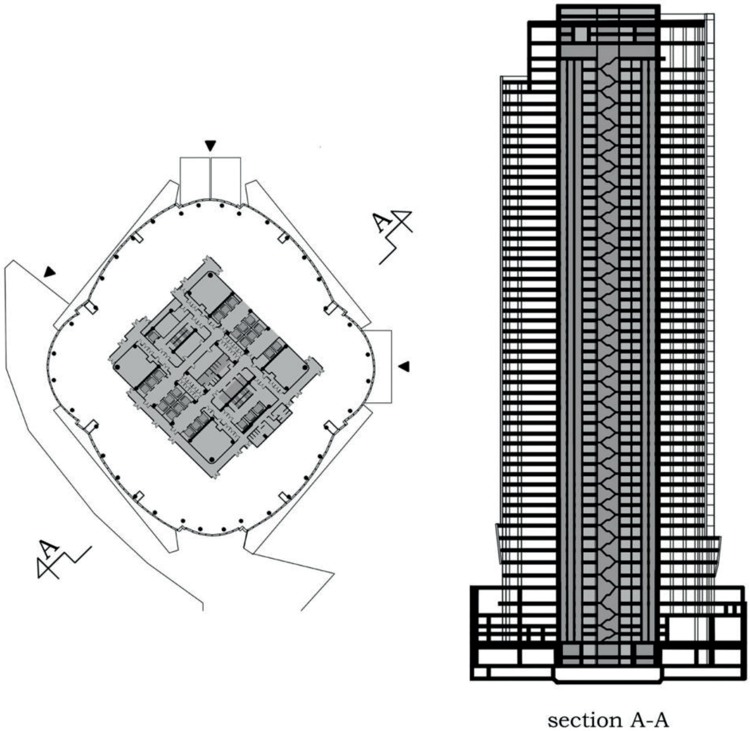

Fig. 18. Roppongi Hills Mori Tower: floor plan and section, developed by authors [13]

4.6. Dentsu Headquaters Building (Tokyo, 2002)

The Dentsu Headquarters Building is an office high-rise building with a steel structure. The building is 213 m high and contains 48 floors above-ground level and 5 floors underground (Fig. 19). The skyscraper design was made by the architectural studio Jean Nouvel. This large complex, located in the center of Tokyo, is mainly used as the headquarters of the largest advertising agency in Japan and one of the largest in the world, Dentsu Inc. The skyscraper occupies the area of the old railway line, near the Tokyo station, and is part of the extensive reconstruction of this area. In order to ensure functionality and an original appearance that corresponds to the beginning of the 21st century, three aspects were considered during the design and subsequent implementation of the building: 100 years of operation, symbiosis with the environment and energy saving. In accordance with the urban plan for SIO-SITE (a comprehensive urban development project), the Dentsu building not only provides office space, but also attractive amenities for visitors that integrate commercial and cultural facilities. In the building is located a restaurant, cafe, theater, library, museum and specialist stores. In order to realize the main concept of "100 years of usability", the design aimed for a highly functional, very durable building that would ensure safety from wind and seismic forces.

The building is designed on a triangular plan with an internal atrium and is approximately 120 m long on its longer side and 41 m on its shorter side (Fig. 20). The communication part was located along the north façade and in the central part parallel to the obtuse sides of triangle.

The height / width ratio is 5 for the shorter side and 1.7 for the longer side, which classifies this building into that of a slender profile. The interior of the building is a massive steel structure with a series of atriums that are characterized by curvature and extensive surfaces [15]. Atriums are located on the north side, while its main façade is oriented from the south. The tower is divided into ten floors, showing the location of various companies. Vertical movement is implemented by panoramic public and office elevators. The elevator battery runs through the entire building, but only reaches the level of the passage. These transition zones determine the main levels of the various atriums. The levels have their own set of elevators for the ten floors occupied by each sector. The façade of the building is fully covered with ceramic printed glass, which not only emphasizes the landscape, but also significantly reduces air-conditioning loads and saves energy. In addition, the light that diffuses and passes through the ceramic printed glass helps daylight to be used with less glare. From the south side, in the façade, ceramic glass with 12 shades from white to gray is used, which creates a very diverse view.

The key element of the design of the structure was to determine the method of deformation control in the transverse direction, where bending is greatest. The main load-bearing structure of the building is a steel mega-frame. These frames are resistant to seismic vibrations and use two types of vibration dampers that are installed in the upper part of the building, controlling lateral and bending deformation (2 Tuned Mass Dampers with Active Mass Damper - total weight equal 440 ton). For the asymmetric configuration of the building, a steel shell filled with concrete with a strength of 80 MPa was used. In the atrium for the frame construction, fire-resistant steel with a maximum thickness of 80 mm was used. The foundations of the skyscraper were built on granite rock, which was also exposed in the interior of a six-storey space with stone walls and waterfalls.

The Dentsu skyscraper was designed based on the concept of coexistence with the global environment in which energy saving was a priority. In particular, the focus was on using natural energy and increasing energy efficiency resources. The building has at least 35 major architectural and hardware innovations that have effectively contributed to increased energy efficiency and reduced CO_2 emissions. At the time of completion, the building was about 30% more efficient than conventional constructions of the same scale.

Fig. 19. Dentsu Tower (photographs by authors)

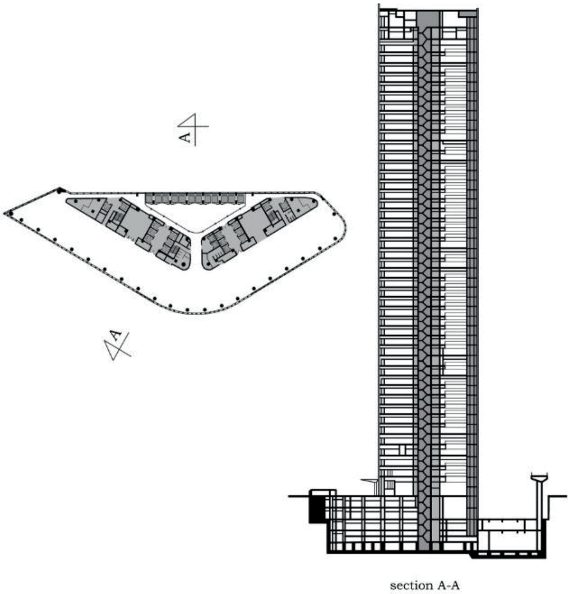

Fig. 20. Dentsu Tower: floor plan and section, developed by authors [15]

4.7. Mode Gakuen Cocoon Tower (Tokyo, 2008)

Mode Gakuen Cocoon Tower is an educational high-rise building with a steel and reinforced concrete structure. The building is 203.7 m high and contains 50 floors above-ground level and four underground floors (Fig. 21). The building design was made by the architectural studio Tange Associates. 50 renowned architectural studios participated in the competition for its design and over 150 proposals were submitted. Mode Gakuen Cocoon Tower is an innovative educational center where three educational institutions are operated: Professional Fashion School (Tokyo Mode Gakuen), Special College of Technology and Design (HAL Tokyo) and Higher Medical School (College Shuto Iko). In terms of the height of the building, it is the world's second tallest educational building after the Moscow State University (239 m), and holds about 10,000 students. It is located between the most frequented Tokyo train station Shinjuki and the central business district.

The Mode Gakuen Cocoon Tower is designed on a circle plan, with a central communication shaft on a hexagon plan and three extended arms form three axes between which classrooms were arranged on a rectangular plan [16]. These three rectangles are rotated by an angle of 120 degrees in relation to the core (Fig. 22).

Each class has a width of 24 m. The depth of the classrooms varies with height, because the vertical section is an elliptical curve. From the 1st to 50th floor, the class rooms are arranged in a curved form. The internal core in the building consists of staircases and elevator shafts. The spaces between the classrooms are student rooms and are directed in three directions: east, south-west and north-west. Each of these rooms have a three-story atrium with a view of the surrounding landscape. The building has a sectional façade with a dotted print, creating intersecting stripes in various angles. Composite elements were applied to the façade in the form of fluted strips coinciding with the diagrid structure in classrooms.

A lower building with a height of 30 m, which houses two large auditoria and retail outlets, is adjacent to the high-rise building. Both buildings have the same four-story underground structure, which is used as a car park and retail space. The main entrances were placed from the north and south side in the vestibule connecting the high-rise building with a ball-shaped building.

The Mode Gakuen Cocoon Tower has a raft foundation with a thickness of 3.8 m that cooperates with reinforced concrete piles. The main load-bearing structure of the tower consists of three peripheral elliptical diagrid frames and an internal frame core. The building has relatively high shear deformations in the middle floors due to the bending of each frame. Because the three frames are rigidly connected to the base and the upper part of the construction, the structure can be treated as a portal frame. The perimeter frames have a width of 24 m, with intersections of 4 m at each floor level, and are curved vertically in the shape of an ellipse. Their task is to transfer transverse forces and overturn moments from the action of wind and seismic effects. In addition, to reduce these impacts on each floor from 15 to 39, 6 viscoelastic dampers were used.

The height of each floor is adapted to the elliptical curve, which allows the diagrid elements to cross at the same angle on each floor. The floor beams in the classrooms are the load-bearing element for the storey and connect in a horizontal diagrid frame and the inner core, preventing the buckling of these frames from out of the plane. In the student rooms located in a three-story atrium, the glazing of the façade is three storeys high with a maximum width of 20 m. Vierendele double arched trusses were used to transfer the weight of the façade glass and counteract wind action. Vierendeel trusses are suspended on beams located above, so that no structural element would obstruct the view on any storey. Unlike many other tall buildings in Tokyo, the Gakuen Cocoon Tower does not have a flat roof. This is very important due to the fact that the cleaning system and the provision of space for helicopters is an essential requirement for a high building in Japan. Therefore, in order to fulfill these conditions, a sliding roof was used. A gondola hanger with a cleaning system is installed under a floating roof and moves on "Y" shaped rails with a rotating table in the middle. The hanger is able to provide the gondola to the entire outer surface of the building by extending and turning the arm at each end of the rails. The Mode Gakuen Cocoon Tower has a cogeneration system that generates 40% of energy, which increases the operational efficiency of the building, as well as reducing energy costs and greenhouse gas emissions. The elliptical shape allows for even distribution of sunlight and the aero-dynamic scattering of strong wind streams.

Fig. 21. Mode Gakuen Cocoon Tower (photographs by authors)

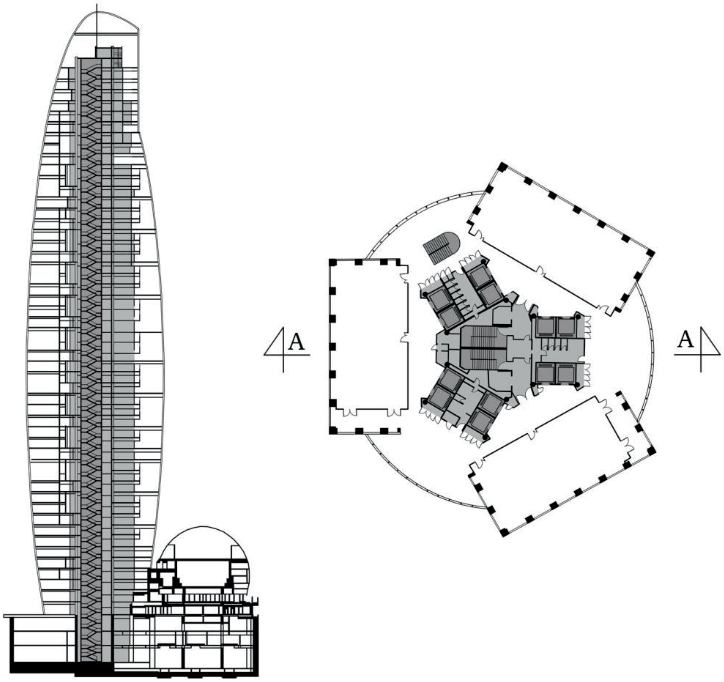

Fig. 22. Mode Gakuen Cocoon Tower: plan and section, developed by authors [16]

4.8. Mode Gakuen Spiral Towers (Nagoya)

Mode Gakuen Spiral Towers is educational high-rise building with steel structure. The building is 170 m and contains 38 floors above and 3 below ground level (Fig. 23). The building was designed by Nikken Sekkei studio. Mode Gakuen Spiral Towers is located on a busy main street of Nagoya City in front of Nagoya Station. The building houses three vocational schools; Mode-Gakuen for fashion, HAL for information technology and design, and ISEN for medicine and welfare. The building is built on an elliptical plan with three niches with a central core in the ellipse form (Fig. 24). The project consists of three spiral wings that are, radially arranged in relation to each other [17]. The entrance to the building is located at ground level. The central element of the facade has horizontal divisions accentuated with balconies and vertical ones with rectangular windows. The outer surface is made of a steel diagrid with triangular windows. The facade is distinguished by triangular windows and horizontal balcony lines.

The planar configuration of each floor changes with the height. 12 straight columns are arranged around the oval core and braces are connected to these columns in a mesh network that forms an inner truss tube. The truss tube is made of concrete-filled steel tubular columns with constructional braces fixed around the base. The columns act as a central pillar supporting the three slightly tapering wings of the building. This tubular structure is very strong and rigid with regard to the horizontal and twisting forces that are generated by earthquakes and high winds. In this type of tower building, there are considerable bending deformations and a high level of axial forces affecting the outer columns, which results in greater deformation in the upper part of the building. The construction of the building in the form of an inner truss tube and two vibration damping systems ensure high resistance to seismic actions. The towers are integrated with mass damper systems, expanding columns and active mass dampers. Vibration – damping columns efficiently absorb seismic energy by means of viscosity dampers, which are installed at 26 points on the periphery. There is also a mass damper located on the rooftop. Double-glazed windows and airflow windows are used to reduce heat loads around the perimeter zone. The foundations combine a thick raft slab and cast concrete piles.

Fig. 23. Mode Gakuen Spiral Towers (photographs by authors)

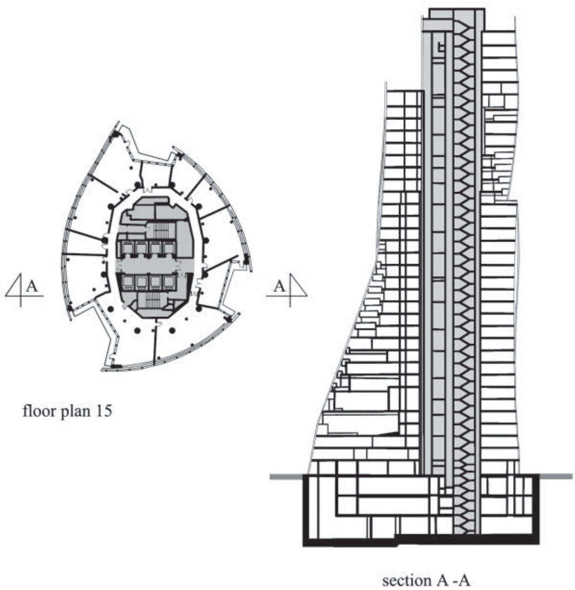

Fig. 24. Mode Gakuen Spiral Towers: floor plan and section, developed by authors [17]

5. Conclusions

Due to seismic activity, Japan is a country with very difficult conditions to build, especially high-rise buildings. Historically, traditional construction was characterized by light wooden constructions, usually skeletal and insensitive to slight deformation, with brick buildings being less frequent. Houses consisted of practically one fixed wall, in which there was a recess called takomona, used for storing paintings and works of art. The other walls were made of a lightweight wooden lattice, covered with paper soaked in oil. Characteristic buildings of Japanese architecture were tall and slender pagodas, in which the structure is loaded from above with a massive wooden stake to ensure stability.

Earthquake-proof properties of Japanese timber pagodas have been scientifically studied for a century by researchers to interpret why they have not collapsed during strong earthquakes. The main pile with several roofs and the friction connections between them are working as natural dampers. Damping condition due not only friction at bracket complexes and the other joints but also dissipation energy into ground would be effective in reduction of response to ground motions [18]. Japanese architecture is characterized by asymmetry which is related to commitment to nature. Houses were often built in mountainous areas, on forested slopes. Currently in Japan, we can find many buildings with symmetrical shapes which is related to the influx of Chinese Buddhism and the influence of the Western culture. Traditional residential buildings are being replaced by multi-storey buildings with a higher communication shaft. The contemporary architecture of Japan is also eclecticism, which is characterized by the freedom to mix styles, combining the features of high-tech, deconstructionism, minimalism and metabolism.

Undoubtedly, the least-resistant construction for an earthquake is a skyscraper, which is a certain paradox in comparison with their number in Japan, and especially in Tokyo, which in this respect has the fourth most in the world. Since the Kobe earthquake in 1995, Japan has become a world leader in building new buildings, as well as modernizing old ones so that they can withstand rapid seismic quakes. The high-rise earthquake-proof buildings in Japan are very often constructed using modern "tube" and "tube in tube" systems using the latest high-strength structures, for example, steel columns filled with concrete.

The most modern skyscrapers in Tokyo are able to withstand earthquakes of over seven degrees on the Richter scale. Of course, more forces affect a building with a larger earthquake, and its construction therefore experiences larger displacements. A building's response to earthquakes are vibrations in the form of sinusoidal motion. In order to counteract both these forces and the impact of wind, apart from a rigid construction, very advanced technologies of damping devices are used. For example, the foundations of these buildings (Maison Hermes Tokyo) are mounted with a system of spring or elastomer vibration dampers, due to which tectonic movements affect the upper part of the building to a lesser extent. In addition, as presented by the characteristics of high-rise buildings, viscous oil dampers (Mode Gakuen Cocoon), anti-buckling steel stabilizers (Midtown Tower, Roppongi Hills, Kabukiza Tower) and tuned mass dampers (Tokyo Tree Tower) are used at various levels of these buildings. When using all these supporting elements, it is most important that the location of the center of gravity of the building does not change during earthquakes. The main load-bearing structure of the presented skyscrapers are steel mega-frames with steel columns filled with concrete and an internal frame core.

References

[1] www.skyscrapercenter.com/city. [Accessed: 21 Apr 2019].

[2] Perez R. "The Historical Development of the Tokyo Skyline: Timeline and Morphology". Journal of Asian Architecture and Building Engineering, September 2014, pp. 609-615. https://doi.org/10.3130/jaabe.13.609

[3] Malott D., Robertson L., Hiei K., Werner H. „Next Tokyo 2045: A Mile-High Tower Rooted in Intersecting Ecologies". CTBUH Journal, Issue II, 2015, pp. 30-35.

[4] Tsuji M., Kanno R. "Advances in Steel Structures and Steel Materials in Japan". Nippon Steel & Sumitomo Metal Technical Report, no. 113, December 2016, pp. 3-12.

[5] Arch20 – Next Tokyo 2045. Available online: https://www.arch2o.com/next-tokyo-2045-kpf/arch2o-next-tokyo-2045-01/ [Accessed: 16 Sept 2019].

[6] Kareem A., Spence J., Bernardini E., Bobby S., Wei D. "Using computational fluid dynamics to optimize tall building design". CTBUHJ, Issue III, 2013, pp. 38-42.

[7] Kawecki J., Masłowski R. "Zastosowanie tłumików pasywnych quasi-aktywnych i hybrydowych do redukcji drgań sejsmicznych i parasejsmicznych budowli – przegląd rozwiązań" (in Polish). Czasopismo Techniczne, zeszyt 11, 2010, pp. 59-67.

[8] Kareem A., Kijewski T., Tamura Y."Mitigation of Motions of Tall Buildings with Specific Examples of Recent Applications", 1999, p. 104.

[9] Harada T., Yonezu M."Forging a Supertall Compact City". International Journal on Tall Buildings and Urban Habitat, Issue II, 2015, pp. 12-20.

[10] Hanaima A., Hirano T., Tohki H. "Osaka World Trade Center". Structural Engineering International, vol. 8,1998, Issue 1, pp. 28-29.

[11] Mitsui Fudosan Co., Ltd. "Homepage of Tokyo Midtown", from Tokyo Midtown Website: http://www.tokyo-midtown.com/en/midtown.html. [Accesed: 21 Aug 2018].

[12] Hitomi Y., Takahashi H., Karasaki H. "Toranomon Hills – Super High-Rise Building on Urban Highway". International Journal of High-Rise Buildings, vol. 3, no. 3, 2014, pp. 167-171.

[13] Tsuchihashi T., Yasuda M. "Rapid Diagnosis Systems Using Accelerometers in Sejsmic Damage of Tall Buildings". International Journal of High-Rise Buildings, vol. 6, 2017, pp. 207-216. https://doi.org/10.21022/IJHRB.2017.6.3.207

[14] Alexander L. „The Tokyo skyscrapers that can withstand a major earthquake". Available online: https://www.ft.com/content/3efc4da8-c3bd-11e2-aa5b-00144feab7de [Accessed: 16 Sept 2019].

[15] Yamanaka M. "Dentsu Building". Steel Construction Today &Tomorrow, no 17, 2006.

[16] Noritaka P. "Case Study: Mode Gakuen Cocoon Tower". CTBUH Research Paper, Issue 1, 2009, pp. 16-19.

[17] Groesbeck C., DeVries J., Klemencic R., McDonald J. "Tall Buildings in Future Development of Metropolitan Universities". CTBUH Research Paper, 9th World Congress, 2012, pp. 707-714.

[18] Toshikazu H., Chikahiro M., Yasushi N., Kazuhito N., Naohito K., Hideyuki M., Masayuki M. "Seismic and Wind Performance of Five-Storied Pagoda of Timber Heritage Structure". Advanced Materials Research, vols. 133-134, 2010, pp. 79-95. https://doi.org/10.4028/www.scientific.net/AMR.133-134.79

The impact of artistic circles on the way of using and arrangement apartments in multi-family residential buildings in Poland in the 1950s and 1960s
Part I - Development of architectural project ideas

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Abstract: This article (part I) presents the activities of artistic circles - architects - and their impact on the ways of using and arrangement of the living area. The way of using apartment is understood as:

1) The way of arranging basic living functions by inhabitants (sleeping, resting, preparing and eating meals, receiving guests, studying, personal hygiene);

2) The relationships between inhabitants and an apartment dependent on education, occupational structure, origin, life style, inherited cultural patterns, fashion as well as a group of physical characteristics and apartment attributes);

3) The rights of family members to use the apartment space, including the right to intimacy and having own private space, as well as the representative needs.

The aim of this article is to show the evolution of design thinking in the field of functional and spatial layouts of apartments and indicating the main trends of these changes. The selected functional layouts of apartments (including the remarks of the author of the design), representative of the given period of time, have been analyzed with respect to social and political conditions. In summary, the most important tendencies, which may be observed in respect of discussed changes, have been indicated. These include:

- expanding the living-room area of the apartment by designing a kitchen closer to the living-room or even combining a kitchen with a living -room;
- the differentiated approach to the issues of creating sleeping areas due to the understanding of children's individual needs to have their own living space;
- the concern to upgrade the quality of hygiene in an apartment - by creating separate restrooms and designing bathrooms with a space for a washing machine.

Keywords: the use of the apartment, upgrades of modern housing, the factors affecting the use of housing

1. Introduction

Contemporary functional and spatial layouts of apartments in the vast majority present a model of the kitchen open to the living room. Architects try to obtain the most optimal spatial solutions often in very small spaces, and the adopted model of shaping the daytime zone in the apartment aims to provide users with a sense of greater space. The question arises whether the design of the apartments will be based only on the kitchen model in the form of an annex open to the living room and whether the process of developing design thought in this area has been completed. One can trace the evolution of the effects of creative environments (architects), which could lead to contemporary design solutions.

In Poland in the mid-1950s a large-scale campaign to improve the quality of home furnishings began. With the support of the then authorities, it was possible to introduce significant changes in the rather outdated layouts of apartments in typical buildings. It was important that rational furnishing of the apartment gave even in the most humble conditions the opportunity to improve housework and improve the quality of rest. Creative environments - architects, interior and furniture designers, publicists - have focused their efforts on creating a friendly, functional living space, i.e. housing, which would ensure a sense of security and the opportunity to cultivate the values important in organizing life.

The subject of this article is the activities of architects (over the 1950s and 1960s) and its impact on the use and arrangement of living space. A definition of how the apartment is used should be defined, and it is understood as:

- how users organize basic life functions (sleep, rest, preparation and consumption of meals, receiving guests, learning, playing, and hygienic activities);
- relations between users and the apartment depending on:
  - education, professional structure, origin, lifestyle, inherited cultural patterns, fashion;
  - a set of physical features and attributes of the apartment (functional and spatial layout, room structure, surface standard, technical equipment in installations and devices) conditioning the possibilities of meeting the needs of users;
- the rights of family members to use the space of the apartment, including the need for intimacy and to have their own private space and representative needs, including the desire for prestige and acceptance in a given social circle.

The way the apartment is used is influenced by factors independent of the household (political and legal, civilization-related) and dependent factors, such as: family structure, level of education, financial status, occupation, cultural patterns derived from the previous environment, values important in the organization of functions in the apartment, the influence of contemporary designs and fashion.

This article - *Development of architectural project ideas* - is the first part of a broader description of the impact of creative environments on the use and arrangement of housing. The second part shall provide for an analysis of interior design as a result of the work of interior designers, furniture, journalists, and guide authors. The purpose of the article - Part I - is to present the architectural evolution of design thought in the field of shaping functional and spatial layouts of apartments and to indicate the main trends of introduced changes.

Applied methodology:

- query including recognition and analysis:
  - housing related literature;
  - Polish trade magazines;
  - contents of legal acts regarding the design of apartments in multi-family housing;
  - CSO data (statistical yearbooks);
- research into designs of functional and spatial systems characteristic of a given research period against the background of socio-political conditions. The authors' comments - Helena and Szymon Syrkus [1] and Oskar Hansen [2] - about the spatial solutions of the apartments they proposed were also used to describe these phenomena.

2. Socio-cultural conditions of housing construction

In the 1950s and 1960s, there was an almost twofold increase in urban population in Poland - from 8.9 million in 1949 to 17 million in 1970 [3]. The large demographic boom in the 1950s and labor migrations of rural residents to cities contributed to this. The cities became a mixture of the influx population, the first-generation burghers and the "old" middle-class. There was a division of society into the working class and intelligentsia, and the structure of employment was dominated by industrial workers, who constituted as much as 93.5% of the population in cities in 1956. People with higher and secondary education (white-collar workers) constituted only 6.5% in 1956 and 16.1% in 1970 [4], [5].

According to settlement research of the Institute of Housing[1] (Instytut Budownictwa Mieszkaniowego IBM) most of the residents of the new housing estates were young married couples with preschool and school children. About 50% of mothers worked professionally at the time. Nurseries and kindergartens, as well as older women who were not professionally active outside the home provided help in raising children. Often, two generations of married couples lived in one flat: parents and children, parents and their adult children and grandchildren. Equally frequent was the forced sharing of an apartment with another, unrelated family, which took place until the liquidation of forced housing in the late 1950s.

The families of blue-collar and white-collar workers differed in cultural patterns - habits, customs, in general - in the lifestyle. However, the working-class family, like the family of a white-collar worker, increasingly read books and listened to the radio. Young people studied in almost every home. Children from working-class families became white-collar workers in high school and college. "The two »lifestyles« are getting closer and closer together. On the other hand - in relation to the pre-war period - the »lifestyle« of the white collar family has become more simple and strict. The work of women outside the home, with almost complete absence of paid domestic help, at that time put side-by-side the issue of toil with household activities in both a working-class and intellectual families. Therefore, the lifestyle, which has long existed in the environments of hard-working people, is now also transferred to the family of an average-paid white-collar worker [9]".

Aleksander Matejko, referring to research conducted in the years 1950-1956 by the Institute of Housing (IBM) [10] emphasized that the move to new settlements for all studied families was a breakthrough event. Obtaining a new, own apartment after years spent in often difficult housing conditions, after many years of waiting, caused enormous emotional experiences, feelings of joy and enthusiasm. There was readiness not only for the modernization of the household again, but also for wider changes and reorganization of the family and personal life itself [11].

The architects faced the challenge of creating decent housing for thousands of families. Among the designers were excellent artists - to name a few, the members of the pre-war Praesensu: Barbara and Stanisław Brukalski, Bohdan Lachert, Roman Piotrowski, Helena and Szymon Syrkus and Józef Szanajca. Later, others also got involved: Oskar Hansen, Maria and Kazimierz Piechotek, Halina Skibniewska, and Zofia Fafius. Sensitivity to the social impact of architecture was of great importance. Already before the war, it was postulated to build widely available, cheap and small apartments, in buildings designed from prefabricate, using new construction techniques and technologies.

[1] Since the beginning of the 1950s, the Institute of Housing has commissioned research to obtain information on the quality of life in housing estates and how to use housing, preferences and suggestions from users. The study was conducted by Wanda Litterer in 1949-1950 [6], Aleksander Matejko in 1956, Władysław Malicka in 1956 [7], Wanda Czeczerda [8].

3. Political conditions, norms and functional arrangements of apartments

After World War II, the Polish state assumed the obligation to finance housing, and the goal was to provide each family with independent housing. Widespread impoverishment of the society, awareness of the constant shortage of apartments, as well as the belief that in order to quickly meet housing needs it was necessary to make the most of the production potential - they made the decision to introduce a housing design standard [12].

3.1. Functional layouts of apartments according to the norms of 1947 and 1951

The first arrangements for the housing standards were introduced by the act of July 3rd, 1947 "On building norms and standards" [13]. It was set at a level close to the assumptions of the pre-war "socially needed housing" [14]. The binding sizes of five basic categories of apartments - P, PK, 2PK, 3PK, 4PK - have been established. The smallest (P - room with a kitchenette) had 22 m^2, the largest 58 m^2 of usable area (an increase of up to 10% was allowed.) The unit standard of 11 m^2 per inhabitant (approx. 7 m^2 of living space) resulted from these recommendations. The surface of the apartment for 4 people - 2.5 or 3- rooms - could not exceed 41 m^2.

In 1951, a norm was developed [15] which increased the number of categories and variants of apartments (from 5 to 10) and strictly defined the layout of the rooms in the apartment and the boundaries of the area for individual rooms. It also increased the usable floor space of flats - from 41 to 50 m^2. In the first half of the 1950s, as a result of the use of housing standards (from 1947 and 1951), characteristic functional layouts of flats developed, which became typical for housing estates implemented by ZOR (Zakładowe Osiedla Robotnicze, company towns) throughout the country: mainly small - 1, 2, 3-room apartments, with a relatively large kitchen.

An example would be a housing estate in the Muranów district in Warsaw, designed by architect Bohdan Lachert [16]. These were flats in the standard 10 m^2 of living space per person and with one sleeping space in the kitchen, so the kitchens had to be large: 7.8 m^2; 8.8 m^2 and 9.8 m^2 (Fig. 1a).

In turn, when designing the Praga II housing estate in Warsaw (implemented by ZOR according to the design of architect Jerzy Gieysztor and his colleagues) [17], flats in the standard 9 m^2 living space per person, from studios to 4-5 rooms with kitchen, equipped with : bathrooms, central heating, radio and telephone network (!) and lifts in buildings with over 5 floors. Typical ZOR layouts of apartments are of two types:

- with a large kitchen, in which it is possible to insert a dining table and bathrooms with a sink, and even a separate toilet: PK - 34.1 m^2 and 2PK - 32.5 m^2 and 40.9 m^2 (Fig. 1b);
- with a more modest kitchen area (small, only with a window cabinet) and a bathroom without a sink: PK - 33.2 m^2 and 38.3 m^2 and 2PK - 51.5 m^2 (Fig. 1c).

This indicates that designers were seeking optimal solutions to satisfy two groups of residents: working-class families and white-collar workers who represent different cultural patterns of housing use. In their minds, workers from rural environments needed a large, multi-functional kitchen, while intellectual families needed larger rooms. Small kitchens meant that eating everyday meals moved to the room, which was not accepted in rural families. In the families of white-collar workers, however, the rooms were used for studying, parents' work, rest and the size of these rooms did not satisfy the residents. What became apparent is that with culturally extreme patterns, universal housing could not be created.

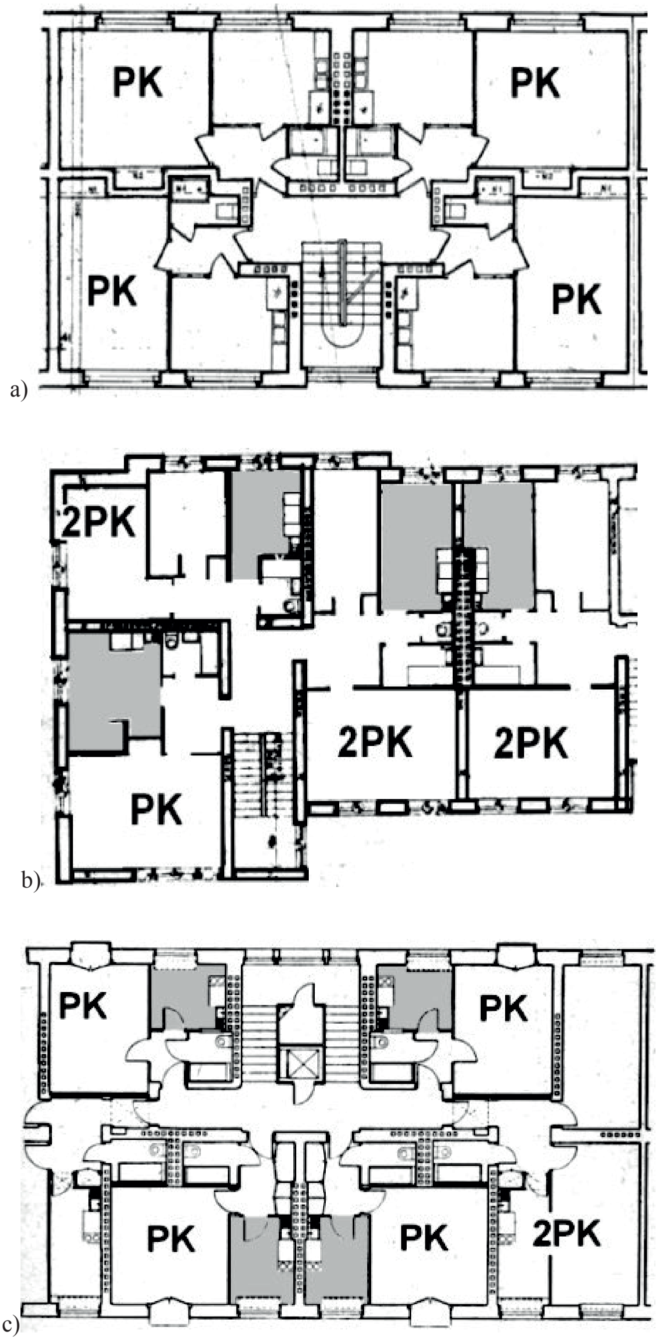


Fig. 1. Repetitive sections of buildings: a) in Muranów, 1949r., b), c) Praga II housing estate, 1952; Source: own study based on [16], [17]

3.2. Search for flexible functional layouts of apartments designed according to the 1954 norm

The next norms were introduced by the Resolution of the Presidium of the Government on February 6, 1954 [18]. This change brought a reduction in the number of apartment categories to five, but increased the living space in relation to the usable floor space. This was to serve greater flexibility in the use of apartments. From 1956, studies and the search was intensified for new, more functional solutions which, according to architects - for example Zygmunt Kleyff, Helena and Szymon Syrkus, Zofia Fafius - would be adequate to the needs of a modern family.

In addition to the traditional technology used in multi-family housing, the architects began to look for more modern methods of erecting buildings, enabling faster and cheaper construction of a large number of apartments. The housing estate at Kasprzaka Street in Warsaw was the so-called experimental estate designed by architect Zygmunt Kleyff and a team of his colleagues [19]. Implementation of the project, the work on which had started in 1955, took place in 1957. Two prototype large-panel buildings were created, in which a modular mesh and a catalog of elements of several stylized and unchangeable functional, constructional and installation nodes were created.

The apartments were designed on the basis of the1954 norm: PK apartments (for 2 people) with a usable area of 37.2 m^2 and 30.6 m^2, 2PK (for 4-5 people) with a usable area of 48.6 m^2 and 58.4 m^2 and 3PK (5-6 people) with a usable area of 74.8 m^2 and 60.4 m^2 (Fig. 2a, b).

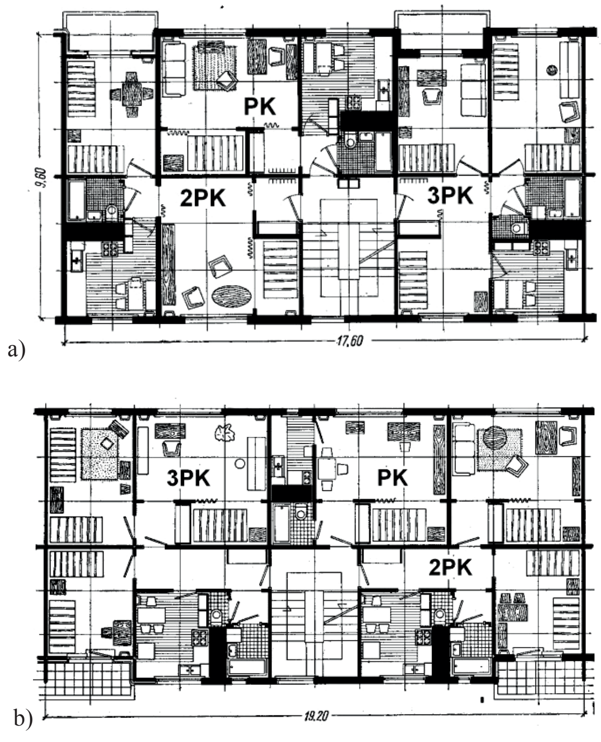
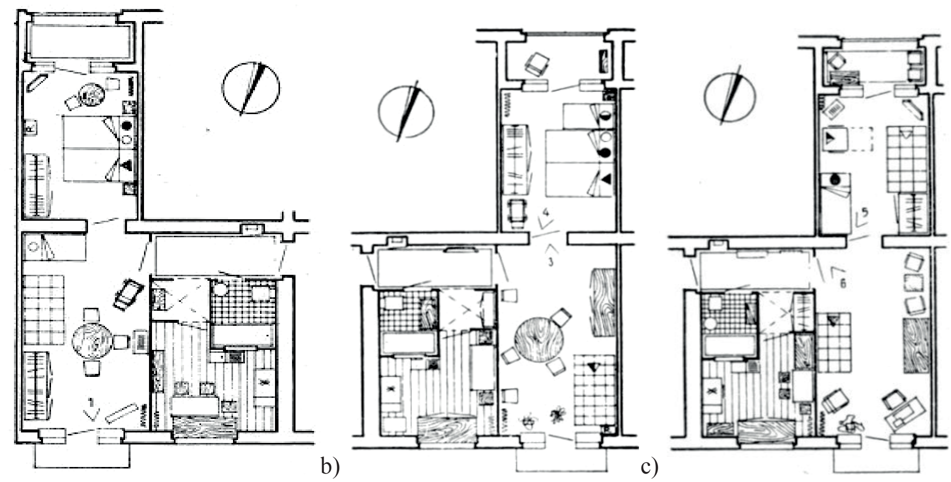


Fig. 2. a), b). Floor plans of apartments Kasprzak housing estate, 1957. Source: own study based on [19]

The following solutions proposed by the team of Zygmunt Kleyff pay attention to the layouts of flats:

- a kitchen with an arranged place to eat, which was a response to the clear preferences of users;
- bedroom areas in the living rooms (after opening them to the living room, more space could be obtained;
- the use of two systems: traditional, in which individual rooms are entered from a separate hall; and non-traditional, in which the living room space from the entrance connects with communication, sometimes with the kitchen, which is a new, more open approach to the living area of the apartment (Fig. 2b);
- the introduction of larger bathroom blocks in the apartments (3PK) with a separate toilet, which allowed to put a washing machine in the bathroom.



a) b) c)

Fig. 3. The way of using the apartment: a), b) - workers' and c) - white-collar, Nowa Huta housing estate, 1956. Source: own study based on [20]

To understand how revolutionary solutions for interior design were proposed by architects, one should compare the way of organizing space in the flats of working-class and intellectual families at that time [20]. The family sleeps in the bedroom, and the representativeness of the living room comes first in the hierarchy of values. It is acceptable for a small child or older learners to sleep there. At the very least, separate beds are dedicated in white-collar family apartments (Fig. 3a -c). Architects attempted to change the housing awareness of tenants, but cultural patterns derived from previous environments were strongly established.

In the industrialized technology, a housing estate on Koło in Warsaw, designed by architects Helena and Szymon Syrkus, was implemented in 1947-1962. Noteworthy is the designers' care about the variety of spatial solutions of apartments depending on the composition of the family. "We also wanted to achieve much more freedom of various shapes of apartments in the same category using a permanent assortment of structural elements than in the 1955 series. In this way, we could provide future tenants the possibility to choose the type of apartment that best suits their needs within the same or similar usable area (11 m^2 per person). As housing cooperatives develop, building not for an anonymous recipient, but for predetermined families, the selection of the right apartment can be made before the building is erected on the basis of clearly legible projects or, as we have postulated for many years, on the basis of furnished scale models 1: 1 "[1].

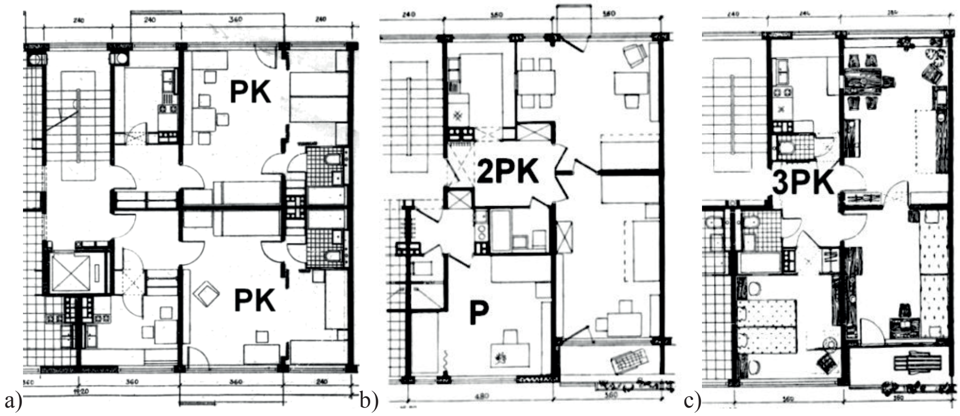


Fig. 4. Floor plans of the Koło housing estate, Warsaw, 1957. Source: own study based on [1].

The apartments' designs use:

- the separation of sleeping niches in PK type apartments (for 3 people) with an area of 42.1 m^2 and 44.2 m^2 whose area, according to the norm from 1954, was the area of 2PK type apartments (Fig. 4a); notable is the position the sleeping niche in the immediate vicinity of the bathroom - after closing the niche, the toilet can be used directly;
- connecting space by placing doors also between rooms (Fig. 4b, c): 3PK - 65.4 m^2 usable and 2PK - 53.2 m^2 of usable space;
- locating the kitchen in the vicinity of the living room, which was not yet an obvious and popular solution, and connecting it through the supply window (Fig. 4b, c).

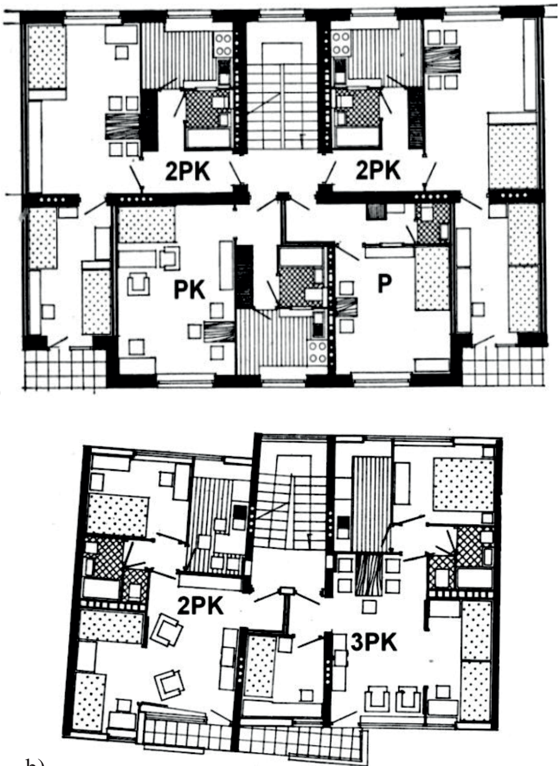
Three different approaches to the arrangement of sleeping places can be noted - probably the result of a clash of views on this topic and the issue of the child's place in the space of the apartment:

- parents' bedroom annexes are separated, and an additional sleeping place is provided in the living room - probably with a child in mind, which is not a comfortable solution (Fig. 4a);
- the children have their own room, while the parents occupy fold-out beds in the living room (Fig. 4b);
- a favorable solution in which parents have a separate bedroom and children have their own room in a 3PK apartment with a usable area of 65.4 m^2 (Fig. 4c).

The housing needs of children were considered by Zofia Fafius and the team when designing the Wierzbno housing estate in Warsaw - Wierzbno B, which was implemented in 1956–57 in large-block technology [21]. In the proposed apartments, the following design and arrangement decisions are noteworthy:

- placing sleeping areas with the care for parents 'comfort, creating a bedroom even in the vicinity of sanitary blocks (Fig. 5b), and placing additional beds in the living room (for children), or on the contrary - placing parents' sleeping place in the living room, and leaving children their own rooms (Fig. 5a) according to the emerging contemporary pattern. As can be clearly observed, the designers were still struggling to adopt one concept, and the spatial needs of children are voiced;

- introducing an open space by connecting the hall, living room and sleeping area and obtaining the maximally increased interior space (Fig. 5b).



a)

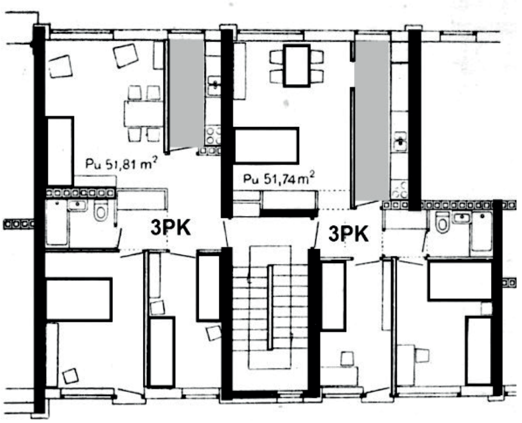
b)

Fig. 5. a), b). Plans of apartments in the Wierzbno housing estate in Warsaw, 1957. Source: own study based on [21]

An example of a special concern of designers for improving the quality of life of residents as units with individual needs and a specific housing culture was to be the WSM (Warsaw Housing Cooperative) housing estate in Rakowiec. The project of Oskar and Zofia Hansen's housing estate, based on the guidelines of the housing norm from 1954, was completed in 1959. "To create for EVERYONE the best place in the housing estate, it is best to form an apartment for them - conditions for their otherness, for their reflexes - that was the motto of the WSM Rakowiec. [...] give the widest choice possible! So maximum diversity while maintaining most stylized building elements. [...] clear differentiation of the situation of individual residential divisions and ultimately different treatment of a particular apartment will give the opportunity to really perceive it as "one's own apartment" [2].

Oskar Hansen designed the apartments individually, even taking into account the profession of users. The seamstress could live in a one-sided apartment, where there are no drafts (scraps of materials would not spread throughout the room), and in turn a large family would receive a double-sided apartment, easily ventilated due to the smells of meals cooked in larger quantities. The designer considered the right model of the laboratory type kitchen, and the table was located in the vicinity of the kitchen, which is sometimes opened to the living room in the apartments PK (Fig. 6a) and 3PK (Fig. 6b).

a)

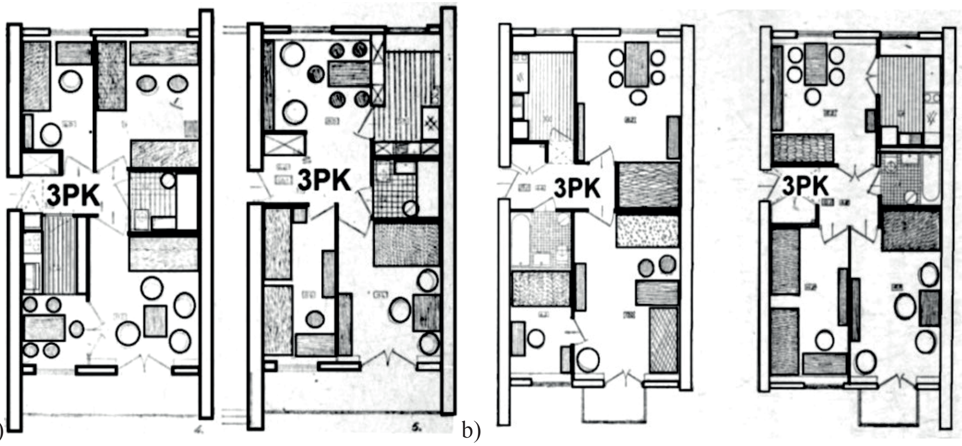


b

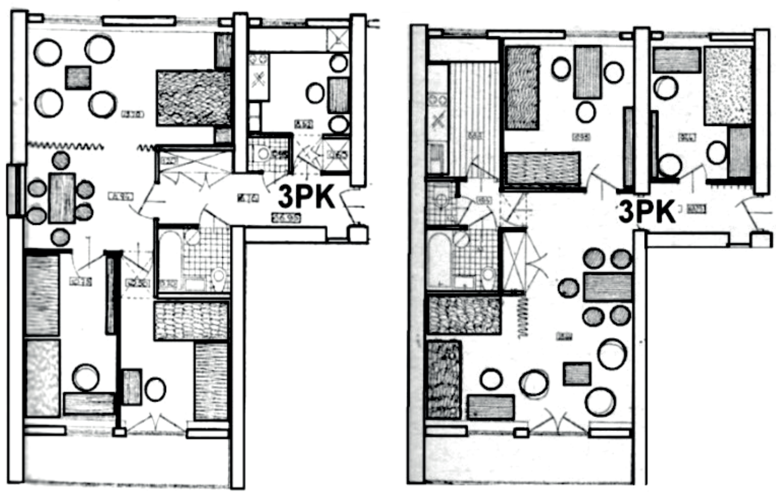
Fig. 6. a), b) Views of apartments in Rakowiec, 1959. Source: own study based on [2]

"This approach has resulted in a wide range of spatial solutions for apartments. The principle of separating in the apartment the part intended for living functions - linking the living room with the kitchen and with the intention of bringing together the place of preparation of the meal and the place to eat - and separating the individual spaces - sleeping rooms, tying them with the bathroom. [...] We thought that first and foremost good equipment of the economic part was important. Saving time and effort in homework gives a social profit in relation to the expenditure on the device and finishing the apartment. Kitchen equipment corresponding to the correct organization of the working process: wardrobe or a place for a fridge to store products, a sink with a drip plate, a work table, a gas stove, a place to put away the pots, and introducing hanging cupboards in addition to the bottom ones. The single-row system was found to be the most convenient for the assembly of stylized elements and for the user. Great emphasis was also placed on placing the right number of built-in cabinets "[2].

In the years 1957–1964 Bielany II and Bielany III housing estates were created. Designed by Maria and Kazimierz Piechotka - after the so-called Gomułka's thaw - were already examples of reviving modernism. It was a period when houses with a characteristic shape were created: with gable roofs with gently sloping surfaces, two-colored brick facing arranged in the so-called Bielany brickwork and the characteristic prefabricated windows with black frames and white sashes [22].



a) b)



c) d)

Fig. 7. Floor plans of apartments : a), b) - for 4 and 5 persons; c), d) - for 6 persons - Bielany II, 1958. Source: own study based on [22].

The introduction of the principle of 11.5 m^2 of usable floor space per inhabitant gave Bielany II designers the opportunity to try a number of types of apartments with a variety of internal layouts. One of the most interesting attempts was to design a flat for 4 people with an area of 43.4 m^2, in which there were 3 rooms (17.2 m^2, 7.2 m^2 and 9.4 m^2), kitchen (4.0 m^2), bathroom (3.2 m^2) and hall (2.6 m^2). This was in contrast to the previous solutions from the earlier stages of implementation of the housing estate, where apartments of 40 m^2 intended for 3-4 people had one room and kitchen.

Innovative solutions tried to keep up with the modern perception of how to live, where everyone had the right to their intimate place. For each type of apartment, designers predicted a number of variants (Fig. 7a, b, c, d) differing in details. After the tenants moved in, a survey was to be carried out, based on which it could be determined which variant enjoyed the greatest recognition of the inhabitants. What is interesting is the designers' approach to the common space in six-person apartments (3PK with a usable area of 66.7 m^2, where the area was like a 4PK-type apartment). An innovative desire to create a multi-functional room becomes very apparent. The living room extended with bedroom areas (Fig. 7b, d) or dining rooms (Fig. 7a, c, d) could have become much more spacious considering the lean area. The situation of parents' beds in niches in living rooms reduced marital intimacy, but it definitely improved spatial comfort.

It seems that the situation was a stalemate in the face of existing surface-allocation standards and the needs of families were not satisfactorily met, to the regret of designers and sociologist researchers.

3.3. Functional layouts of apartments in accordance with the provisions of the 1959 norm

The design standard for apartments and residential buildings from 1959 [23] brings a breakthrough modification consisting in the introduction of apartment categories due to the number of inhabitants, not residential rooms, which theoretically gave designers greater freedom in designing apartments suitable for different types of families.

There were 7 categories of apartments - from M1 to M7. The average size of the apartment was 44m^2 (in 1959 the average size was 48.6 m^2, and in 1970 - 43.7 m^2). Normative regulations allowed the design of small rooms and kitchens without windows. In apartments of category above M4, an interconnecting living room with at most one sleeping space was allowed. It is not without reason that these normative arrangements have been referred to as austere. More smaller rooms (rooms) were designed on the same ZOR-like areas, which served to create individual spaces for users. The drastic reduction of the normative area per person to 7 m^2 made the design of dark kitchens and interconnecting living rooms almost a necessity. This resulted in the creation of small kitchen-laboratories[2], as well as a significant reduction in the area of individual rooms (up to 6 m^2), which residents sometimes could not

[2] In Europe, the author of the idea of "laboratory-style" kitchens, implemented on a small area, was the Viennese architect Margarete Schütte-Lihotzky. As part of a project to build new housing estates under the name of New Frankfurt in Frankfurt am Main, in 1926, she proposed a "laboratory" kitchen model, also known as the "Frankfurt" kitchen, with an area of 6.5 m^2. The presentations took place in master houses, at exhibitions, as part of lectures and press coverage, and even via a short film (in the prototype "Frankfurt kitchen", the length of the road traveled and the time spent on carrying out subsequent tasks were checked and compared to traditional kitchens). In the 1930s, Polish architects were also interested in the functionality of apartments. Famous architects Barbara and Stanisław Brukalski in the apartments on the WSM estates in Rakowiec and Żoliborz presented the idea of a small "laboratory" kitchen annex, open to the room, and modeled on the "Frankfurt" kitchen. In an effort to adapt the environment to the needs and capabilities of man, new solutions have been introduced [26]. Matching fitted furniture was used. The worktop was supplemented with standing and hanging cabinets, shelves, a sink with running water and containers for loose products with dispensers. The furniture was additionally combined with a waste bin and an ironing board folded on the wall, characteristic of the "Frankfurt" kitchen [27].

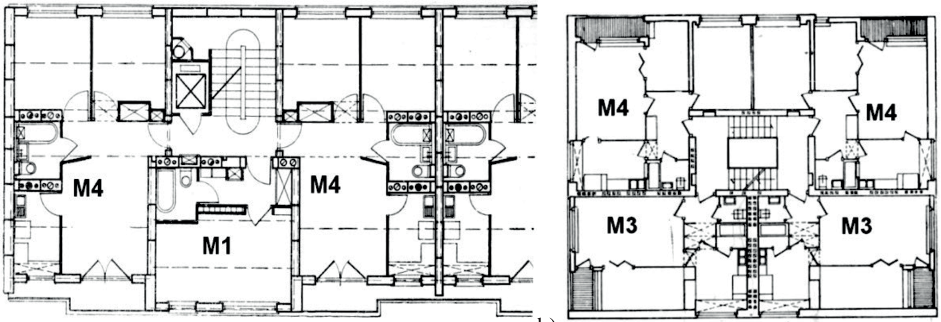
use. Table 1 shows the differences in normative arrangements from 1954 and 1959 regarding the area of individual rooms [24].

Table 1. Comparison of room sizes according to the norms of 1954 and 1959

room	surfaces of rooms according to the standards of the years	
	1954	1959
kitchen	4,5 – 9 m^2	4-5m^2 -7m^2
living room	16-20m^2/2 sleeping areas	12-16 m^2/1 sleeping area
single bedroom	10-12 m^2	6m^2
double bedroom	12-14 m^2	9 m^2

Based on the new normative from 1959, architects L. Kołacz and W. Parczewski developed a design for the Szosa Krakowska housing estate in Warsaw [25]. Attention is drawn to the organization of the common living space of the apartment, where the living room connects with communication and is transitive to a small laboratory kitchen, thanks to which a more open layout was created. The communication area is minimized, which resulted in two shapely bedrooms in the M4 apartment with a usable area of 48.7 m^2 (Fig. 8a).

Apartments with a small area were put into use at the Młodych estate in Warsaw's Grochów, completed in 1958-1962 (the authors of the project were arch. S. Ciechanowicz and T. Kobylański) [25]. M4 flats with a usable area of 48.7 m^2 and M3 with a usable area of 39.8 m^2 had a living room directly connected to the kitchen and bedroom. The kitchen was also accessible from the anteroom. This arrangement tied together the space for rest, preparation of meals and their consumption (Fig. 8b).



a) b)

Fig. 8. Floor plans of flats: a) the Szosa Krakowska housing estate, Warsaw, 1962. b) Osiedle Młodych housing estate in Warsaw, 1962. Source: own study based on [25]

A particularly interesting example of different variants of using the same types of apartments was the design of the Sady Żoliborskie housing estate in Warsaw by Hanna Skibniewska [25].

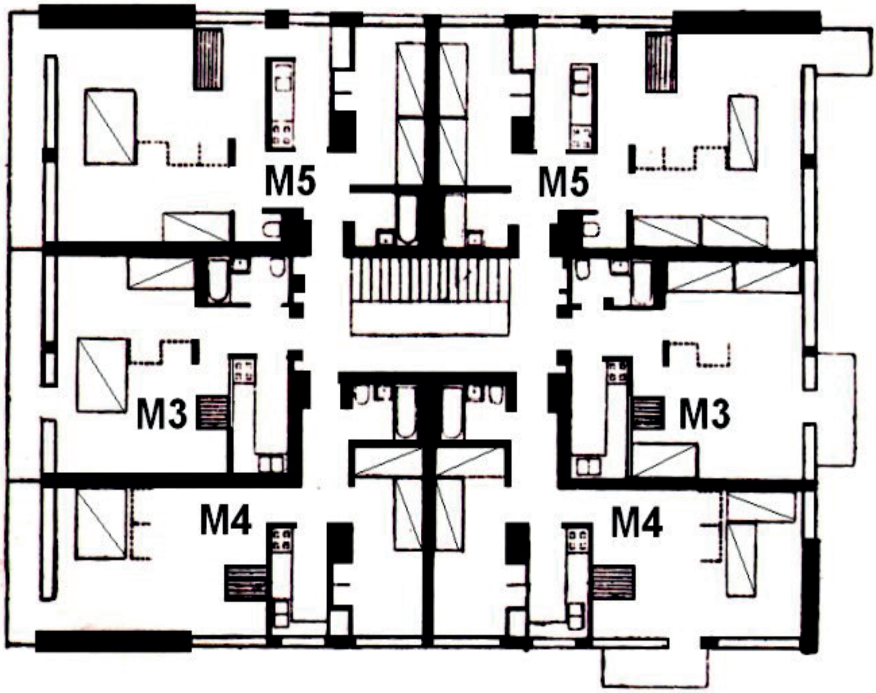


Fig. 9. Plan of the building in Sady Żoliborskie – 1963. Source: own study based on [25]

Noteworthy is the great care for the development of floor plans of flats, where wall units were arranged to divide the interiors depending on the family composition. The designer certainly knew the troubles of residents struggling with furnishing the apartments with large-size furniture. Flexible apartments with small square acreage were created: M3 - 33.8 m^2, M4 - 45.5 m^2 and M5 - 55.6 m^2 of usable floor space. (Fig. 9). Unfortunately, due to the high costs of implementing wall units, they were replaced with ordinary partitions. Designers proposed small laboratory-type kitchens lit directly and indirectly (M3), connected to a dining area in the living room. The spacial needs of children who have a separate room here while parents sleep in the living room have been taken into account.

It is interesting (the idea often found in implemented apartments) that the proportions of separate bedrooms did not give the opportunity to arrange a marital bed (which was moreover condemned as a relic of the past) in a typical arrangement. Parents, therefore, slept in the living room area or in two beds in the bedroom. Both situations were uncomfortable and one additional room was always missing.

Various kitchen layouts were designed by architects B. Chyliński and H. Graf [28] at the Kępa Potocka housing estate in Warsaw's Żoliborz, built in 1967 in industrialized technology proposed:

- a single-line kitchen (6 m^2) of the laboratory type with a width of 1.7 m in a flat M4 with a usable area of 50.6 m^2 (Fig. 10a);
- a kitchen (4.4 m^2), indirectly lit and separated from the room by a wall unit in a M3 apartment with a usable area of 39.6 m^2 (Fig.10b);
- a small kitchen (3.2 m^2) accessible from the room in the M2 apartment with a usable area of 27.6 m^2 (Fig.10a);
- a dark kitchenette (2.5 m^2) in the apartment M2 - 21 m^2 (Fig.10a).

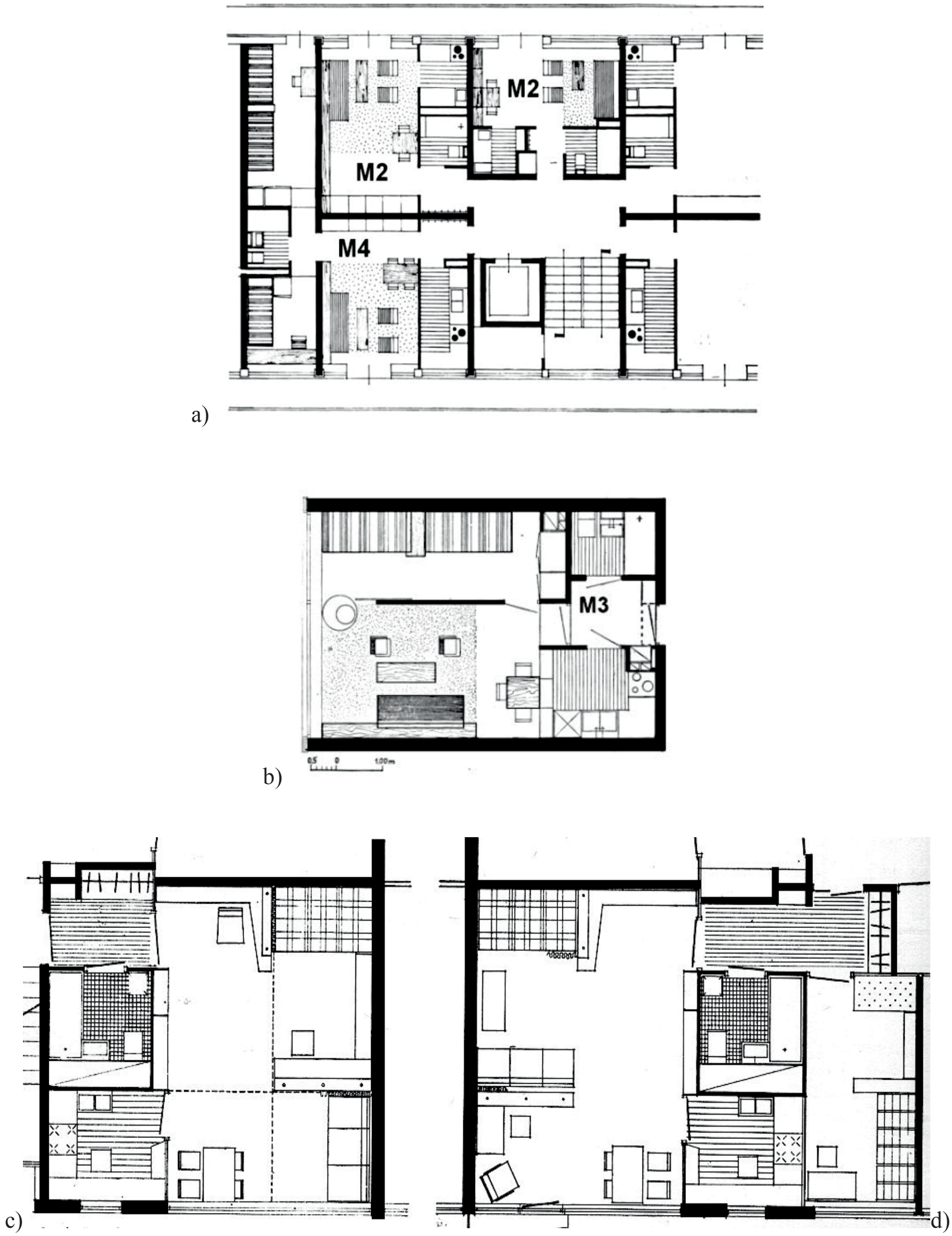


Fig. 10. a, b, c. Floor plans of apartments in Kępa Potocka, 1967. Source: own study based on [28]

Analyzing the functional arrangement of apartments M4 and M3, one can notice some inconsistencies in the location of sleeping areas:

- in the M4 apartment (for a family with two children - Fig. 10a) there are two bedrooms, while their proportions allow placing the beds only along the wall. The architect's idea is not clear - is the room with two beds the parents' bedroom (there is no traditional way to arrange a double bed) or the children's room, and then the parents sleep in the living room?

- in the second case, parents sleep in a small room or on a sofa bed in the room; in the M3 apartment (for parents with a child - Fig.10b), the situation is also unclear - whether the narrow niche is intended for parents and the sofa is used for the child's sleeping area, or whether the architect thought about two children and parents sleeping in the living room. This ambiguity indicates great difficulty in design decisions made by architects. In the existing legal situation, it was impossible to meet all the needs of tenants.

It is worth noting the detailed interior design - appropriate for emerging stylistically new furniture available in stores. Already at project construction stage, designers show tenants the various options of furnishing small apartments. Wall units were used - with built-in tables, desks or couches - set against the walls as well as dividing the room into two zones (Fig.10c).

The residents' assessment of their apartments was quite changeable - from positive in the early 1950s to negative in the 1960s. Although the apartments from the early 1950s were small - one- or two-room, they met the users' expectations, especially thanks to the relatively spacious kitchens, where the family life mainly concentrated. The lowering of the construction and housing standard in the 1960s, caused by normative provisions of 1959, was met by far negatively by society, because it contradicted the belief of socio-economic development taking place and the perceptible improvement of the economic situation of Polish society. Instead of the expected transition from a very modest standard to standards corresponding to social development - there was a regression (the average usable floor space of an apartment completed in 1950 in cities was 47.9 m^2, in 1960 - 46.9 m^2, in 1965 - 43.4 m^2, in 1970 - 42.8 m^2).

4. Summary and Conclusions

4.1. Summary

Architects were a very important link in the process of shaping the awareness of housing culture. It was them, limited by the technology of building construction and norms, created functional layouts of apartments, mainly taking into account the needs of future residents. Users had to get used to and accept smaller and smaller living spaces. Designers were tasked to help them in this process.

An analysis of the functional layouts of apartments in newly established estates indicates a clear transition from layouts with relatively large kitchens and rooms (in the 1950s) to divisions into a larger number of smaller rooms due to the need to isolate family members (in the 1960s). In the late 1950s, architects worked on improving the utility value of apartments, paying attention to the varying needs of different groups of residents.

The main trends in the design of the apartment space were:

1. Increasing the area of the day zone (as part of the applicable normative provisions)
   - bedroom areas were designed in living rooms, where, after opening them to the living room, more interior space could be obtained,
   - the space was connected by placing doors also between rooms,
   - attempts were made to create a multifunctional room - a non-traditional spatial arrangement was used (in traditional rooms we enter from a separate hall), in which the living room space from the entrance connects with communication, sometimes with the kitchen, which is a new, more open approach to the living zone of the apartment.

2. Propagating flexible interior design - multi-functional furniture separating individual rooms was introduced.
3. Searching for optimal kitchen solutions:
   - a kitchen with an arranged dining area which was a response to the clear preferences of users;
   - the modern model of dining in the living room was clearly promoted, and it was even experimentally proposed to connect the kitchen with the living room through a door, a feeding window, a double-sided sideboard or a dining room.
4. Searching for optimal solutions in the arrangement of sleeping areas, which was probably the result of a clash of views on this topic and on the issue of the child's place in the space of the apartment. At the beginning of the 1950s, all household members were sleeping in the bedroom, and in time, the need for individual spaces (especially in white-collar environments) for parents and children arose. The following options were considered:
   - children have their own room (and even separate rooms), while parents occupy fold-out beds in the living room (separate spaces are designed),
   - a favorable solution, in which parents have a separate bedroom (unfortunately, often its proportions make it impossible to put the marital bed in the traditional way) and the children their room,
   - a controversial solution - parents have their own bedroom, while children are expected to sleep in the living room in separate areas,
   - placing sleeping areas with attention to parents' comfort, creating bedrooms even in the vicinity of sanitary blocks.
5. The introduction of bathroom areas with a separate toilet, which allowed to put a washing machine in the bathroom and enabled a family of several people to use the bathroom almost without interference.

4.2. Conclusions

The architects' design decisions were a consequence of government policy. However, the quality of functional solutions of the designed apartments depended on the knowledge, talents and diligence of the architects. The development of design thought in project ideas - especially in the late 1950s - not only led to changes in the spatial structure of apartments, but also changed the awareness of society's housing needs and habits in the organization of housing functions. It initiated the evolution of cultural patterns in the use of housing. Too small laboratory-style kitchens did not allow for placing a dining table there. Worker families were forced to eat in the living room, thus breaking the rural (traditional) pattern of the home. The new apartments did not provide adequate spatial conditions for cultivating the traditional rural pattern, which as a result was gradually disappearing. Families of white-collar workers - representing the middle-class pattern of apartment use - provided children with separate rooms. They deplored the need to sleep in the living room, which in previous environments would have been unacceptable. Architects' design decisions have certainly contributed to the shaping of a modern space management model in families with more democratic relationships between parents and children.

References

[1] Syrkusowie H. i S., “Budownictwo mieszkaniowe z elementów wielkopłytowych”, „Architektura” nr 7/1957, p. 263

[2] Dobrzyńska M., Malicki Z., “Osiedle Warszawskiej Spółdzielni Mieszkaniowej na Rakowcu”, „Architektura” nr 7/1959, p. 297

[3] Wiking.edu, Demografia Polski,www.wiking.edu.pl/article.php?id=269, [Accessed: 5 Sept 2019]

[4] Główny Urząd Statystyczny, Rocznik Statystyczny 1980. Rok XL, GUS, Warszawa, p. 42

[5] Główny Urząd Statystyczny, Rocznik Statystyczny 1986. Rok XLVI, GUS, Warszawa, p. 39

[6] Litterer W. , “Nowe osiedla mieszkaniowe i ich mieszkańcy”, Polskie Wydawnictwa Gospodarcze, Warszawa 1952

[7] Malicka W., “Próba analizy graficznej użytkowania mieszkań.[in:] Zaludnienie i użytkowanie mieszkań w nowych osiedlach”, IBM, Warszawa 1959

[8] Czeczerda W., “Ludność w nowych zespołach mieszkaniowych”, IBM, Warszawa 1959

[9] Putowska J., “Jak urządzić mieszkanie”, Arkady, Warszawa 1960, p. 12

[10] Matejko A., “Wartość użytkowa nowych mieszkań w świetle doświadczeń ich mieszkańców”, in: Zaludnienie i użytkowanie mieszkań w nowych osiedlach, red. Wł. Czajka, IBM, Arkady, Warszawa 1959, p. 65

[11] Turowski J., “Środowisko mieszkalne w świadomości ludności miejskiej”, Ossolineum, Wrocław, Warszawa, Kraków, Gdańsk 1979, p. 44

[12] Nowicki J., “Standard i przestrzenne rozwiązania w spółdzielczym budownictwie mieszkaniowym”, „Sprawy Mieszkaniowe” z. 4/1993, p. 57

[13] Ustawa z dnia 3 lipca 1947 roku „O normach i standardach budowlanych”, Dziennik Ustaw 1947 nr 52, poz. 269

[14] Korzeniewski W., “Mieszkania społecznie najpotrzebniejsze. Wczoraj i dzisiaj”, Źródło: cejsh.icm.edu.pl/cejsh/element/bwmeta1.../PRM_2009-1-2_04_Korzeniewski.pdf [Accessed: 1 Oct 1916)

[15] Uchwała nr 612 Rady Ministrów z dnia 18 sierpnia 1951 r., „Normatyw projektowania budynków mieszkalnych i mieszkań w miastach i osiedlach typu miejskiego”

[16] Lachert B., “Muranów-Dzielnica Mieszkaniowa”, „Architektura” nr 5/1949, p. 134

[17] Piotrowski W., “Osiedle mieszkaniowe Praga II”, „Architektura” nr 7-8/1952, p. 191

[18] Uchwała nr 70 Prezydium Rządu z dnia 6 lutego 1954 r., Normatyw projektowania budynków mieszkalnych i mieszkań w miastach i osiedlach typu miejskiego, , „Monitor Polski” nr 120, Warszawa 1954

[19] Kleyff Z., Osiedle doświadczalne przy ul. Kasprzaka w Warszawie, „Architektura” nr 8/1958, pp.309-314.

[20] Matejko A., “O użytkowaniu mieszkań”, „Architektura” nr 5/1957, p. 196

[21] Fafius Z., “Osiedle Wierzbno”, „Architektura” nr 9/1958, pp. 253-263

[22] Lewandowski T., “Bielany”, „Architektura” nr 7/1958, p. 285

[23] Uchwała nr 364 Rady Ministrów z dnia 20 sierpnia 1959 r., Normatyw projektowania mieszkań i budynków mieszkalnych wielorodzinnych w miastach i osiedlach, , „Monitor Polski” nr 81, Warszawa 1959

[24] Płachcińska A., “Standard w społecznym budownictwie mieszkaniowym”, „Sprawy Mieszkaniowe” nr 2, IGM, Warszawa 1994, p.9

[25] Filipow Z. “Budownictwo mieszkaniowe w Warszawie”, „Architektura” nr 1-2/1963, pp. 10, 21, 24

[26] Charytonowicz J., “Dokąd zmierza współczesna ergonomia. Wybrane kierunki badań ergonomicznych w 2008 roku”, JAKS, Wrocław 2008, p. 15

[27] Nowakowski P., “Architektura i ergonomia kuchni domowych na tle ewolucji zwyczajów kulinarnych”, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2015, p. 44. doi:10.5277/Y03.2015.01

[28] Graf H., “Osiedle Kępa Potocka”, „Architektura” nr 5-6/1967, pp.195-199

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The wooden roof structures of Żuławy Region arcaded houses of type III - research, current state and analysis

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Abstract: Historic arcaded houses of the delta of the Vistula were the subject of great interest of many researchers, but their work was focused mainly on historical-architectural aspects. There are no publications which would focus on details and comprehensive analyses of construction systems for this group of historic buildings. The article is the result of field research, archival query and calculations made by the author. The paper analyses the rafter framing constructions of the preserved arcaded houses of type III. The author has prepared a list of construction elements of roofs, carpentry joints, rafter inclination angles and described the state of preservation of roof structure. The paper also includes calculations of the average volume construction material of the roof structure per square meter of roof slope plan.

Keywords: arcaded houses, timber roof structure, carpentry joints.

1. Introduction

The arcaded houses in Żuławy Region are the part of the cultural heritage of the Delta of the Vistula. They can be found mainly in rural areas[1].There are three basic types of arcaded houses in Żuławy, according to Kloepel's typology[2] [1], also confirmed by Stankiewicz[3]. The buildings mentioned in the article belong to the type III (Fig. 1). It was the last form of development of the Żuławy house that took place in the second half of the 18th century. The type III differs from the others (the type I and II) by a risalit supported on columns and perpendicular to the ridge. The plan of the house resembles the letter T. The floor above the main body of the house does not exist, but is preserved in the risalit. The number of columns in the arcade, in the front part of the risalit, is reduced to six or four. The width of the passage is limited by the additional columns. The arcade no longer performs an utility role; it becomes a decorative element [2]. The Żuławy arcaded houses are a valuable example of old wood carving techniques, which are rarely used today.

Roof structure is relatively well-preserved building element of the Żuławy houses, which did not undergo any significant changes and has a large percentage of the authentic substance. They belong to the oldest types of wooden structures. Their main function is to

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1 The exception is a few arcaded houses located in cities: Gdańsk, Nowy Staw, Nowy Dwór Gdański.

2 Otto Kloeppel (1873-1942) architect, conservator, professor and rector of the Technical University of the Free City of Gdansk.

3 Jerzy Stankiewicz (1923-1994) graduate and professor of the Faculty of Architecture at the Gdańsk University of Technology.

transfer the loads due to weight of elements, roof covering, wind and snow pressure to the supports [3].

The aim of the article is to thoroughly describe the historic roof structure that has been preserved, to perform their typology, to determine the amount of wood used for the construction of the structure per square meter of roof slope plan and to classify the carpentry joints in its construction. This article is also supposed to indicate common features and differences in load-bearing systems of roof structures of arcaded houses from the end of the 18th and the first half of the 19th century.

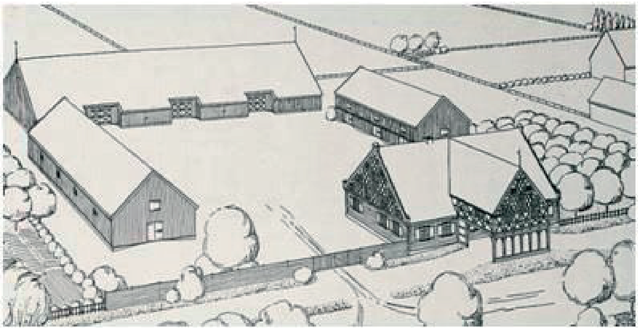

Fig. 1. An arcaded house – type III. Source: [1]

2. Literature research

The literature on typology, technology and design of roof structure is quite extensive [3], [4], [5], [6], [7], [8]. In recent years, there have been completed works that complement the systematics, division and nomenclature of the historic wooden roof structures [9] and carpentry joints [10].

The works devoted to arcaded houses focused mainly on their architecture, development of the building form and interior design [1], [2], [11]. In recent years, there have also been publications on technical and conservation issues related to the Żuławy arcaded houses, which are the result of the author's research [12], [13].

The first graphic designs presenting the structure of roof structure in Żuławy arcaded houses and their geometry can be found in Kloepel's pre-war study. However, these are rather general and simplified drawings of cross-sections of only a few houses (Gdańsk Lipce - type I, Miłocin - type II, Izbiska - type III, Przemysław - type III, Lubieszewo - type III)[4]. In the post-war years, there were inventories of some houses made by PP PKZ,Gdańsk Branch[5].The studies contain vertical sections of houses, but only of selected buildings (Klecie type I [14], Gdańsk Lipce type I [15], Miłocin type II [16], Lubieszewo type III [17], Żuławki type III [18]).

The subject of the roof structure of the arcaded houses in Żuławy was also discussed by Koperska-Kośmicka [11], somewhat on the margins of the general debate on the architecture of buildings. The author included in it a description of the shape of roofs, their

4 Some of Kloepel's drawings were reproduced in Stankiewicz's work.

5 The documentation of the The Polish Studios for Conservation of Cultural Property (PPKZ S.A.), of the Gdańsk Branch, is kept in the archives of the National Heritage Institute (NID) in Gdańsk. The materials include architectural and conservation inventories, reports on renovation works, expert opinions on the construction of arcaded houses from the 1950s to the 1980s. The entire documentation was submitted in 1995-2001 at the request of the Minister of Culture and Art [26].

construction and type of roofing. She also gives information about the types of roof structure arcaded houses, mentioning two types: two-collar beam roof structure and two-collar beam roof structure with posts. The paper also contains a diagram (for 8 houses) showing the angles of roof slope inclination depending on the covering material applied. It shows that for three hundred years (16th - early 19th century) the roof slope angle was about 47° to max. 49°. In the second half of the 19th century it dropped to 40° or even 30°.

In the above-mentioned works, however, there is no precise systematics of preserved roof structure for a larger group of arcaded houses with a division according to their types (I, II or III). There are no analyses encompassing details of the structure, size of construction elements, typology of carpentry joints and their state of preservation, nor chronological lists of these structures according to the date of construction of the house.

3. Methodology

The paper applies a mixed research method containing elements of the following methods: logical argumentation, historical-interpretation, case study, quantitative and analytical method [19]. A group of the arcaded houses of type III from the area of Żuławy Wiślane, entered into the register of monuments, was selected for the inventory [20]. Another criterion was the age of the roof structure and no renovations or modernisations conducted in the last seventy years. This was determined on the basis of an archival query of historical records [21], [22], [23], [24] and an interview with the residents[6].The last factor limiting the field of research was the lack of consent for research[7]. Finally, the measurements of the roof structure could be carried out in four arcaded houses of type III in: Bystrze (Fig. 2), Marynowy (Fig. 3), Nowa Kościelnica (Fig. 4) and Rybina (Fig. 5).

Fig. 2. The arcaded house in Bystrze (author's own photography)

6 In many cases, the arcaded houses are owned by descendants or relatives of people who came to Żuławy after the end of the war in 1945. The inhabitants confirmed that the roof structure has not been repaired.

7 In some cases, despite the good condition of the house, the owners did not agree to perform an inventory, or contact with them was difficult, which made it impossible to perform examinations. The arcaded houses are mostly private dwellings.

Fig. 3. The arcaded house in Marynowy (author's own photography)

Fig. 4. The arcaded house in Nowa Kościelnica (author's own photography)

Fig. 5. The arcaded house in Rybina (author's own photography)

The analytical part presented below includes calculations aimed at determining the amount of wood used in the construction of the rafter framing per square meter of roof slope plan[8] [25] according to the (Eq. 1).

$$S = \frac{V[\mathrm{m}^3]}{R[\mathrm{m}] \times D[\mathrm{m}]} \tag{1}$$

V – the volume of the structural elements of one truss [m^3]
R – average spacing of trusses [m]
D – roof span [m]

Only visible roof structure elements (collar beams, rafters, purlins, posts) are included in the calculation. Calculations were made for full trusses[9]. Truss beams are not included here, because they are encased in the floor and ceiling structure, which made it impossible to measure their cross-section. Wind beams, battens and other elements used for fixing the roof covering were not included in the calculations as they do not constitute the main load-bearing elements in the roof frame. In addition, the above-mentioned elements are frequently referred to when repairing roof coverings. The aim of the measurements was to examine the oldest parts of load-bearing structures of roof structure. The article also contains analogical calculations for the existing arcaded houses which were not accessible to the author for research. A source of knowledge about particular dimensions of structural elements was archive conservation and architectural documentation of PP PKZ[10].

4. Research results

The inventories of arcaded houses took place between July and September 2017. The aim of the measurements was to examine individual structural elements of roof structure and their dimensions, and to determine their state of preservation.

4.1 The houses made available for research

4.1.1. Bystrze

The arcaded house in Bystrze no. 5/7 was built in 1819 by Jakub Jamuet [21]. The historic building is located in the village, near the Mątowy Wielkie – Lisewo Malborskie road. The building has a wooden structure. The log walls are plastered. The risalit of the half-timbered structure is based on 10 columns. The foundation of the building is made of brick. The roof construction is two-collar beams[11] and the roof is covered with red pantile.

[8] The author applied the method used in the unpublished doctoral dissertation of A. Kapuściński, where similar calculations were made for the roof strucutre of Gdańsk churches. Thanks to this method, it is possible to estimate the amount of structure wood used in a given group of structures depending on the analysed time interval.

[9] The full truss includes all the components of the roof strucutre (rafters, collar beams, posts, purlins, truss beams). In the arcaded houses mentioned in the article, not all collar beams are supported by posts.

[10] The footnotes to the documentation are given at each house.

[11] The rafter framing of the arcaded house in Bystrze has no columns. The roof structure is partially stiffened by partition walls of rooms located in the attic. They are located only at the risalit and at the gable wall. Before the war, they were used as guest rooms during the summer months.

The cross-sections of the individual elements of the rafter framing are as follows: rafters 15x28cm, collar beams 15x19cm (Tab. 1). The rafter framing construction of the arcaded house in Bystrze has been made with the use of traditional carpentry joints: lap and simple lap joints (Fig. 6).

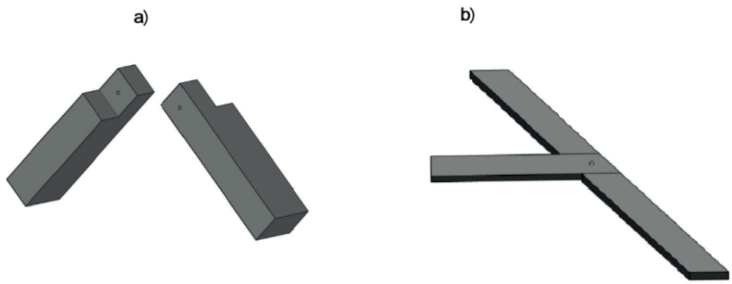

Fig. 6. Carpentry joints: a) lap joint , b) connection of collar beam with rafter with simple lap joint. (author's study)

The connection of rafters in the ridge is made with lap joints (Fig.7), the connection of the collar beam with the rafter with simple lap joints, for which two dowels are used (Fig. 8). The roof slope inclination angle is 45° (Fig. 9)[12]. The number of trusses above the main body of the house is 15, the span of the roof is 12.40m and the spacing of trusses is 1.25m. The condition of the structure is acceptable[13]. As a result of leakage of the roof covering, numerous dampness and damages are visible in the roof structure. Gravitational ventilation of the attic is not disturbed; there is constant air circulation.

Fig. 7. Bystrze– the view on the ridge. (author's own photography)

Nowadays, they are used as storage rooms. Partitions are not a constant element for all trusses, so their elements were not included in the calculations. The house in Bystrze is not the only building with such roof structure. Two-collar beam trusses are also found in arcaded houses in Balewo, Przymysław, Rozgarcie, Świerki [11].

12 Drawings of roof structure of Żuławy arcaded houses are simplified and present the main structural elements, their dimensions and inclination angle. They are a graphic supplement to the description contained in the text.

13 The house has two owners for whom the costs of renovation are too much of a financial burden.

Fig. 8. Bystrze – connection of a collar beam with a rafter. (author's own photography)

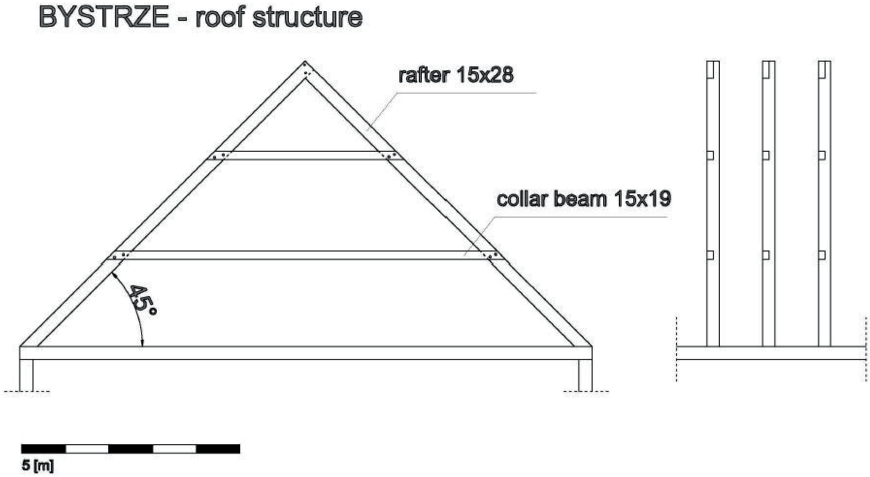

Fig. 9. The simplified scheme of the roof structure of the arcaded house in Bystrze. (author's study)

Table 1. The summary of the rafter framing elements of the house in Bystrze

No.	RAFTERFRAMING ELEMENTS	QUAN.	DIMENSIONS [m]			VOLUME[m³]
			width	height	length	
1.	rafters	2	0.15	0.28	9.25	0.78
2.	Upper collar beam	1	0.15	0.19	4.10	0.12
3.	Lower collar beam	1	0.15	0.19	8.75	0.25
					total:	1.14

The average volume of the construction material per square meter of roof slope plan:

$$s_1 = \frac{1.14\,\mathrm{m}^3}{1.25\,\mathrm{m} \times 12.40\,\mathrm{m}} = 0.074$$

4.1.2. Marynowy

The arcaded house in Marynowy no. 42 was built in 1804 by Hermann Hekker [22]. The building is located in the village near the Malbork – Nowy Dwór Gdański road. It has a wooden frame and the log walls are not plastered. The risalit of the half-timbered structure, with a filling of the yellow small brick in herringbone, is based on 10 columns. The foundation of the building is made of brick. Two-collar rafter construction; lower collar beam is supported by posts (Figs 10-11); the roof is covered with the red pantile. The individual cross-sections of the rafter framing elements are: 14x24cm purlin, 8x18.5cm post, 18x26cm rafters, collar beams: lower 15x25cm and upper 13x26cm (Tab. 2). Connection of the collar beam with the rafter with the simple lap joint; connection of the rafters with the ridge with the lap joint. The slope inclination angle is 43° (Fig. 12). The number of trusses is 18, their spacing is 1.10m, the roof span is 12.50m. Planks of 5cm thickness are placed on the lower collar beam. The condition of the structure is acceptable[14].As a result of leakage of the roof covering, numerous moisture and damages are visible in the rafter framing. Gravitational ventilation of the attic is not disturbed; there is constant air circulation.

Fig. 10. Marynowy – the view on the rafter framing with two collar beams (author's own photography)

Fig. 11. Marynowy– the posts supporting a collar beam (author's own photography)

[14] The Marynowy house also has two owners for whom the renovation costs are too much of a financial burden.

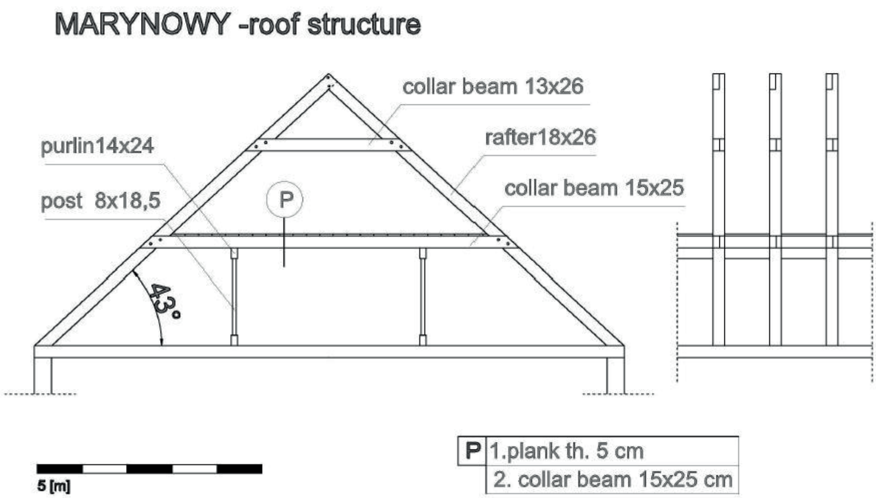

Fig. 12. The simplified scheme of the roof structure of the arcaded house in Marynowy. (author's study)

Table 2. The summary of the house rafter framing elements in Marynowy

No.	RAFTERFRAMING ELEMENTS	QUAN.	DIMENSIONS [m]			VOLUME[m³]
			width	height	length	
1.	Rafters	2	0.18	0.26	8.90	0.83
2.	Upper collarbeam	1	0.13	0.26	3.00	0.10
3.	Lower collarbeam	1	0.15	0.25	7.60	0.29
4.	Purlin	2	0.14	0.24	1.10	0.07
5.	Post	2	0.08	0.185	1.70	0.05
					total:	1.34

The average volume of the construction material per square metre of roof slope plan:

$$s_2 = \frac{1.34\,\mathrm{m}^3}{1.10\,\mathrm{m} \times 12.50\,\mathrm{m}} = 0.098$$

4.1.3. Nowa Kościelnica

The arcaded house in Nowa Kościelnica no. 50/51 was built in 1840 [23]. The building is located in the village, near the Ostaszewo - Niedźwiedzica road. It has a wooden construction and the log walls are not plastered. The risalit of the half-timbered structure is based on 10 posts. The foundation is made of stone. The rafter roof structure is two-collar beams, the roof is covered with red pantile. Individual sections of the rafter framing elements are: rafters 17x30cm, collar beams: lower 16x23cm and upper 12x20cm (Tab. 3). Connection of the collar beam with the rafter with the simple lap joint, connection of the rafters in the ridge with the lap joints (Fig.13). The slope inclination angle is 47° (Fig. 15). The number of trusses is 15, their spacing is 1.40m, the roof span is 11.80m. On the lower beam there are 5cm thick plates. The structure is in good condition. The roofing is sealed. The components of the rafter framing are well preserved and despite their age, they do not show any major damage. Some elements of the rafter framing show carpentry markings, one may see the symbol IIII on a collar beam (Fig.14). Gravitational ventilation of the attic is not disturbed, there is constant air circulation.

Fig. 13. Nowa Kościelnica – connection of the rafter (author's own photography)

Fig. 14. Nowa Kościelnica – connection of the rafter with the collar beam(author's own photo.)

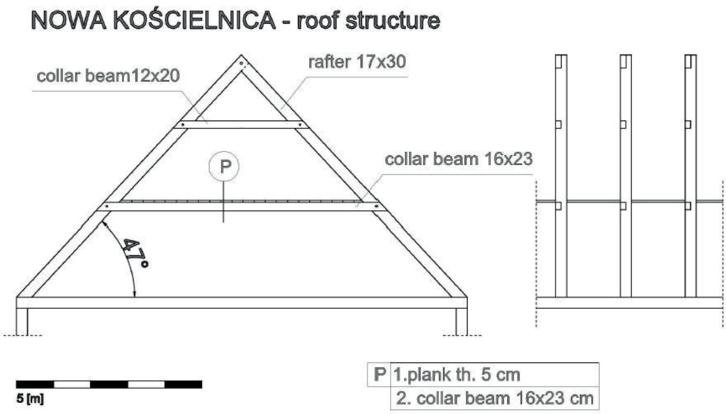

Fig. 15. The simplified scheme of the roof structure of the arcaded house in Nowa Kościelnica. (author's study)

Table 3. The summary of the house rafter framing elements in Nowa Kościelnica

No.	RAFTERFRAMING ELEMENTS	QUAN.	DIMENSIONS [m]			VOLUME[m³]
			width	heigth	length	
1.	Rafters	2	0.17	0.30	8.90	0.91
2.	Upper collar beam	1	0.12	0.20	2.90	0.07
3.	Lower collar beam	1	0.16	0.23	7.00	0.26
					total:	1.24

The average volume of the construction material per square meter of roof slope plan:

$$s_3 = \frac{1.24\,\mathrm{m}^3}{1.40\,\mathrm{m} \times 11.80\,\mathrm{m}} = 0.075$$

4.1.4. Rybina

The arcaded house in Rybina no. 12 was built in the first quarter of 19th century [24]. The historic building is located in a hamlet about two kilometers from the centre of the village. It has a wooden frame and the log walls are not plastered. A risalit of a wooden log construction; at the top a boarded timber beam construction, based on 8 columns. The foundation is made of the brick. The rafter roof structure is two-collar-beam, the roof is covered with red pantile. Individual sections of the rafter framing elements are: rafters 16x23cm, collar beams: lower 16x18cm and upper 14x16cm (Tab. 4). Connection of the collar beam with the rafter with the simple lap joint (Fig. 16), connection of the rafters in the ridge with the lap joints. The slope inclination angle is 46° (Fig. 18). The number of trusses is 15, their spacing is 1.25m, the roof span is 11.50m. On the lower beam there are 4.5 cm thick boards. The structure is in good condition. The roofing is sealed. In 2017 the house was completely renovated. One roof truss was repaired by replacing a collar beam (Fig. 17). Gravitational ventilation of the attic is not disturbed, there is constant air circulation.

Fig. 16. Rybina – roof structure (author's own photography)

Fig. 17. Rybina – a new collar beam in the structure (author's own photography)

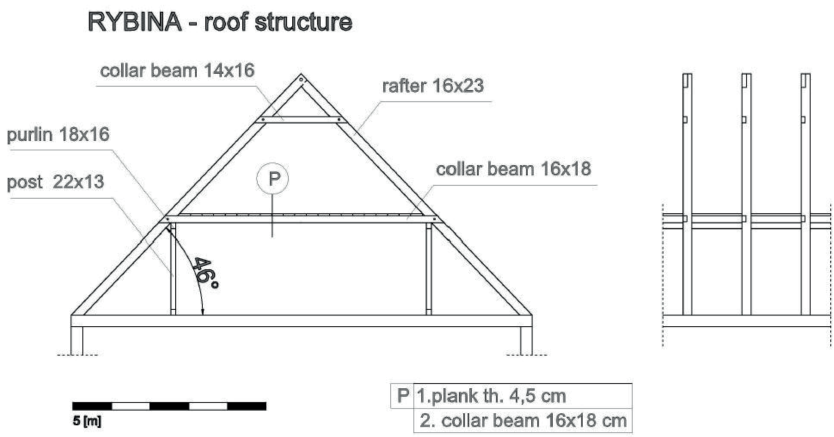

Fig. 18. The simplified scheme of the roof structure of the arcaded house in Rybina. (author's study)

Table 4. The summary of the house rafter framing elements in Rybina

No.	RAFTERFRAMING ELEMENTS	QUAN.	DIMENSIONS [m]			VOLUME[m³]
			width	height	length	
1.	Rafters	2	0.16	0.23	8.60	0.63
2.	Upper collarbeam	1	0.14	0.16	1.80	0.04
3.	Lower collarbeam	1	0.16	0.18	6.75	0.19
4.	Purlin	2	0.16	0.18	1.25	0.07
5.	Post	2	0.13	0.22	2.18	0.12
					total:	1.06

The average volume of the construction material per square meter of roof slope plan:

$$s_4 = \frac{1.06\,\mathrm{m}^3}{1.25\,\mathrm{m} \times 11.50\,\mathrm{m}} = 0.074$$

4.2. Houses not available for research

Other examined buildings are the arcaded houses in Lubieszewo (Fig. 19) and Żuławki (Fig. 20). Because it was not possible to make inventory of the attics, the current state of preservation of the rafter framing constructions cannot be described, nor can a typology of carpentry joints be made. In the conservation documentation of both houses there are no photographs that show details of the construction of roof trusses or information on their joints [17], [18]. On the basis of plans and vertical sections it was possible to obtain data for calculating the amount of wood used for the construction of the rafter framing structure. Additionally, on the basis of the analysis of available conservation documentation, it was possible to determine the types of rafter framing structures and make simplified schemes of trusses.

Fig. 19. The arcade house in Lubieszewo (author's own photography)

Fig. 20. The arcade house in Żuławki (author's own photography)

4.2.1. Lubieszewo

The arcaded house in Lubieszewo no. 29 was built in the first half of 19th century [20]. The historic building is located in the village, near the Ostaszewo – Nowy Dwór Gdański road. It has a wooden construction and the log walls are not plastered. A risalit of a half-timbered structure is based on 8 columns. The foundation is made of the brick and stone. The rafter roof structure is two-collar beams; the lower collar beam is supported with posts. The roof is covered with red pantile. Individual sections of the rafter framing elements are: rafters 17x28cm, collar beams: lower and upper 11x23cm, purlin 13x15cm, post 15x15 cm (Tab. 5). The slope inclination angle is 46° (Fig. 21). The number of trusses is 15, their spacing is 1.50m, the roof span is 11.65m [17].

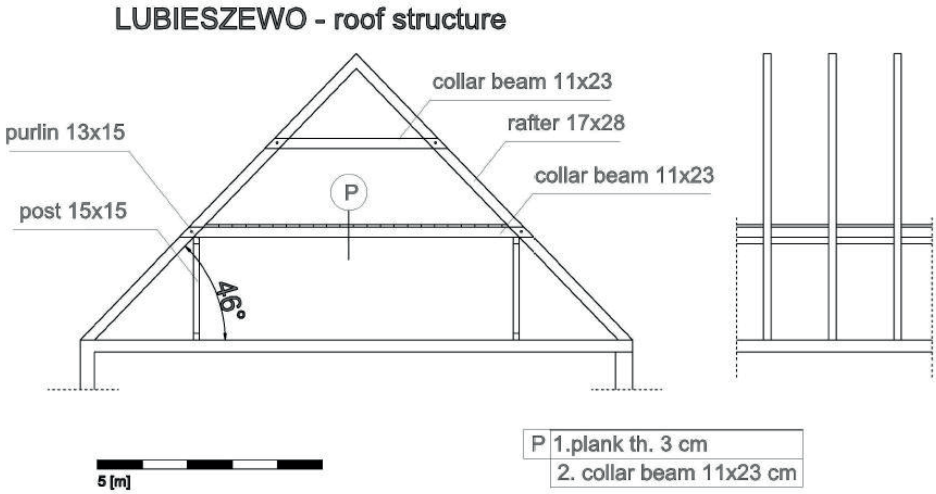

Fig. 21. The simplified scheme of the roof structure of the arcaded house in Lubieszewo (author's study)

Table 5. Summary of the house rafter framing elements in Lubieszewo

No.	RAFTERFRAMING ELEMENTS	QUAN.	DIMENSIONS [m]			VOLUME[m³]
			width	height	length	
1.	Rafters	2	0.17	0.28	8.40	0.80
2.	Upper collarbeam	1	0.11	0.23	3.45	0.09
3.	Lower collarbeam	1	0.11	0.23	7.25	0.18
4.	Purlin	2	0.13	0.15	1.50	0.06
5.	Post	2	0.15	0.15	2.00	0.09
					total:	1.22

The average volume of the construction material per square meter of roof slope plan:

$$s_5 = \frac{1.22\,\text{m}^3}{1.50\,\text{m} \times 11.65\,\text{m}} = 0.070$$

4.2.2. Żuławki

The arcaded house in Żuławki no. 32-33 was built in 1797 for Cornelius Froese. The arcade was added in 1851. The historic building is located in the village, near the Ostaszewo – Mikoszewo road. It has a wooden construction and the log walls are partly plastered. A risalit of half-timbered structure construction is based on 8 columns; the filling is made of the red small brick. The foundation is made of the brick. The rafter roof structure is two-collar-beam; the lower collar beam is supported by posts. The lower collar beam is covered with plates. The roof is covered with red pantile. Individual sections of the rafter framing elements are: rafters 16x21cm, collar beams: upper 13x18cm and lower 17x25cm, purlin 14x16cm, post 14x13cm (Tab. 6). The slope inclination angle is 48° (Fig. 22). The number of trusses is 14, their spacing is 1.40m, the roof span is 10.70m [18].

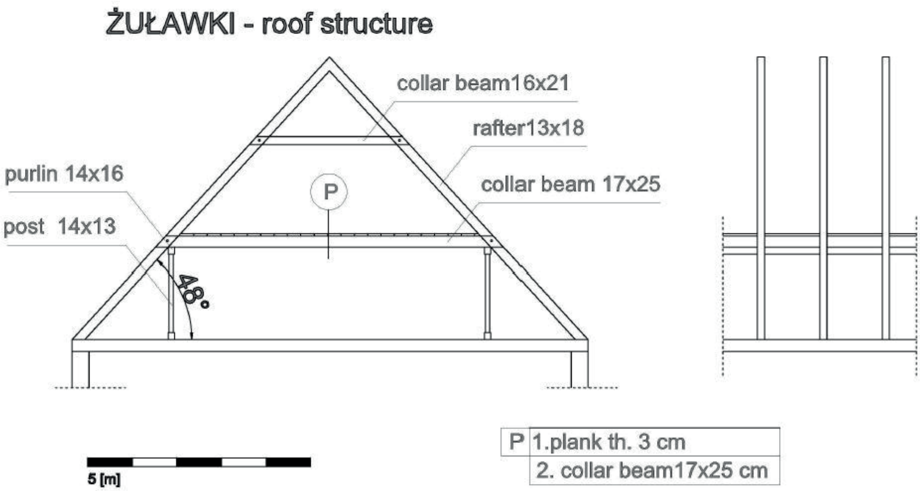

Fig. 22. The simplified scheme of the roof structure of the arcaded house in Żuławki. (author's study)

Table 6. The summary of the house rafter framing elements in Żuławki

No.	RAFTERFRAMING ELEMENTS	QUAN.	DIMENSIONS [m]			VOLUME[m³]
			width	height	length	
1.	Rafters	2	0.13	0.18	8.55	0.40
2.	Upper collarbeam	1	0.16	0.21	3.05	0.10
3.	Lower collarbeam	1	0.17	0.25	7.25	0.31
4.	Purlin	2	0.14	0.16	1.40	0.06
5.	Post	2	0.14	0.13	1.75	0.06
					total:	0.93

The average volume of the construction material per square meter of roof slope plan:

$$s_6 = \frac{0.93\,\mathrm{m}^3}{1.40\,\mathrm{m} \times 10.70\,\mathrm{m}} = 0.062$$

4.3. The summary of calculations

Table no. 7 (Tab. 7) presents a summary of the values of rafter inclination angles and the average volume of construction material per square meter of the roof slope plan for the arcaded houses analysed above. The objects in the table were listed chronologically, along with the number of trusses.

Table 7. Summary of the results of the analysis of arcaded houses

No.	Location:	The date of building of the house	The no. of trusses	angle [°]	Average vol. s_n[-]
1.	Żuławki	1797	14	48	0.062
2.	Marynowy	1804	18	43	0.098
3.	Bystrze	1819	15	45	0.074
4.	Rybina	1st quarter of 19th century	15	46	0.074
5.	Nowa Kościelnica	1840	15	47	0.075
6.	Lubieszewo	1st half of 19th century	15	46	0.070
			average:	45.83	0.075

5. Conclusions

The analysis of six objects revealed that the most common construction method of the roofs of the Żuławy arcaded houses of type III, from the end of the 18th century and the first half of the 19th century, is a two-collar roof truss. In four arcaded houses (Marynowy, Rybina, Lubieszewo, Żuławki) there are posts supporting the lower collar beam. In five arcaded houses, the lower beam was covered with plates from the top, which created a bare ceiling construction, with the exception of the roof structure of the house in Bystrze.

The volume of construction material per square meter of roof slope plan of the analysed arcaded houses is from 0.062 to 0.098; the average value for all houses is 0.075. The rafter inclination angle varies from 43° to 48°, which gives the average value for the analysed six historic buildings of 45.83°, approximately 46°. The number of trusses ranges from 14 to 18, most often it is 15. Similar dimensions of cross sections of structural elements of collar beams and rafters, as well as the way of their connection draw one's attention. In all houses in Bystrze, Marynowy, Nowa Kościelnica and Rybina the collar beams are connected with rafters with the simple lap joint and rafters in the ridge with the lap joint.

The study confirms the durability of wooden constructions. Despite the passage of many years, the main elements of the rafter framing in the Żuławy arcaded houses still fulfill their role in load transfer. The research also brings conclusions regarding the maintenance of wooden building constructions. The condition for good preservation of rafter framing is a sealed roof covering and lack of excessive moisture in construction elements. Good examples are houses in Nowa Kościelnica and Rybina. The roof constructions of arcaded houses in Bystrze and Marynowy require renovation of the roof covering. Their technical condition deteriorates year by year. Another factor contributing to the proper functioning of the construction is the undamaged gravitational ventilation of the attics. Constant air circulation guarantees the maintenance of proper wood humidity. Unfortunately, this does not eliminate the negative effects of leaking roof covering. None of the houses in Bystrze, Marynowy, Nowa Kościelnica, Rybina had any ventilation problems. Attics do not have sealed structure.

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References

[1] Kloeppel O., „Die bauerliche Haus-, Hof – Und Siedlungsanlage imWeichsel-Nogat-Delta. Danzig 1924

[2] Stankiewicz J., „Zabytki budownictwa i architektury na Żuławach". Rocznik Gdański, vol. XV/XVI. Gdańskie Towarzystwo Naukowe, Gdańsk 1956/1957

[3] Kotwica J., „Konstrukcje drewniane w budownictwie tradycyjnym". Arkady, Warszawa 2011

[4] Heurich J., „Przewodnik dla cieśli". Skład główny w Księgarni Gebethnera i Wolffa, Warszawa 1871

[5] Kopkowicz F., "Ciesielstwo polskie", Arkady, Warszawa 1958

[6] Michniewicz W., "Konstrukcje drewniane", Arkady, Warszawa 1958

[7] Mielczarek Z., "Budownictwo drewniane", Arkady, Warszawa 1994

[8] Neuhaus H., "Budownictwo drewniane". Polskie Wydawnictwo Techniczne, Rzeszów 2004

[9] Tajchman J., "Propozycja systematyki i uporządkowania terminologii ciesielskich konstrukcji dachowych występujących na terenie Polski od XIV do XX w.", Monument. Studia i Materiały Krajowego Ośrodka Badań i Dokumentacji Zabytków, no. 2/2005

[10] Jasieńsko J., Nowak T., Karolak A., „Historyczne złącza ciesielskie". Wiadomości konserwatorskie, no. 40, 2014

[11] Koperska-Kośmicka M., "Żuławskie domy podcieniowe. Przyczyny degradacji i problematyka konserwatorska zabytkowych struktur architektonicznych w środowisku kulturowym Delty Wisły". Rozprawa doktorska, Faculty of Architecure, Gdańsk University of Technology, 2012

[12] Zybała T., "Wpływ stanu zachowania materiału konstrukcyjnego na nośność zabytkowych drewnianych słupów, w żuławskich domach podcieniowych, z XVIII i XIX wieku". Budownictwo i Architektura, vol. 16., no. 3/2017. DOI: 10.24358/Bud-Arch_17_163_08

[13] Zybała T., "Techniczne problemy konstrukcji ścian szkieletowych na przykładzie zabytkowego domu podcieniowego w Gdańsku Lipcach". Przestrzeń Ekonomia Społeczeństwo no. 11/I/2017

[14] Specht A., „Dom podcieniowy. Inwentaryzacja konserwatorska - przeskalowanie – skala 1:50". Gdańsk 1978, signature [NID: P/02928]

[15] Szulc A., "Lipce. Dom Podcieniowy, Trakt św. Wojciecha nr 297". Inwentaryzacja. Gdańsk 1957, [sign. NID:P/00085]

[16] Kożuch A., "Miłocin. Dom podcieniowy nr 2." Inwentaryzacja. Gdańsk, 1957 [sign. NID: ZN/1826]

[17] Strumiłło I., „Lubieszewo. Dom mieszkalny nr 22". Inwentaryzacja.Gdańsk, 1957 [sign. NID: ZN/2995]

[18] Stankiewicz K., „Żuławki. Dom podcieniowy nr 32 - 33." Inwentaryzacja konserwatorska. Gdańsk 1980 [sign. NID: P/02749]

[19] Niezabitowska E.D., „Metody i techniki badawcze w architekturze". Gliwice, 2014

[20] Rejestr zabytków województwa pomorskiego, source: http://www.nid.pl/pl/Informacje_ogolne /Zabytki_w_Polsce/rejestr-zabytkow/zestawieniazabytkow-nieruchomych/, [Accessed: 05 JAN 2016]

[21] MonumentsRecord Card- Bystrze Dom mieszkalny podcieniowy nr 5 i 7 [sign. NID: 3713]

[22] Monuments Record Card - Marynowy – dom podcieniowy nr 42 (42/44) [sign. NID: 3850]

[23] MonumentsRecord Card - Nowa Kościelnica – dom podcieniowy nr 50/51 [sign. NID: 4146]

[24] MonumentsRecord Card - Rybina Budynek mieszkalny- dom podcieniowy nr 12a [sign. NID: 4524]

[25] Kapuściński A., „Drewniane więźby dachowe średniowiecznych kościołów Gdańska". Rozprawa doktorska, Faculty of Architecure, Gdańsk University of Technology, 2012

[26] nid.pl, [Accessed: 1 Dec 2015]

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Architecture and sounds the interdisciplinary research on the use of audio signals in the cognition and design of architectural space

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Abstract: In the contemporary world of image, the basic attribute of architecture is its visuality. Architectural spaces are designed primarily to be viewed by the public or the "eyes" of cameras. The design for the sense of sight only impoverishes the quality of human contact with architecture. The art of shaping space should involve all perception channels. One of the most important senses, allowing to feel the created space, to get to know it and live in it, is hearing. The sonic image of architectural space not only accompanies the visual image, but also significantly defines the quality of existential and aesthetic experiences. The architect's task should be to skilfully use acoustic signals as an integral part of the design process. This belief has inspired a multidisciplinary project entitled: "Sounds of architecture", devoted to the study of the phenomenon of sound and its significance in the perception and use of the architectural environment by people. This project was carried out under the guidance of the author in 2014-2015 with the involvement of representatives of various disciplines of science and art. The result of interdisciplinary research was the monograph "Sounds of Architecture", published in 2016.

Keywords: multi-sensory design, extra-visual perception, sound space, audiosphere

1. Introduction

In the perception of postmodern man, the outside world is the reality of the image. The human eye – an efficient, vigilant mechanism, reinforced with many objects ("extensions" of the natural sense), perfectly perceives, registers, researches, frames, freely zooms in or out images. Contrary to the primary laws of optics, today a man is able to "stop" transient visual phenomena and operate them perfectly, making images invaluable tools of social impact, non-verbal communication and manipulation [16].

In the postmodern world, the visuality is a fundamental attribute of architecture. The advantage of sight as a tool for cognition of architectural space manifests itself at all "levels" of perception processes: from unconscious perception of the background in search and identification of essential elements ("level" of impressions), through momentary focus on specific architectural images ("level" of observations), to fully conscious inspection of selected objects, allowing for their multi-criteria analysis and evaluation on the basis of obtained visual information ("level" of mental cognition).

Orthodox ocularcentrism, manifesting itself in the attitudes of the contemporary architects, but also in the expectations of their clients, seriously impoverishes the potential of architecture – multi-modal art, capable of providing usefulness and arousing admiration through various sensory channels [16], [17]. The progressive deprivation of other senses of the human sensory system leaves its mark on both the existential and aesthetic aspects of cognitive experience. Architecture – the art of shaping space should involve all perception channels (and thus, apart from the sense of sight, also the sense of touch, smell, taste and hearing), thus creating a complete, truly valuable image of the built space [12].

The above considerations inspired the author to search for "lost" languages of contemporary architecture. One of them remains the language of sounds - inherent, though definitely underestimated characteristics of the built environment. The belief that there is a multiple value in audio signals, still rooted in ancient architectural treatises and echoing back in successive epochs of the construction art, seems to require a special reminiscence. Especially today – in the era of visual architecture, oriented primarily on the use of visual information. These reflections became the basis for a multidisciplinary project entitled "Sounds of architecture", devoted to the study of the phenomenon of sound and its significance in the perception and use in the architectural space. This project was carried out by the author in 2014-2015 with the participation of the representatives of various disciplines of science and art.

The topic of sound in the literature on architecture is present mainly in specialist studies on urban acoustics and building acoustics (within the domain of engineering knowledge) [4], [15], [19], [23], [25]. The available sources concern mainly the issues of sound propagation as well as generating and correcting acoustic phenomena in urban and architectural space and interior design. Apart from these works, which continue the physical approach (the oldest scientific approach to acoustics), within the blurred boundaries of architecture, a trend of research on human sound environment is currently being developed, seeking scientific support within such disciplines as: architecture psychology, humanistic geography, sociology and cultural studies [16], [17], [26]. These sciences bring to architecture the notion of sound as a phenomenon, embedded not only in the biological and intellectual abilities of man, but also in his psyche, spirituality and cultural codes of the environment. One of the branches of this domain is interdisciplinary research in the field of shaping, protection and revitalisation of broadly understood landscape (including sound landscape), within the formula of sustainable urban development. The research is complemented by bio-architectural analyses of universal design, presenting the compensatory, but also complementary role of sounds as a language for reading the spatial environment.

The idea behind the "Sounds of Architecture" project was to take an interdisciplinary and possibly broad approach to the subject, presenting the phenomenon of sound from many different research perspectives. The aim of the scientific project was to present the potential of audio signals as an integral component of architecture, including active design material, but also as the way to a fuller experience of architectural space by man.

Representatives of various disciplines and areas of science, culture and art were invited to participate in the project, including urban planners, landscape architects, architects, interior designers, engineers, acoustics, anthropologists, culture experts, specialists in disability issues, museum workers, musicologists.

The starting point for the scientific discourse were the following suggestions:

1. Undesirable sounds. Discomfort and risks associated with acoustic phenomena.
2. Useful sounds. The use of sounds for spatial orientation and mobility.
3. Desired sounds. Sound as a generator of positive experiences. Emotional dimension of sounds. Sound aesthetics.
4. The sonosphere. Acoustic landscapes of places. The audiosphere. Phonetic identity of space. Protection of the audio landscape.
5. Acoustic ecology. Acoustic sterility.
6. Sounds of buildings, sounds in buildings.

7. Music and architecture. Houses for music. Analogy, complementarity, synergy of aesthetic experiences.
8. The phonosphere. Acoustic presence of a man in architecture. Spoken word as a tool for shaping the concept of architectural space.

The thesis for targeted, multi-author analyses became the conviction that the broadly understood "sounds of architecture" constitute a significant "layer" of architectural space, shaping the perception of the rich world of architecture.

2. The course, themes and results of the research

The research team consisted of 14 researchers representing the following universities and institutions: Faculty of Architecture and Faculty of Civil Engineering and Environmental Sciences of the Białystok University of Technology, Faculty of Civil Engineering and Architecture of the Lublin University of Technology, Faculty of Architecture and Faculty of Electronics of the Wrocław University of Technology, Faculty of Civil Engineering of the Częstochowa University of Technology, Faculty of Architecture and Faculty of Civil Engineering of the Kraków University of Technology, the National Museum in Kraków, Institute of Cultural Studies of the University of Wrocław, Maria Curie-Skłodowska University in Lublin. Specialist education and scientific experience of the authors made it possible to place selected topics of discussion in the context of a number of disciplines, including: technical-engineering sciences (architecture and urban planning, automatics, electronics and electrotechnics, civil engineering and transport), science and natural sciences (life sciences, Earth and environmental sciences), humanities (cultural and religious sciences, art sciences, history of art), social sciences (social communication sciences, socio-economic geography and spatial management, sociological sciences). Extensive and diverse professional background of the authors was an important asset to conduct research at the interfaces of disciplines, in unclear and not necessarily recognised areas.

The result of the work of the research team was a scientific monograph "The Sounds of Architecture" [7], containing a number of proprietary papers, presented in 5 thematic areas. Logically, the presentation of the research results is a transition from measurable criteria (physics and mathematical models of sound) to hardly measurable values of the acoustics of the architectural environment. In addition, a discussion on subjective issues of sound aesthetics and symbolism attributed to certain sounds was also held.

The scope and results of the research undertaken in particular 5 areas are discussed in the following subchapters of this text.

2.1. Sound issues in building physics

The first element of the research was to define the physical nature of sound and basic physical concepts essential for the purpose of scientific understanding of the phenomenon of the acoustic wave. The currently available methods of modelling acoustic phenomena as well as the most important properties and physical parameters of room acoustics were analysed. The elaboration of the discussed topic were the analyses of insulation of acoustic partitions and basic determinants of sound penetration through various building partitions. On the selected example of a partition, the values used for the assessment of acoustic insulation of building partitions were analysed. Attention was drawn to the current problem of inaccuracy of commercial information related to these parameters.

2.2. Architectural acoustics

The next step was to analyse the topics of the so-called architectural acoustics – a unique field of interdisciplinary cooperation between designers from different disciplines involved in the construction process. There were discussed the principles of this sometimes difficult inter-branch cooperation, subjected to achieve the desired results in three basic areas of acoustic design of buildings, including: noise protection, noise emission and interior acoustics. An attempt was made to identify the key problems of the design process and to indicate the rules for the optimisation of dialogue between acousticians and main designers, as well as between acousticians and other professionals [9].

A part of the research in this area was the analysis of architectural methods propagated from the 11th to the 16th century A.D., which involved embedding pots into the walls of pendentives or vaults of many representative buildings (including sacral buildings). Some sources indicate that they served as loudspeakers to improve the acoustics of buildings. This hypothesis is supported by the ancient treatise of Vitruvius, which provides practical advice on the use of copper, brown or clay pots in the construction of theatres [24]. At the same time, the literature on the subject also includes sources undermining the "acoustic" roots of this custom. Reasons for this are found, for example, in the engineering of construction (reduction of the weight of walls and vaults) or construction technology (mounting of scaffolding rods). Some of them give also liturgical or mystical explanations.

Two different architectural approaches representing the same idea of intentional use of sound as an important and noticeable "component" of architecture have been analysed. The first of the observed phenomena were architectural buildings with interiors designed in such a way as to be a kind of natural resonators. As it was proved, the desired acoustic effects in these interiors can be enhanced by such measures and components as: natural material, appropriately shaped surface tectonics, accurate geometry of the projection of the hollow space and the shape of the vault. The second of the analysed approaches exemplified architectural structures with artificial sonic environment. In the research, special attention was paid to the so-called multimedia projects, including interactive installations and sound sculptures, in which a key role is played by the human body's motility [3].

The last element of this area of research were analyses devoted to the issue of complementarity and proper correlation in architectural design of acoustic issues and visual aspects. As it has been demonstrated, the visible image of often extremely complicated acoustic solutions becomes particularly important in spaces with the so-called qualified acoustics, including prestigious concert halls, theatres, auditorium halls, etc. An inseparable element of the interior design composition are specialist spatial structures, ensuring appropriate acoustics, and at the same time significantly determining the aesthetic reception of interiors [6], [10].

2.3. Sound as a carrier of information in the architectural space

One of the parts of the extensive field of multisensory design was the research on contemporary use of sound in the Polish museum institutions. As it was observed, appropriate coding and reception of customised (in terms of language, narration, content, route variants, volume, etc.) announcements to visitors is a new social phenomenon and the unique fashion for interactivity (multimediality), increasing the value of museum exhibitions. The conducted research has also demonstrated the importance of such auxiliary solutions as universal and discreet tools to help the blind and visually impaired visitors, for whom an alternative soundtrack is often the only way to discover the collections of a museum [21].

While continuing research on the informational value of sounds for mobility and the use of architectural space by visually impaired audience, it was concluded that an accurate analysis of the phonic landscape - acoustic signals characteristic of certain places – can become an invaluable way for blind people to create mental images of urban space [11], [22]. This thesis was supported by an innovative method of orientation in the city area using the sounds of the environment, developed by an interdisciplinary team of Polish scientists in 2010 [20].

2.4. Acoustic identity of architectural space

The research carried out in this area opened the way to analysis of the problems of progressive loss of phonic identity in the areas of human residence. As it was noted, cities in different parts of the world are becoming more and more acoustically similar to each other, losing their unique acoustic character and thus deconstructing irrevocably coherent, polymodal image of the so-called "spirit of the place". Meanwhile, the unique repertoire of sounds associated with indigenous, local culture and contemporary social activity is an element that leaves unusual, vivid images in human memory, imprinting their aesthetic stigma to a degree not lesser than the colourful visual images of the surroundings. Thus, it has been proven that city design is a process in which it is necessary to consider the sounds produced by each component of the spatial structure. It has been suggested that one of the elements of multi-criteria analyses of urban space should be the preparation of maps that would valorise sound space on the basis of the perceptions of its inhabitants.

The subject of acoustic and architectural identity of cities was also pursued in the aspect of urban spaces that are dedicated to music. The analyses were carried out on the basis of unique realisations of Scandinavian concert halls constructed during the last years, which became recognisable elements (or even symbols) of the urban structure and the building blocks of a new identity of cities.

The subject of the team's research were also questions related to the so-called sound landscape of places and spaces. These analyses were conducted on the example of the audiosphere of residential complexes, realised in the 1970s and 1980s in Wrocław [13], [14]. Attention was drawn to the characteristic acoustic identity of residential spaces, created both by specific urban and architectural solutions, as well as by the habits of people. When analysing the sound environment of "blocks of flats", a characteristic difficulty in separating public and private spaces was observed (private sounds – sounds of home easily penetrate into the common space). The spectrum of research also covered the topics of subjective reception of housing estate sounds, analysed on the basis of interviews (statements of residents) obtained during field research.

An important element of this part of the research were analyses related to the subject of creative interference in the sound landscape of the city (acoustic revitalisation of the landscape) in order to restore authenticity, appropriate values or purity of the sound landscape. Attention was drawn to the growing interest of the public in the subject of sound identity, manifested for example by the creation of special "sound walks", "sound maps", "sound postcards". They are part of the promotional activities of many cities in Europe and all over the world, which use the so-called soundmarks (characteristic sounds which are the symbols of places) and sound landscapes. The research also identified the problem of increasing noise and pollution of the human sound environment associated with the rapid development of the automotive industry. The intention of the research was to demonstrate the need to take into account the potential of sounds in design and implementation processes aimed at revitalisation of urban spaces. Referring to R. M. Schafer's research [18], it was concluded that in practice, these activities should include maintenance, "repair" and proper design of sounds in given areas [1], [2].

Another important aspect of the architectural and phonic identity tandem was addressed in another research thread, focused on the analysis of rural areas in the Polish-Belarusian borderlands. As it was observed, the Orthodox communities living in these areas have preserved to this day the attributes of traditional cultures, in which the basic category of consciousness is determined by religion, combined with pagan demonology and animistic beliefs. Celebrated holidays, both those from the Julian calendar and ordinary family celebrations, were inseparably connected with traditional music and singing. They gave the proper setting to all important events and ceremonies, determined their course and character. As it was shown, these songs, resounding in human homes, their neighbourhoods and also in the countryside, should be treated as indispensable attributes shaping the identity of the spiritual culture of rural ethnic communities.

2.5. Sound as a carrier of emotions in architectural space

The final part of the research was devoted to the use of sound as a carrier of emotions in architectural space. The scientific discourse began with analyses of the issue of conscious use of sound in social rehabilitation of blind people. As was attempted to prove, conscious (properly supported) analysis of phonic signals can become a path to emotional, including aesthetic, experience of architectural space. This theory is supported by practice based on e.g. learning to shape spatial images through the language of music and sounds [5], [8]. Although they are used by some Polish therapists (and art-therapists), they are not always treated as equally important elements of multi-aspect typhlorehabilitation. As it was determined, issues related to the creation of emotional images of space do not currently have a solid scientific basis. Therefore, the use of rehabilitation possibilities of sound in this aspect requires further research, systematising this domain in theory and allowing it to be used in practice.

The closing element of the discourse was a scientific reflection on the concept of sacrum – the experience of the sacred, integrally connected with the reception of acoustic phenomena. The silence of sacral interiors and places of remembrance, where a conscious architectural procedure of cutting off from the outer audiosphere makes it easier for the recipients to achieve a state of contemplation and concentration, was "listened to" in a special way. Attention was drawn to the human need to commune with silence and the importance of silence in the contemporary world. The second aspect of the research – shaping the sense of sacrum through appropriate sounds - both those coming from nature and those being the product of conscious human activity – was also analysed. Two elements, which are the components of sacrum, elation (fascino) and the experience of horror (tremendum), were defined and explained.

3. Synthesis of research and further research perspectives

The interdisciplinary research carried out as part of the "Sounds of Architecture" project has revealed a number of multi-criteria architectural problems that can be solved by implementing the expertise in the domain of acoustics. As it was demonstrated, the effect of multidisciplinary cooperation can lead to a number of values experienced by users of architectural space at different spatial scales (large urban space, medium space of structures and buildings, small space of architectural interiors).

The results of a comprehensive research show, first and foremost, the following advantages:

- comfort of use and functionality of space (including collision-free use of complex spaces, functioning of special buildings dedicated to sound reception),
- safety and sense of security in using space,
- cognitive values (related to direct or indirect cognition of new places and facilities),
- informational values (including identification of places and objects, individual communication and social communication systems in the architectural space),
- cultural values (related to the identity and recognition of places)
- economic values (related to individual and mass tourism to places and buildings)
- creation of desirable social behaviours (usable culture),
- health and rehabilitation (including typhlorehabilitation),
- recreation (psychophysical regeneration in the sound landscape),
- aesthetics of sound,
- symbolism of sounds.

These properties seem to undoubtedly indicate the need for implementation and constant use of acoustic knowledge in the broadly understood domain of architecture. One should take into account its practical dimension (related to design, realisation, making available buildings and space, as well as space management), the creation of modern legislation and the issue of modern and wise education of architects – ensuring an appropriate level of practical training.

The discourse has revealed many complex issues within the designated research area. Individual research, which was an attempt to delve into selected panels and topics, is only a part of the research field, in which acoustics is intertwined with architectural knowledge and practice. In order to better identify and use the potential of sound in architectural and urban design, further discussion is needed with the aim of:

- extending and substantial complementing the issues indicated by the authors,
- supplementing the problem areas with threads that could not be developed by the appointed research team,
- successive identification and scientific development of new fields of acoustics that enter into the spectrum of architecture.

Among the topics that the author recognises as the coordinator of the project and the creator of the debate framework, there are in particular such issues as:

- Analogy of architectural art and music – this matter, although existing in the literature, did not find its place in the debate.
- Acoustic information and warning systems in the urban and architectural scale – this topic is discussed in the literature on safety in public space and the situation of the people with visual impairment and/or the elderly. In the described paper this topic is only mentioned, and it certainly requires particular attention and further elaboration.
- New methods and techniques of transmitting of acoustic information in tourism and city promotion – this topic, referring to new, universal tools of social communication (including tools linked to personal devices of visitors), is not included in the work. Due to the rapid technological development and evolving social expectations (including in particular the recognition of the needs of the people with disabilities), this field requires constant monitoring and updating of knowledge, but also its appropriate use in the field of architecture.

- The problems of the deaf and hard-of-hearing in the architectural space – despite invitations, the experts who could provide specialist knowledge in this domain didn't join our project. This area is currently not sufficiently recognised and popularised in the literature on architecture.

The outlined aspects, as well as the topics and hypotheses identified by the research team may serve as a starting point and inspiration for further research in the area of architecture, aiming at recognising the role of sound and its effective use in the design and reception of architectural space. Continuation of open discussion and simultaneous exploration of new research threads require the cooperation of a wide range of specialists representing various scientific disciplines, including branches of science defining scientific bridges between architecture and acoustics.

4. Summary

This paper is an attempt to draw attention to the enormous, but at the same time definitely underestimated potential of sounds in architectural experience. This issue still remains on the margin of education in the area of architecture and conducted scientific research. However, it requires a special mention, observation and adequate scientific basis. In the era of the primacy of the human eye, supported by the rapid development of visual technologies, we too easily limit the narrative potential of architecture only to the language of sight. Meanwhile, as the above publication has attempted to prove, auditory impressions, perceptions and experiences can have a huge role in creating and enriching the relations between a man and architectural space. Yet, this requires architects to master the "language" of acoustics, which enables them to control and use (eliminate, generate, correct, shape, nurture, etc.) specific phonic signals of the spatial environment.

A proper grasp of the problem of sounds in the design process may become a way to create architecture that better meets existential needs (readability, comfort, safety, recognition), but also aesthetic needs of a man (surprise, curiosity, beauty). The sketched depth and variety of auditory experiences while using architectural space seems to be sufficient to understand acoustics not only as a subsidiary branch, but even as a complementary part of architecture.

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References

[1] Bernat S., „Ochrona środowiska przed hałasem – podejście jakościowe", *Czasopismo Techniczne,* vol. 7-A, Kraków 2007, pp. 277-282.

[2] Bernat S., *Dźwięk w krajobrazie. Podejście geograficzne*. UMCS, Lublin 2015.

[3] Cisek E., „Interaktywna architektura dźwięku", *Czasopismo Techniczne*, 7-A/2010/2, vol. 15, 107, Kraków 2010, pp. 46-51.

[4] Chmielewski J. M., *Teoria urbanistyki w projektowaniu i planowaniu miast*. Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2005.

[5] Jutrzyna E., *Terapia muzyką w teorii i praktyce tyflologicznej*. Polski Związek Niewidomych Zakład Nagrań i Wydawnictw, Warszawa 2007.

[6] Kamisiński T., Szeląg A., Rubacha J, "Sound reflection from overhead stage canopies depending on ceiling modification", *Archives of Acoustic*, vol. 37, 2012, pp. 213-218.

[7] Kłopotowska A. [eds.], *Dźwięki Architektury*, Oficyna Wydawnicza Politechniki Białostockiej, Białystok 2015.

[8] Kłopotowska A., *Doświadczanie przestrzeni w rehabilitacji osób z dysfunkcją wzroku. Sztuka a tyflorehabilitacja*, Oficyna Wydawnicza Politechniki Białostockiej, Białystok 2016

[9] Kozłowski P. Z., Grządziel W., *Nowa siedziba Narodowej Orkiestry Symfonicznej Polskiego Radia w Katowicach. Akustyka wnętrz, ochrona przeciwdźwiękowa, elektroakustyka, technologia estradowa*. Pracownia Akustyczna Kozłowski sp. j. (within the Konior studio project), Wrocław 2010.

[10] Kulowski A., *Akustyka sal. Zalecenia projektowe dla architektów*. Wydawnictwo Politechniki Gdańskiej, Gdańsk 2011.

[11] Kuryłowicz E., *Projektowanie uniwersalne. Udostępnianie otoczenia osobom niepełnosprawnym.* Centrum Badawczo – Rozwojowe Rehabilitacji Osób Niepełnosprawnych, Warszawa 1996.

[12] Kusiak J., Świątkowska B [eds.], *Miasto – Zdrój. Architektura i programowanie zmysłów*. Fundacja Nowej Kultury Bęc – Zmiana, Warszawa 2013.

[13] Losiak R., „Miejskie pejzaże dźwiękowe. Z projektu badań nad audiosferą w doświadczeniu odbiorczym", [in:] A. Janiak, W. Krzemińska, A. Wojtasik-Tokarz [eds.], *Przestrzenie wizualne i akustyczne człowieka, Antropologia audiowizualna jako przedmiot i metoda badań*, Wydawnictwo Naukowe Dolnośląskiej Szkoły Wyższej Edukacji TWP, Wrocław 2007, pp. 237-246.

[14] Losiak R., „Zapamiętane brzmienia miasta. Zmiany w krajobrazie fonicznym Wrocławia w recepcji jego współczesnych mieszkańców", *Muzyka*, no. 1, 2014, pp. 119-147.

[15] Lynch K., *Obraz Miasta.* Archivolta, 2011.

[16] Pallasmaa J., *Oczy skóry*. Instytut Architektury, Kraków 2014.

[17] Rasmussen S. E., *Experiencing architecture*. Massuchusets Institute of Technology, Massachusets, 1959.

[18] Schafer R. M., „Muzyka środowiska", *Res Facta,* no. 9, 1982, p. 289-315.

[19] Sadowski J., *Akustyka architektoniczna*. PWN, Warszawa 1976.

[20] Talukder A., „Nowe spojrzenie na orientację przestrzenną", *Tyflświat,* no. 2(2), 2008.

[21] Trzeciakiewicz M. [eds.], *Audiodeskrypcja w teorii i praktyce*. Warszawa 2014.

[22] Wysocki M., *Projektowanie otoczenia dla osób niewidomych. Pozawzrokowa percepcja przestrzeni*. Wydawnictwa Politechniki Gdańskiej, Gdańsk 2010.

[23] Wejchert K., *Elementy kompozycji urbanistycznej*. Arkady, Warszawa 1984.

[24] Witruwiusz, *O Architekturze Ksiąg Dziesięć*. Prószyński i S-ka, 1999.

[25] Zakrzewski T., *Akustyka budowlana*. Politechnika Śląska, Gliwice 1997.

[26] Yi – Fu Tuan, *Space and place*. University of Minnessota Press, Minneapolis 1977.

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Assessment of therapeutic qualities of ten public parks in Bydgoszcz

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Abstract: This paper presents a binary rough assessment of ten public parks in Bydgoszcz, followed by a detailed assessment of one of them – Dolina Pięciu Stawów. The assessment was conducted using the universal pattern of design for health-affirming urban landscapes. The binary rough assessment results were satisfactory and similar for all parks. The results of the assessments indicated areas for possible improvement and can be used by the designers and inhabitants as justification for amendments. The major advantages of selected parks were qualities of space for mental and physical regeneration while the major deficiencies resulted from a lack of recreational equipment for various age groups and limited opportunities for social contacts. There were no major discrepancies and the fact that the rough assessment showed only little variation depending on the size of parks is proof of its limitation. This subjectivity of the rough evaluation was mitigated by a detailed assessment of Dolina Pięciu Stawów. This evaluation indicated further areas for improvement. The universal pattern of design for health-affirming urban places can be used as a ready-to-use tool.

Keywords: architecture, urban design, health-affirming urban places, health-affirming urban landscapes

1. Introduction

Living conditions in modern cities are indirectly linked to many lifestyle diseases. There is a direct link between the incidences of diseases and the distance from the place of residence to open green areas [1], [2]. Today, one of the key design problems is the creation of an urban environment that can promote the residents' health. Research evidence indicates that many factors have a positive impact on humans. One of them is architecture and urban design [3], [4]. Everyday contact with nature, the appropriate level of physical activity, the possibility of mental regeneration and satisfying social relations are linked to longevity and good health [5], [6]. It is a crucial challenge for the designers to create health-affirming places and urban landscapes. The definition of health-affirming landscapes implies that they unite the qualities of therapeutic landscapes, i.e. material aspects, social constructions, symbolic significances, and allegories of positive aspects of human health and well-being to influence people physical, mental and spiritual healing [7], [8]. A study by Japanese doctors demonstrated that senior's longevity relates to the frequency of park visits regardless. Neither gender differences nor social status discrepancies were observed [9]. Other studies evidenced the health impact of walking [10], [11].

The role of organized greenery is crucial for bringing people to nature. The natural areas and public parks can be used analogously, but the composed greenery has some advantages.

The first is of universal accessibility. The even surface of manmade pathways could facilitate navigation of park areas for people with reduced mobility and disabilities. The clear signage, benches, handrails, and ramps could embolden people who are scared of falling and prone to accidents due to any debilitating conditions. The organized forms of greenery can offer varied visual stimulation – invigorating or calming. Potential nuisances like poisonous, thorny or allergic plants could be avoided. Many of the therapeutic qualities could be enhanced by human intervention, e.g. framed views, long vistas, etc.

In this paper, the results of the study undertaken in the city of Bydgoszcz are presented. The city of Bydgoszcz was chosen because it is one of the greenest cities in Poland. There are numerous parks and green squares, therefore, there is plentiful material for comparison [12]. The public parks in Bydgoszcz are accessible and well maintained and therefore it was anticipated that the results would be relatively good.

2. Methods of assessment of health-affirming qualities

The health-affirming qualities were assessed using the author's original method – the universal pattern of design for health-affirming urban places (Tab. 1). This tool was developed using the triangulation of research evidence and field studies [13]. This tool can be used as an audit tool to determine the potential health affirming qualities of urban places. This pattern can be used to evaluate existing parks as well as a design tool to make improvements in open public green areas. In this study, the tool was expanded with the "access to park" category. This category is based on evidence which demonstrated that pleasant walkways to public parks are directly connected to increased frequency of visits to parks [14], [15], [16].

This tool was used to assess the therapeutic qualities of ten public parks in Bydgoszcz for a rough assessment, followed by a detailed assessment of one selected park – Dolina Pięciu Stawów. The selection of ten public parks was based on the criterion of accessibility, variety of size and functions and the pattern of the urban tissue. Ten popular parks with easy universal access either by foot or by bus were selected. The selection encompasses parks surrounded by a dense urban grid with high population density. The Balaton, Księżycowy and Dolina Pięciu Stawów could be treated as examples of urban regeneration projects.

Dolina Pięciu Stawów was chosen for detailed assessment because it is located in the center of the city and within close walking distance from numerous users. The health-affirming impact of this park design could be important. The size of this park is approx. 5 ha – it is an example of a pocket park. The other reason is that this park is a result of the successful urban regeneration project. It was created on a brownfield, which has an impact on soil and water quality [17], [18], [19].

Both the rough and detailed assessment was performed by one and the same researcher. Typically, one hour was spent in each park, more time was needed for larger parks with numerous equipment and garden features. All parks were visited between 01.06.2019 – 04.09.2019

Table 1. Universal pattern of design for health affirming urban places. Source: [13]

UNIVERSAL PATTERN OF DESIGN FOR HEALTH AFFIRMING URBAN PLACES					
1. UNIVERSAL DESIGN	2. PARK'S FUNCTIONAL PROGRAM	3. ORGANIZATION OF SPACE AND FUNCTIONS	4. PLACEMAKING	5. SUSTAINA-BILITY	6. ACCESS TO PARK
1.1 Place Area Location Surrounding urban pattern 1.2 Environmental characteristics Soil quality Water quality Air quality Noise level Biodiversity Forms of nature protection 1.3 Universal accessibility (addressing need of people with disabilities) 1.4 Access to park Distance to potential users Public transport stops Walkways to park	2.1. Psychological and physical regeneration Natural Landscapes Green open space Place to rest in the sun and in the shade Place to rest in silence and solitude Possibility to observe other people Possibility to observe animals 2.2. Social Contacts Enhancement Organization of events inside the park Gathering place for groups 2.3. Physical Activity Promotion Sports and recreational infrastructure Community gardens 2.4. Catering for basic needs Safety and security (presence of guards, cleanness, maintenance, etc.) Places to sit and rest Shelter Restrooms Drinking water Food (possibility to buy food in the park or close vicinities)	3.1. The park spatial composition follows the surrounding urban pattern 3.2. Architectural variety of urban environment Focal points and landmarks Structure of interiors and connections Long vistas (Extent) Pathways with views Invisible fragments of the scene (Vista engaging the imagination) Mystery, Fascination Framed views Human scale 3.3. Optimal level of complexity 3.4. Natural surfaces 3.5. Engaging features Risk/Peril Movement 3.6. Presence of Water 3.7. Sensory stimuli design Sensory stimuli: Sight Sensory stimuli: Hearing Sensory stimuli: Smell Sensory stimuli: Touch Sensory stimuli: Taste Sensory path	4.1. Works of Art 4.2. Monuments in the park 4.3. Historic places Culture and connection to the past 4.4. Thematic gardens 4.5. Personalization 4.6. Animation of place	5.1. Green Infrastructure 5.2. Parks of Second (New) Generation 5.3. Biodiversity protection Part of park not-available to visitors Native plants Native animals Natural maintenance methods 5.4. Sustainable water management Rainwater infiltration Irrigation with non-potable water Park in a flood risk zone 5.5. Urban metabolism 5.6. Ecological energy sources	6.1 Sidewalk Infrastructure Width of sidewalk Evenness of surface Lack of obstructions Slope Sufficient drainage 6.2 General conditions: Maintenance Overall aesthetics Street art Sufficient seating Perceived safety Buffering from traffic Street activities Vacant lots 6.3 Traffic Speed Volume Number and safety of crossings Stop signs On-street parking 6.4 User Experience Air quality Noise level Sufficient lighting Sunshine and shade Transparency of ground floors of building

2.1. The binary rough assessment of 10 public parks

Ten parks were chosen for assessment (Tab. 2). The size of selected parks ranged from 2 ha (Park Księżycowy) to 830 ha (Leśny Park Kultury i Wypoczynku Myślęcinek). The rough assessment was limited to therapeutic qualities of park area. The category "access to park" evaluation was limited to entrances to park.

Table 2. Parks chosen to analysis

1. Dolina Pięciu Stawów	6. Park Balaton
2. Botanical Garden	7. Park Załuskiego
3. Park Jana Kochanowskiego	8. Park nad starym kanałem
4. Park Henryka Dąbrowskiego	9. Park Księżycowy
5. Leśny Park Kultury Wypoczynku Myślęcinek	10. Park Kazimierza Wielkiego

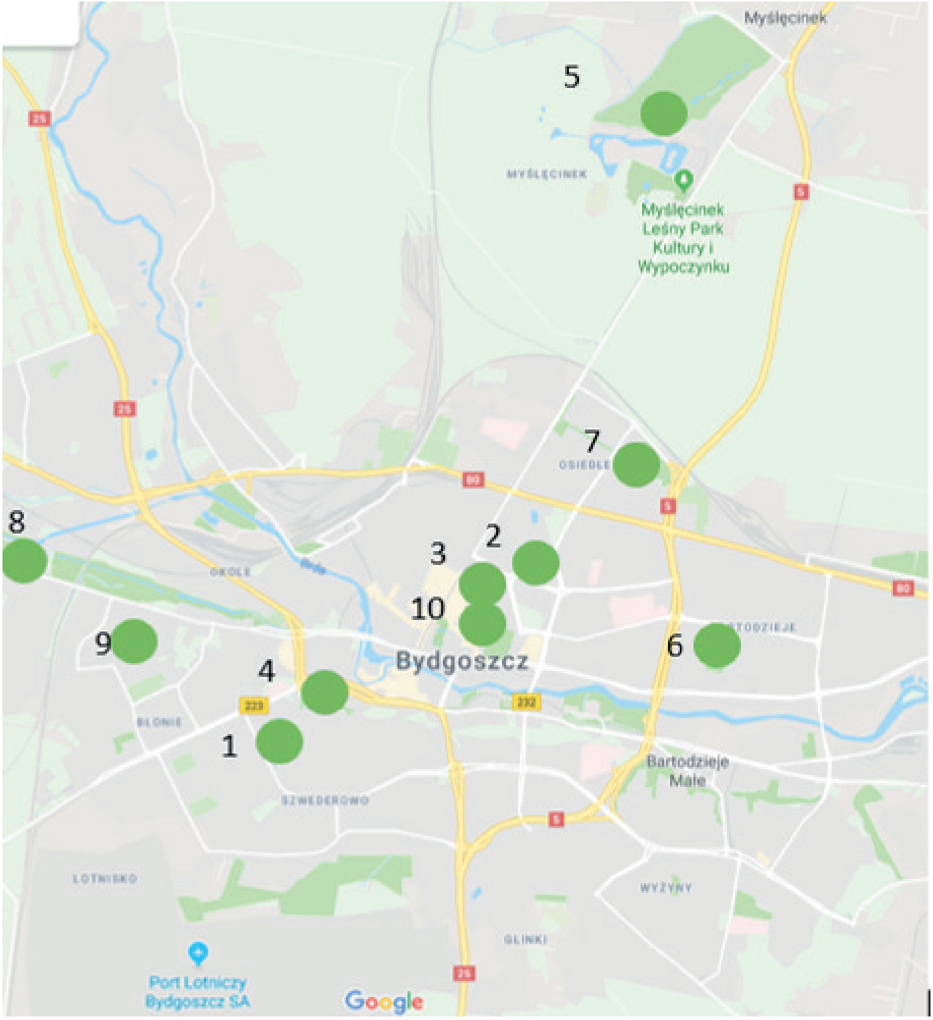

Fig. 1. Approximate location of studied parks in Bydgoszcz urban tissue. Map source: google maps, retrived on: 09.09.2019

Table 3. The rough assessment of ten public parks in Bydgoszcz

The Universal Pattern for Therapeutic Parks – attributes and characteristics	Selected public parks									
	1. Dolina Pięciu Stawów	2. Botanical Garden	3. Park Jana Kochanowskiego	4. Park Henryka Dąbrowskiego	5. Leśny Park Kultury i Wypoczynku Myślęcinek	6. Park Balaton	7. Park Załuskiego	8. Park nad starym kanałem	9. Park Księżycowy	10. Park Kazimierza Wielkiego
1. Universal design										
1.1 Place										
Area, approximately	5 ha	2,4 ha	3,2 ha	2,9 ha	830 ha	5,1 ha	16,9 ha	46,6 ha	2,0 ha	2,3 ha
Location	city centre	Bydgoszcz	Bydgoszcz	Bydgoszcz	Bydgoszcz	Bydgoszcz	Bydgoszcz	Bydgoszcz	Bydgoszcz	Bydgoszcz
Surrounding urban pattern	dense urban tissue	dense urban tissue	dense urban tissue,	dense urban tissue, steep slope	loose urban tissue, forest	dense urban tissue,	dense urban tissue,	dense urban tissue, riverfront	dense urban tissue,	dense urban tissue,
1.2 Environmental characteristics										
Soil quality	brownfield	good	good	good	good	recultivated brownfield	good	good	good	good
Water quality	historic retention ponds reconstructed from 2001-2003 and 2007 [19]	good	good	good	good	good	n/a	good	good	good
Air quality	very good according to polish air quality standards	very good	very good	very good	very good	very good	very good	very good	very good	very good
Biodiversity	rich in species	rich in species	rich in species	rich in species	rich in species	rich in species	rich in species	rich in species	rich in species	rich in species
Forms of nature protection	no	no	no	no	no	no	no	no	no	no
1.3 Universal accessibility	accessible	accessible	accessible	partially accessible, steep slope	accessible	accessible	accessible	accessible	accessible	accessible
1.4 Access to park										
Distance to potential users	less than 500m	less than 500m	less than 500m	less than 500m	Using public transportation, cars, bicicles, etc. Less than 1000m walking	less than 500m	less than 500m	less than 500m	less than 500m	less than 500m
Public transport stops	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Walkways to park	multiples	multiples	multiples	multiples	multiples	multiples	multiples	multiples	multiples	multiples

2. Park's functional program										
2.1. Psychological and physical regeneration										
Natural Landscapes	1	1	1	1	1	1	1	1	1	1
Green open space	1	1	1	1	1	1	1	1	1	1
Place to rest in the sun and in the shade	1	1	1	1	1	1	1	1	1	1
Place to rest in silence and solitude	1	1	1	1	1	1	1	1	1	1
Possibility to observe other people	1	1	1	1	1	1	1	1	1	1
Possibility to observe animals	1	1	1	1	1	1	1	1	1	1
2.2. Social Contacts Enhancement										
Organization of events inside the park	1	1	1	1	1	1	1	1	1	1
Gathering place for groups	1	1	1	1	1	1	1	1	1	1
2.3. Physical Activity Promotion										
Sports and recreational infrastructure	1	0	1	1	1	1	1	1	1	1
Community gardens	0	0	0	0	0	0	0	0	0	0
2.4. Catering for basic needs										
Safety and security	1	1	1	1	1	1	1	1	1	1
Places to sit and rest	1	1	1	1	1	1	1	1	1	1
Shelter	0	0	1	0	1	1	0	1	0	1
Restrooms	0	0	1	0	1	1	0	1	0	1
Drinking water	0	0	0	0	1	0	0	1	0	1
Food	0	0	0	0	1	0	0	1	0	1
3. Organisation of space and functions										
3.1. The park spatial composition follows the surrounding urban pattern	1	1	1	1	1	1	1	1	1	1
3.2. Architectural variety of urban environment	1	1	1	1	1	1	1	1	1	1
Focal points and landmarks	1	1	1	1	1	1	1	1	1	1
Structure of interiors and connections	1	1	1	1	1	1	1	1	1	1
Long vistas (Extent)	1	1	1	1	1	1	1	1	1	1
Pathways with views	1	1	1	1	1	1	1	1	1	1
Invisible fragments of the scene (Vista engaging the imagination)	1	1	1	1	1	1	1	1	1	1
Mystery, Fascination	1	1	1	1	1	1	1	1	1	1
Framed views	1	1	1	1	1	1	1	1	1	1
Human scale	1	1	1	1	1	1	1	1	1	1
3.3. Optimal level of complexity	1	1	1	1	1	1	1	1	1	1
3.4. Natural surfaces	1	1	1	1	1	1	1	1	1	1

3.5. Engaging features										
Risk/Peril	1	1	1	1	1	1	1	1	1	1
Movement	1	1	1	1	1	1	1	1	1	1
3.6. Presence of Water	1	1	1	1	1	1	0	1	1	1
3.7. Sensory stimuli design										
Sensory stimuli: Sight	1	1	1	1	1	1	1	1	1	1
Sensory stimuli: Hearing	1	1	1	1	1	1	1	1	1	1
Sensory stimuli: Smell	1	1	1	1	1	1	1	1	1	1
Sensory stimuli: Touch	1	1	1	1	1	1	1	1	1	1
Sensory stimuli: Taste	0	0	0	0	0	0	0	0	0	0
Sensory path	0	0	0	0	0	0	0	0	0	0
4. Placemaking										
4.1. Works of Art	0	1	0	0	1	0	1	1	0	1
4.2. Monuments in the park	0	1	0	1	1	0	1	1	0	1
4.3. Historic places										
Culture and connection to the past	1	1	1	1	1	1	1	1	1	1
4.4. Thematic gardens	0	1	1	1	1	1	0	1	1	0
4.5. Personalization	1	1	1	1	1	1	1	1	1	1
4.6. Animation of place	1	1	1	1	1	1	1	1	1	1
5. Pursuit of -sustainable development										
5.1. Green Infra-structure	1	1	1	1	1	1	1	1	1	1
5.2. Parks of Second (New) Generation	1	1	1	1	1	1	1	1	1	1
5.3. Biodiversity protection										
Part of park not-available to visitors	1	1	1	1	1	1	1	1	1	1
Native plants	1	1	1	1	1	1	1	1	1	1
Native animals	1	1	1	1	1	1	1	1	1	1
Natural maintenance methods	1	1	1	1	1	1	1	1	1	1
5.4. Sustainable water management										
Rainwater infiltration	1	1	1	1	1	1	1	1	1	1
Irrigation with non-potable water	Data n/a	Data n/a	Data n/a	Data n/a	Data n/a	Data n/a	Data n/a	Data n/a	Data n/a	Data n/a
Park in a flood risk zone	no	no	no	no	no	no	no	yes	no	no
5.5. Urban metabolism	1	1	1	1	1	1	1	1	1	1
5.6. Ecological energy sources	Data n/a	Data n/a	Data n/a	Data n/a	Data n/a	Data n/a	Data n/a	Data n/a	Data n/a	Data n/a
TOTAL	41	43	44	43	48	44	42	48	43	46

The binary assessment used 1 for presence and 0 for the absence of the given attribute. Therefore, it only allowed for notification if determined quality or equipment were present in the park. It was not possible to indicate that in larger parks there are multiple options, while in smaller parks they were limited to only one. For example, only one green open space to organize a group aerobics in a smaller park, and multiple open green spaces where simultaneous group aerobics for various age groups could be organized.

The results of this study demonstrated that the major advantages of selected parks were qualities of space for mental and physical regeneration, traditionally associated with public parks in Bydgoszcz.

At the same time, the major deficiencies resulted from a lack of recreational equipment for various age groups and opportunities for social contacts. It would be important to provide more seating alongside the pedestrian paths and moveable chairs for informal meetings. The basic needs of users could be satisfied better if there were public toilets, garden pavilions providing shelter, drinking fountains, and fruit-bearing plants and trees. Collective gardens could also be installed within public parks to increase opportunities for social contacts and therapeutic gardening.

As expected, the binary rough assessment results were satisfactory and similar for all 10 parks selected. There were no major discrepancies. The fact that the rough assessment showed little variation depending on the size of parks is proof of its limitation. Although the largest park in Myślęcinek scored 48 points, a bit more than smaller parks, the variation was not strongly pronounced. That may be also a proof that the parks studied were well-equipped and maintained.

Therefore in this study, after the binary rough assessment, one park was chosen for detailed assessment. This subjectivity of the rough evaluation was mitigated by a detailed assessment. The assessment also demonstrates the method of use of the universal pattern. The assessment could be repeated and performed for any public green space.

2.2. The detailed assessment of Dolina Pięciu Stawów public park

Fig. 2. Location and rough borders of Dolina Pięciu Stawów park in Bydgoszcz. Source of map: geoportal360.pl, retrived on: 01.11.2019

Table 4. Assessment of health-affirming urban place – Dolina Pięciu Stawów public park.
Part 1. UNIVERSAL DESIGN

1. UNIVERSAL DESIGN	Rough assessment	Detailed assessment	Suggestions for improvement
1.1 Place			
Area, approximately	5 ha		
Location	city centre		
Surrounding urban pattern	dense urban tissue	Multifamily building blocks, townhouses, large surface commercial centre.	
1.2 Environmental characteristics			
Soil quality		Sufficient for recreational use. No visibles tracks of pollution	
Water quality	historic retention ponds reconstructed from 2001-2003 and 2007 [17]	Non-potable water in the ponds. No swimmimg allowed	
Air quality	very good according to polish air quality standards	Good air circulation, plants and water improve local microclimate.	
Noise level	moderate	Noise nuisance originates from traffic in streets adjacent to park	
Biodiversity	rich in species	Ponds have become a habitat for many species of insects and birds. Tables in the park explain the strive for biodiversity protection.	
Forms of nature protection	no		
1.3 Universal accessibility	accessible	Pathways are wide and even, majority of park's area is accessible.	Accessibility could be improved.
1.4 Access to park			
Distance to potential users	less than 500m	People who live in surrounding buildings, people who use public transport, clients from the commercial centre.	
Public transport stops	yes	Bus stops are located next to park's entrances.	

1. UNIVERSAL DESIGN	Rough assessment	Detailed assessment	Suggestions for improvement
Walkways to park	multiple, park is not fenced, therefore is easily accessible	Additional evaluation of streets leading to park presented below.	

The qualities evaluated in Table 1 are based on objective data retrieved from officially published data and subjective assessment by the researcher. The water quality measurements taken in the park was described by Marcin Gorączko in 2007 [19]. The ponds are located in close vicinity of a former chemical factory, therefore, the water included an excessive amount of silver compounds in 2007 [19]. However, the subjective observation of the phytoremediation process results in summer 2019 led to the conclusion that water in the ponds is inhabited by the biodiversity of plants. The colonies of mallards *Anas platyrhynchos* were observed in the ponds. Moreover, during the park visit, the practice of recreational fishing was observed. However, the ponds are not open to swimming and the water is marked as non-potable.

The air quality is measured by a station located in Plac Poznański in close distance to the park. The results on 31.10.2019 during the heating season in Poland were presented as very good (Fig. 2).

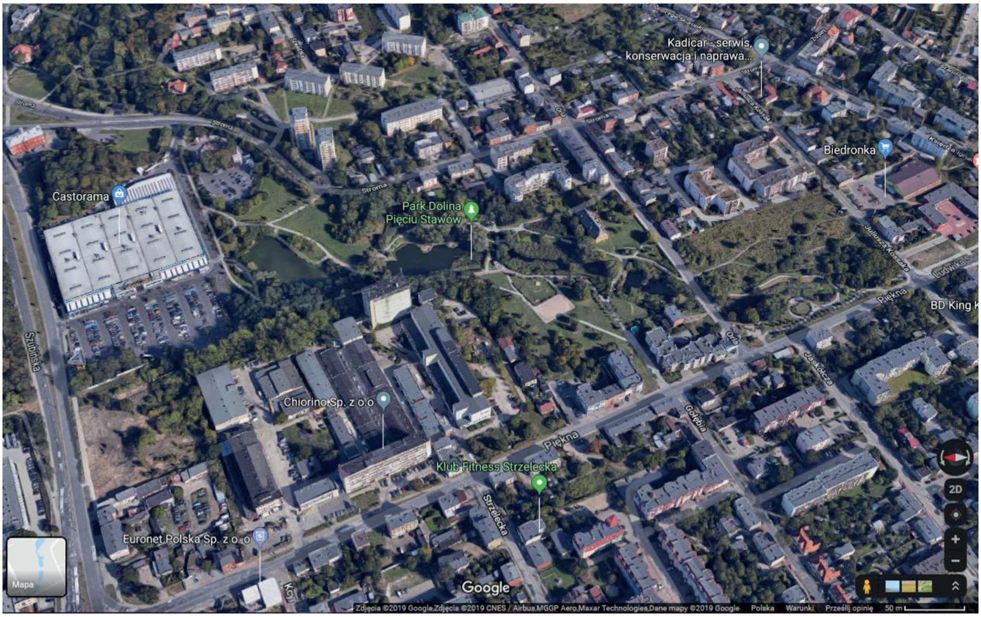

Fig. 3. Aerial photo of Dolina Pięciu Stawów park in Bydgoszcz presenting the surrounding urban tissue. Source: google maps, retrieved on: 09.09.2019

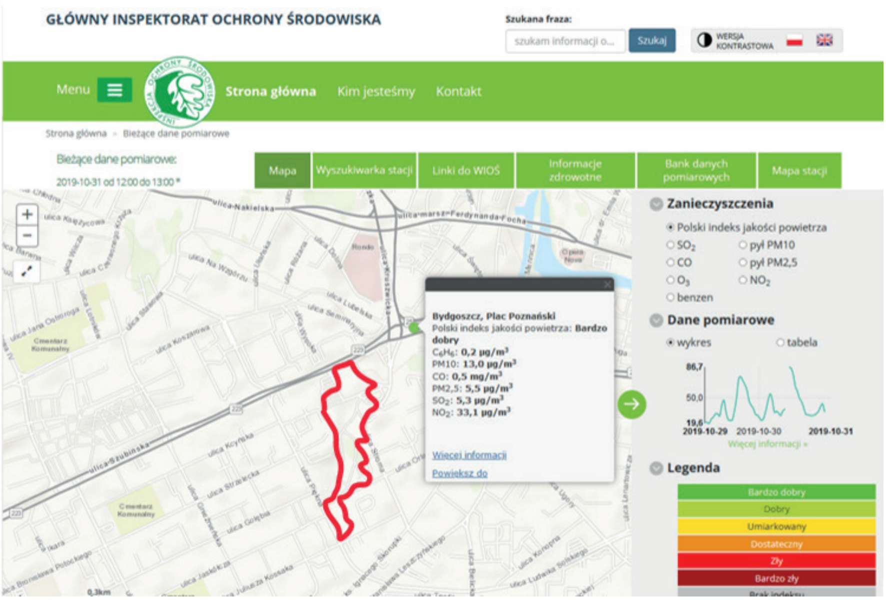

Fig. 4. Fragment of map representing air quality measurement system location near the Dolina Pięciu Stawów Park and air quality indicators on 31.10.2019 afternoon, Measurement station: Bydgoszcz, Plac Poznański, Polish air quality index: Very good, data source: http://powietrze.gios.gov.pl/pjp/current, retrieved on: 31/10/2019

Fig. 5. Fragment of road noise map LDWN prepared for the city of Bydgoszcz presenting the area of the Dolina Pięciu Stawów Park, source: http://mapy.bydgoszcz.pl/VisMap/apps/Bydgoszcz/public/index.html, retrieved on 31.10.2019

One of the minor nuisances present in the park was the traffic noise. The noise level was moderate close to the parking lots located near the large surface shopping center, but not disturbing inside the park. The incidences of noise level exceeding the permissible levels of noise did not concern the area of the park (Fig. 4). However on the streets leading to the park, the noise levels were exceeded on Szubińska and Piękna streets.

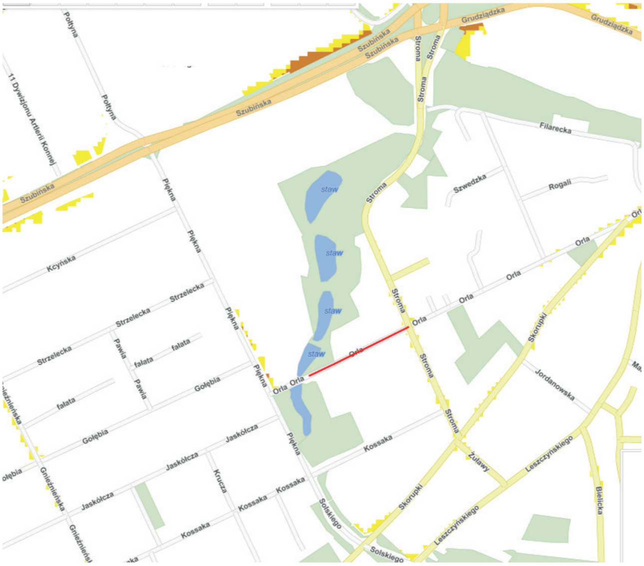

Fig. 6. Fragment from the map of exceedances of permissible levels of road noise LDWN in the city of Bydgoszcz presenting the area of the Dolina Pięciu Stawów Park, source: http://mapy.bydgoszcz.pl/VisMap/apps/Bydgoszcz/public/index.html,, retrieved on 31.10.2019

The assessment of therapeutic qualities of public park determined following strong points of the park: natural scenic beauty which can be associated with lots of opportunities for physical and mental regeneration (Fig. 2), universal accessibility, well-defined connections to green infrastructure, protection of biodiversity and wildlife. These points are crucial and responsible for this park's popularity among users as they explained to the researcher during the study.

Table 5. Assessment of health-affirming urban place – Dolina Pięciu Stawów public park. Part 2. PARK'S FUNCTIONAL PROGRAM

2. Park's functional program	Rough Binary Assessment	Detailed Assessment	Suggestions for improvement
2.1. Psychological and physical regeneration			
Natural Landscapes	1	Natural borders created with maturing trees create parks interiors which give impression of pristine natural landscape.	
Green open space	1	Multiple	

2. Park's functional program	Rough Binary Assessment	Detailed Assessment	Suggestions for improvement
2.1. Psychological and physical regeneration			
Place to rest in the sun and in the shade	1	Multiple	The benches should have backrests and armrests.
Place to rest in silence and solitude	1	Numerous places.	
Possibility to observe other people	1	There are many places to observe activities of other people. It is a form of effortless social contact – emotional participation, required for psychological restoration [20].	
Possibility to observe animals	1	There are many places to observe wildlife (birds, i.e. colonies of mallards *Anas platyrhynchos*)	
2.2. Social Contacts Enhancement			
Organization of events inside the park	1	Open green areas can serve to organise events.	
Gathering place for groups	1	There are spatial possibilities to organize meetings.	
2.3. Physical Activity Promotion			
Sports and recreational infrastructure	1	Limited recreational infrastructure for children.	It would be beneficial to install new recreational infrastructure for various age groups.
Community gardens	0	There are no community gardens inside the park.	Park's space offers possibilities for organizing the community gardens.
2.4. Catering for basic needs			
Safety and security	1	Subjectively assessed by the researcher as safe place. Park is well maintained, clean and offers good visibility. Constant presence of park users was observed. Good visability. Park space is monitored.	
Places to sit and rest	1	There are numerous benches.	It would be useful to build a garden pavilion with running potable water and electricity.
Shelter	0	There are no man made shelters in the park. Visitors can find provisional shelter under the canopies of trees.	It would be useful to install a garden pavilion.
Restrooms	0	Not in the park. However, there are toilets in the commercial centre nearby.	It would be useful to construct a public toilet in the park.
Drinking water	0	Not in the park. However, there is drinking water fountain in the commercial centre nearby.	It would be useful to install a drinking fountain in the park.

2. Park's functional program	Rough Binary Assessment	Detailed Assessment	Suggestions for improvement
2.1. Psychological and physical regeneration			
Food	0	Not in the park. However, there are food stands in the commercial centre nearby.	It would be useful to allow construction of a food stand in the park

On the other hand, the assessment helped to determine opportunities for improvement, which included: lack of comfortable seating for the elderly and disabled (with backrests and armrests), lack of recreational equipment for various age groups of children and adults, neither community gardens nor edible plants and no garden pavilions to provide shelter. Providing satisfactory infrastructure for various groups of users is crucial for placemaking efforts. However, various groups have different needs and careful design is needed to minimize possible conflicts of groups of users with different needs. Other points for improvement could be to install a table with a description of the history of this place, drinking fountains, improve orientation with better pronounced focal points and pockets of activities and install equipment to facilitate meetings and gatherings, e.g. open-air theatre.

Table 6. Assessment of health-affirming urban place – Dolina Pięciu Stawów public park.
Part 3. ORGANISATION OF SPACE AND FUNCTIONS

3. Organisation of space and functions	Rough Binary Assessment	Detailed Assessment	Suggestions for improvement
3.1. The park spatial composition follows the surrounding urban pattern	1	Park is well inscribed into surrounding urban tissue.	
3.2. Architectural variety of urban environment			
Focal points and landmarks	1	The sculptural forms at the crossroads of pedestrian paths	It would be useful to install focal points that would be more pronounced.
Structure of interiors and connections	1	Clear, legible structure of interiors and connections.	
Long vistas (Extent)	1	Yes, parks offers numerous picturesque long vistas	
Pathways with views	1	Yes.	
Invisible fragments of the scene (Vista engaging the imagination)	1	Yes, numerous designed vistas engaging the imagination	
Mystery, Fascination	1	Parks offers the feeling of mystery and fascination.	

3. Organisation of space and functions	Rough Binary Assessment	Detailed Assessment	Suggestions for improvement
Framed views	1	Numerous framed views.	
Human scale	1	Park is designed in human scale.	
3.3. Optimal level of complexity	1	Subjectively evaluated as satisfactory.	
3.4. Natural surfaces	1	Yes.	
3.5. Engaging features			
Risk/Peril	1	Multiple elements offer the subjective feeling of overcoming controlled risk.	
Movement	1	Water in the ponds and cascades, shimmering greenery.	
3.6. Presence of Water	1	Presence of water increases the recreational values of space.	
3.7. Sensory stimuli design			
Sensory stimuli: Sight	1	Numerous features, variety of visual stimuli, rich in details	
Sensory stimuli: Hearing	1	Shimmering water in the cascades	
Sensory stimuli: Smell	1	Groups of plants with strong and pleasant scent, water.	
Sensory stimuli: Touch	1	Groups of plants with various textures, water.	
Sensory stimuli: Taste	0	No.	It would be useful to plant edible plants, allow food trucks or food stands in the park
Sensory path	0	No	It is recommended to create a sensory path

The organization of space and functions of Dolina Pięciu Stawów was evaluated as satisfactory. The architectural structure is legible and well-organized. Parks offers various possibilities for physical and mental regeneration: engaging features, sensory stimuli and optimal level of complexity. The proposed suggestions for improvements included planting some edible plants (e.g. fruit trees), allowing food trucks or food stands in the park. It would be also recommended to create a sensory path.

Table 7. Assessment of health-affirming urban place – Dolina Pięciu Stawów public park. Part 4. PLACEMAKING

4. Placemaking	Rough Binary Assessment	Detailed Assessment	Suggestions for improvement
4.1. Works of Art	0	No.	It could be interesting to organise temporary exhibitions of sculpture in the park.
4.2. Monuments in the park	0	House located next to park, at Orla 66 is inscribed in the register of national monuments. The building was for sale and required renovation [23]	It is recommended to renovate the historic house located at Orla 66 and remodel it to serve as shelter with restrooms, food and water. (e.g. café or restaurant)
4.3. Historic places			
Culture and connection to the past	1	Historic retention ponds and water reservoirs.	It could be interesting to install a table with this place history.
4.4. Thematic gardens	0	No.	It could be interesting to install thematic gardens in this park.
4.5. Personalization	1	During events organised by local government and associations	
4.6. Animation of place	1	During events organised by local government and associations	

The park visitors interviewed during this study emphasized the strong place identity of Dolina Pięciu Stawów public park. The open green area could be a place for the organization of local events like temporary exhibitions of sculptures or tables with the description of local history. Thematic gardens could also enrich the phenomenon of local identity.

Table 8. Assessment of health-affirming urban place – Dolina Pięciu Stawów public park. Part 5. PURSUIT OF -SUSTAINABLE DEVELOPMENT

5. Pursuit of -sustainable development	Rough Binary Assessment	Detailed Assessment	Suggestions for improvement
5.1. Green Infrastructure	1	Park is an important part of green and blue infrastructure.	
5.2. Parks of Second (New) Generation	1	Can be regarded as such.	

5. Pursuit of -sustainable development	Rough Binary Assessment	Detailed Assessment	Suggestions for improvement
5.3. Biodiversity protection			
Part of park not-available to visitors	1	Parts of ponds.	Provide enclosures for wildlife not available to visitors.
Native plants	1	Yes. Native plants were observed.	Increase the percentage of native plants.
Native animals	1	Yes. Native animals were observed.	
Natural maintenance methods	0	No data	
5.4. Sustainable water management			
Rainwater infiltration	1	Porous, permeable surfaces on some pathways	
Irrigation with non-potable water	Data n/a		It is recommended to use non-potable water for irrigation.
Park in a flood risk zone	yes	Partially [17, 18, 19]	
5.5. Urban metabolism	1	Waste segregation.	
5.6. Ecological energy sources	Data n/a		It is recommended to use ecological energy sources

The efforts for sustainable development were assessed as satisfactory. The suggestions included increasing the percentage of native plants and providing enclosures for wildlife not available to visitors. Another improvement could include using ecological energy sources (photovoltaic cells) for lighting or non-potable water for irrigation when necessary.

Fig. 7. The scenic beauty of Dolina Pięciu Stawów, 2019, author's photo

The results of the detailed evaluation of access to the park demonstrated that there were some deficiencies.

Nine streets were evaluated: Szubińska, Piekna, Orla, Stroma, Kossaka, Kcyńska, Strzelecka, Gołębia, and Jaskółcza. The traffic and noise level were important, but some deficiencies of sidewalks and drainage were also observed on Piekna, Orla, Stroma, and Kossaka streets. Lack of ramp for the disabled alongside the stairs was marked as a crucial deficiency of Szubińska street. Kcyńska, Strzelecka, Gołębia, and Jaskółcza were recently renovated and therefore the walking experience alongside those streets was evaluated as more pleasant. What was noted was lack of seating along all of the streets leading to the park which could hinder the frequency of park visits, especially among the elderly. Street greenery could also be improved and rain gardens installation could be beneficial.

3. Conclusions

This study confirmed that chosen parks in Bydgoszcz have numerous health-affirming qualities, but there are still possibilities for improvement. The detailed assessment of Dolina Pięciu Stawów indicated areas for possible improvements and facilitated the formulation of design recommendations.

Moreover, this study leads to the conclusion that the universal pattern of design for health-affirming urban places can be used as a ready-to-use tool. It is a useful addition to classic inventory of analyses commonly used in landscape architecture (such as functional and spatial, nature, compositional, sensual analysis, etc.) It offers the possibility to assess both objective and subjective health-affirming qualities of landscapes. This tool was created to facilitate the Evidence-Based Design of public parks with therapeutic qualities. It can be used alongside other tools like SOPARC [21], [22] to evaluate the design and performance of public parks and justify the introduction of advisable changes. SOPARC can be used for the assessment of park users' physical activity, while the universal pattern is a tool for the evaluation of physical features and design qualities of public parks and their vicinities.

The main conclusion resulting from this study is the confirmation that the assessment of the therapeutic qualities of any public park should not be performed alone without the careful assessment of the urban tissue which surrounds it. The qualities of walkways to the park are as important as the qualities of the public park to create health affirming urban places. The results of a detailed assessment of Dolina Pięciu Stawów demonstrated that there could be numerous opportunities for improvement of the user experience and frequency of contacts with nature by improving the walkways to park. On the other hand lack of proper maintenance of sidewalks can hinder the health-affirming effects of any therapeutic park.

Table 7. Assessment of health-affirming urban place – Dolina Pięciu Stawów public park. Part 6. ACCESS TO PARK

6. ACCESS TO PARK									
STREETS	Szubińska	Piękna	Orla	Stroma	Kossaka	Kcyńska	Strzelecka,	Gołębia,	Jaskółcza
6.1. Sidewalk Infrastructure									
Width of sidewalk	good	narrow	narrow	narrow	Too narrow	good	narrow	narrow	narrow
Evenness of surface	good	good	Partially uneven	uneven	Uneven, unpaved	yes	yes	yes	yes
Lack of obstructions	Stairs, no ramp	Lack of obstructions	Lack of obstructions	Cars parked on sidewalks	Cars parked on sidewalks	Cars parked on sidewalks	Lack of obstructions	Lack of obstructions	Lack of obstructions
Slope	Not important	Not important	Not important	Important steep slope	Not important	Not important	Not important	Not important	Not important
Sufficient drainage	sufficient	sufficient	Lack of drainage	Lack of drainage	Lack of drainage	Sufficient drainage	Sufficient drainage	Sufficient drainage	Sufficient drainage
6.2 General conditions									
Maintenance	good	good	good	Requires renovation	Requires renovation	good	good	good	good
Overall aesthetics	good	good	good	Requires renovation	Requires renovation	good	good	good	good
Street art	no	no	no	no	no	no	no	no	no
Sufficient seating	no	no	no	no	no	no	no	no	no
Perceived safety	good	varying	no	no	no	good	good	good	good
Road noise	Noise levels exceeded	Noise levels exceeded	moderate	moderate	moderate	moderate	moderate	moderate	moderate
Buffering from traffic	Partially with greenery	Partially with greenery	no	Partially with greenery	Partially with greenery	Buffering with greenery	Buffering with greenery	Buffering with greenery	Buffering with greenery on one side
Street activities	no	no	no	no	no	no	no	no	no
Vacant lots	yes	Yes, temporary parking lots	yes	yes	yes	yes	yes	yes	yes
6.3 Traffic									
Speed	important	important	slow	slow	slow	slow	slow	slow	slow

Volume	Important, main road	important	little	little	little	little	little	little	little
Number and safety of crossings	Street lights, safe	One safe	One safe	no	multiples	no	no	no	no
Stop signs	no	no	no	no	no	no	no	yes	yes
On-street parking	prohibited	prohibited	yes	yes	yes	yes	yes	no	no
6.4 User Experience									
Air quality	average	average	average	average	average	average	average	average	average
Noise level	important	average	average	average	average	average	average	average	average
Sufficient lighting	yes	yes	average	Requires renovation	Requires renovation	yes	yes	yes	yes
Sunshine and shade	lack of trees providing shade on one side	Trees provide shade	Trees provide shade	Trees provide shade	Trees provide shade	no	Trees provide shade	Trees provide shade	Trees provide shade
Transparency of ground floors of building	Commercial centre – lack of transparency	Residential floors	Residential floors	Residential floors, individual parking	Residential floors, individual parking	Residential floors, individual parking	Residential floors, walls, individual parking	Residential floors, walls, individual parking	Residential floors, walls, individual parking

References

[1] World Health Organization, *Social determinants of health. The solid facts.* Second edition. 2003. ISBN 92-890-1371-0

[2] Maas J., Verheij RA., "Morbidity is related to a Green living environment", *Journal of Epidemiology & Community Health*, vol. 63(12), 2009, pp. 967-973.

[3] Cooper-Marcus C., Sachs N., "Theory, Research, and Design Implications", [in:] *Therapeutic Landscapes. An Evidence-Based Approach to Designing Healing Gardens and Restorative Outdoor Spaces*. John Wiley & Sons, Inc., Hoboken, New Jersey (2014), pp 14-35.

[4] Largo-Wight E., "Cultivating healthy places and communities: evidenced-based nature contact recommendations". *International Journal of Environmental Health Research*, Vol. 21, No. 1, February 2011, pp. 41–61.

[5] Bernat S., „Terapeutyczne właściwości krajobrazu" in: *Krajobraz a zdrowie*, Bernat S. ed. Lublin, 2017, pp. 33 -51.

[6] Lis A., *Struktura podłoża motywacyjnego zachowań* użytkowników parków miejskich. Wydawnictwo Akademii Rolniczej we Wrocławiu, 2005, Wrocław.

[7] Trojanowska M., Sas-Bojarska A., "Health-affirming everyday landscapes in sustainable city. Theories and tools", *Architecture Civil Engineering Environment Journal*, vol. 11(3), 2018, pp. 53-61. https://doi.org/10.21307/ACEE-2018-037

[8] Gesler W., "Therapeutic Landscapes: An evolving theme", Health & Place, vol. 11 (2005), pp. 295-297

[9] Takano T, Nakamura K., Watanabe M., "Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces". *Journal of Epidemiology Community Health*; vo. 56 (2002), pp.913-918.

[10] Rosenblatt Naderi J., "Landscape Design in the Clear Zone: The Effect of Landscape Variables on Pedestrian Health and Driver Safety", 2002. Available: swuc.tamu.edu/publications/papers/167425TP2.pdf [Accessed: 16 Apr 2014]

[11] Rosenblatt Naderi J., "Design of walking environments for spirituals renewal Paper presented to Walk21-V Cities for people", in *The fifth International Conference on Walking in the 21st century*, June 9-11 (2004), Copenhagen, Denmark.

[12] Oleś M., Harłoziński K., „Rola zieleni miejskiej w zrównoważonym rozwoju miasta Bydgoszczy/ The role of urban greenery in the sustainable development of the city Bydgoszcz". *Journal of Education, Health and Sport,* 6(13), 2016 , pp.349-412. https://doi.org/10.5281/zenodo.570916

[13] Trojanowska M., *Parki i ogrody terapeutyczne.* Wydawnictwo Naukowe PWN, Warszawa 2017.

[14] Van Herzele A. and Wiedemann T., "A Monitoring Tool for the Provision of Accessible and Attractive Urban Green Spaces", *Landscape and Urban Planning*, vol. 63, no. 2, 2003, pp. 109-126

[15] Dannenberg, A.L., Cramer, T.W., & Gibson, C.J., "Assessing the Walkability of the Workplace: A New Audit Tool", *American Journal of Health Promotion*, 20 (1), 2005, pp. 39–44.

[16] Frumkin H. et al., "Nature Contact and Human Health: A Research Agenda", *Environmental Health Perspectives,* vol. 125, no.7, 2017. CID: 075001, https://doi.org/10.1289/EHP1663

[17] Gorączko M., „Antropogeniczne zbiorniki wodne na obszarze Bydgoszczy – wprowadzenie do badań limnologicznych", in *Jeziora i sztuczne zbiorniki wodne – procesy przyrodnicze oraz znaczenie społeczno-gospodarcze*, Jankowski A.T., Rzętala M. ed., Uniwersytet Śląski, Polskie Towarzystwo Limnologiczne, Polskie Towarzystwo Geograficzne – Oddział Katowicki, Sosnowiec 2005.

[18] Gorączko M., "Seasonal nad spatial variation in the specific conductivity in the waters of ponds in Bydgoszcz", *Limnological Review*, vol. 6 (2006), pp. 111-116.

[19] Gorączko M., „Wybrane problemy funkcjonowania małych zbiorników wodnych na obszarach Zurbanizowanych”, *Nauka Przyroda Technologie, Dział: Melioracje i Inżynieria Środowiska*, vol. I, No.2, 2007.

[20] Stigsdotter U., Grahn P., “What Makes a Garden a Healing Garden?”, *Journal of Therapeutic Horticulture,* vol. 13, 2002, pp. 60-69.

[21] Han B., Cohen D., McKenzie T.L., “Quantifying the contribution of neighbourhood parks to physical activity”, National Recreation and Park Association Report.

[22] Han B. et al., “How much neighbourhood parks contribute to lacal residents’ physical activity in the city of Los Angeles: a Meta-Analysis”, *Preventive Medicine*, vol. 69 Suppl, 2014, pp. S106-S110. https://doi.org/10.1016/j.ypmed.2014.08.033

[23] Czajkowska M., „Zabytek w świetnej lokalizacji na sprzedaż. Chętnych na razie brak”. *Gazeta Wyborcza, Bydgoszcz*, 18.02.2019. Available: https://bydgoszcz.wyborcza.pl/bydgoszcz/7,48722,24458139,zabytek-w-swietnej-lokalizacji-na-sprzedaz-chetnych-na-razie.html [Accessed: 30 Oct 2019]

Ocena walorów terapeutycznych wybranych dziesięciu parków publicznych w Bydgoszczy

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Streszczenie: W artykule przedstawiono ocenę walorów terapeutycznych 10 parków publicznych w Bydgoszczy. Ocena została przeprowadzona z wykorzystaniem narzędzia – Uniwersalnego wzorca projektowania miejsc sprzyjających promocji zdrowia. Przedstawione badanie obejmowało ogólną ocenę 10 wybranych parków publicznych w Bydgoszczy, a następnie szczegółową ocenę jednego z nich. Wyniki oceny walorów terapeutycznych wybranych parków miejskich wykazały obszary wymagające poprawy i mogą być wykorzystane przez projektantów i mieszkańców jako uzasadnienie wprowadzania zmian. Uniwersalny wzorzec projektowania miejsc sprzyjających promocji zdrowia może być wykorzystany jako gotowe narzędzie wspierające proces projektowy.

Słowa kluczowe: architektura, urbanistyka, krajobrazy miejskie sprzyjające promocji zdrowia