

THE SPECIFICITY OF THE RESTORATION AND MONUMENT PROTECTIVE MEASURES FOR THE PRESERVATION OF HISTORICAL CHINESE GARDENS

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Abstract

The relevance of research and preservation of Chinese historical gardens with small forms is due to several factors. The unique heritage of Chinese landscape design, represented by the gardens of Suzhou, is today listed as a UNESCO World Heritage Site and is an international tourist attraction. It is a source of research on traditional Chinese landscape design techniques based on the principles of Feng Shui, Taoism, Buddhism and Confucian doctrines. All Chinese gardens had been developed with the use of established rules and techniques, among which the authors have described eight main ones that are present in the gardens of Suzhou. The scientific novelty of the research consists in analyzing and concretizing a list of the main techniques of traditional Chinese landscape design and argumentation of the revealed techniques with specific examples of gazebos in the gardens of Suzhou. The methods of figurative expressiveness of pavilions in different regions of China are systematized. Comparison of historical and modern Chinese pavilions demonstrated the narrowing of figurative means, the use of a narrow range of historical prototypes (mainly in the east and southeast), in which the national features of the small-scale architecture are vividly pronounced.

Keywords: Historical Chinese garden; Landscape techniques; Preservation and protection; UNESCO the World Heritage List; Cultural heritage

Introduction

The peculiarity of traditional Chinese architecture is that most of the large pavilions of palaces and temples were repeatedly rebuilt and changed their original appearance. But their national identity was most noticeably preserved in landscape design and small forms – garden pavilions, pavilions among picturesque landscapes, at temples or palaces, and the like. It is a small Chinese pavilion – an analogue of the European arbour – that has become a traditional object with a wide variety of functions – from the strategic military to hedonistic one.

Some scientific publications covered the problems of preserving cultural heritage and its museumification, which makes it possible to design these theses on the historical Chinese gardens, which are national heritage and are included in the UNESCO register [1, 2]. It was

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their transformation into the security objects that preserved their identity and provided the opportunity for professional restoration activities. As can be determined according to the conclusions in the analyzed sources, the theme of the degradation of cultural heritage is international. As a result, historical objects lose authentic materials, change their architectural appearance, and in many cases, the very meaningfulness of the architectural message is lost [2]. A negative role is played by climatic, microbiological and anthropogenic factors, which are classified as "vandalism", which can take various forms, but always negatively affects the historical environment [2].

Concerning the historical Chinese gardens, the term "memory of the place" is also appropriate, based on the relevant publication [3]. Scientists highlighted the widespread interpretation of the glossary item "cultural landscape" from the point of view of tourist attractiveness, which leads to the strengthening of the identity of the historical place not by physical and spatial characteristics, but by folk traditions [3]. The need to understand the necessity of the intrusion into the structure of the cultural landscape is emphasized, and it is directly relevant to the historical Chinese gardens [3]. It is in tune with the publication, which raises the issue of "memory of the place" and the role of esoteric knowledge in understanding the meaning of a place, which in this case can be attributed to traditional Chinese gardens [4]. The mythological and symbolic essence of the architectural environment is significant in those cases when it comes to traditional landscape design or an environment filled with symbols [4].

The authenticity of the natural environment has always strongly influenced the authenticity of the perception of the object in the surroundings, and it explains why the Chinese pavilions in the Chinese garden were perceived authentically, but the simplified Chinese pavilions in European gardens were observed as theatrical decorations. And it is the main idea of the developed publication [5]. The conclusions made in the article, to a certain extent, can be attributed to the Chinese gardens as well since it examines a well-known object in China [6]. The authors of the publication were primarily interested in the sources in which the periodization of a pavilion as a type of building, was characterized since on their basis precisely those periods were identified that were "significant" specifically for the landscape and garden pavilions [7]. And it allowed us to compare graphical and compositional characteristics of old and modern pavilions, thus considering aspects that were not mentioned in the processed sources [8, 9].

The evaluation of the heritage of landscape design in terms of its artistic value is related to the issues raised in some works, connected with art since the traditional Chinese landscape design had the direct relationship with various types of art – poetry, painting and music. Besides, the traditional Chinese landscape design includes three components – to be in a certain place, to move with a change in the surrounding landscape, and at the same time using natural components. Since it based on the principles of feng shui, the authors used the sources that highlight the influence of feng shui on the layout of Chinese gardens [10]. These publications are consonant with those where the issue of artwork is considered concerning the restoration industry; therefore, the stated theses do not contradict the main object of research – Chinese historical gardens and can be attributed to them [11].

An important aspect of the study of Chinese garden pavilions is the morphology of forms, where the main element – the exponent of the national style is a roof of various shapes, determined by natural and climatic conditions and the specifics of the traditional Chinese system "dou-gun". That is why, when preparing the article, articles were developed that just illuminate the specifics of the constructive solution of the Chinese pavilions and the work of the constructive system "dou-gun" [12]. For the article, the morphological aspects associated with the shape of the roof and other structural elements, were the most important, since this provided a rationale for the most traditional types of roofs in Suzhou pavilions.

The most famous private gardens in China are gardens in the city of Suzhou. Their uniqueness is evidenced by the fact that in 1997 the gardens "Zhuōzhèng Yuán" ("The Humble

Administrator's Garden"), "Liú Yuán" ("Lingering Garden"), "Wǎngshī Yuán" ("The Master of the Nets Garden") and "Huánxiù Shānzhuāng" ("Mountain Villa with Embracing Beauty") were recognized as the UNESCO World Heritage Site. Three years later the ancient garden of Suzhou "Cāng Làng Tíng" (middle of the 11th century), variously translated as the Great Wave Pavilion, Surging Wave Pavilion, or Blue Wave Pavilion; and the gardens "Shī Zǐ Lín Yuán" ("The Lion Grove Garden"), "Yì Pǔ" ("The Garden of Cultivation"), "Ōu Yuán" ("The Couple's Retreat Garden") and "Tuisī Yuán" ("The Retreat and Reflection Garden"), were listed as a UN World Cultural Heritage sites. The UNESCO World Heritage Committee recognized Suzhou Gardens as a model of the classical Chinese garden, where all traditional landscape techniques have been embodied, aimed at creating an ideal, not real scenery, unlimited in space.

Suzhou Gardens demonstrate the rise of gardening art during the reign of the Ming and Qing dynasties in the 16th – 18th centuries. It was the authenticity of these private gardens that led to paying special attention to them and the need for their maximum preservation. Only a planned government policy helped to preserve the gardens of Suzhou, and in 1949 the unification of the three separate parts of the "Zhuōzhèng Yuán" garden into one integral landscape ensemble ensured its transformation into a tourist attraction of the city.

In recent years, the scientific publications in China have raised the issue of the conflict between the ecological and natural environment, even the concept of "ecological" and "industrial" civilization was introduced, and it is determined that most often large-scale human interventions cause irreparable harm to the natural environment; they used as a negative example of the destruction of the sustainable natural environment, the hydraulic engineering works at the Shuangyuan Stream in Dali when the Stream was finally cut apart by the nine concrete dams. These measures ensured profit for the industry but at the same time caused environmental degradation. In the Old Summer Palace, known in Chinese as Yuánmíng Yuán ('Gardens of Perfect Brightness'), the bed of Lake Fuhai was being covered with anti-seepage geotextile to reduce water loss and seepage. It caused numerous protests from the experts in the field of ecology and environmental protection and initiated a national movement for environmental education and the cancellation of this project despite the actions of the park administration [13, 14].

Modern Chinese landscape design declares a return to historical traditions based on ecology, research and using the principles of creating the microcosm of a Chinese private garden [10].

The modern researchers analyzing green spaces in large cities of China, consider the factors such as population density, distance from the places of residence of the elderly in public parks and directly link the optimization of public parks with advances in gerontology and medicine in general [15].

Having analyzed the topics of articles in Chinese publications in recent years we found out that most of them are devoted to the problem of greening modern cities, the conflict between the natural and industrial environment and the methods of modern landscape design based on ancient environmental traditions.

Based on the processed sources, it was determined that it is necessary to make an additional in-depth analysis of the issues related to comparing the natural and climatic conditions of particular regions and the distribution of types of pavilions in those regions, comparing the planning principles of famous gardens, specifying the list of basic landscape design techniques, with compositional and morphological characteristics of pavilions, as well as questions of comparing types of historical and modern small pavilions for argumentation, of which they demonstrate more variety of types of composition and architectural forms.

Since the Chinese pavilions were built from various timber species, the sources devoted to the problems of accidents and methods of restoration of wooden elements were analyzed. These sources can be grouped by topic as follows:

- 1) Problems of biodegradation of wooden monuments [16-20];

- 2) Research of wooden monuments, wooden elements and structures [21-25];
- 3) Methods of wood preservation and the use of chemicals [17-20, 22, 26-28];
- 4) Wooden monuments of architecture in China, their research and restoration technologies [20, 25, 29-31].

The analysis of scientific sources devoted to the accident rate of wooden objects and methods of their restoration, allowed the authors to analyze the generality of issues and ways to solve them. These very sources confirmed the author's idea of the need for the systematic approach to restoration measures and the creation of a particular generalized algorithm for restoration actions. The generality of general approaches to restoration activity has been proven; however, there is a difference between the methods, and especially, between the chemicals used for the restoration, preservation and revitalization of wood.

Materials and Methods

The main conclusions of publications devoted to the preservation of the historical environment, to a certain extent apply to the objects of traditional Chinese architecture since few ancient monuments have survived, most of the objects have undergone numerous reconstructions and repairs, and, if we talk about the immediate topic of the article – historical gardens, then some of the imperial gardens have not survived (like the unique Yuanming Yuan Imperial Gardens ('Gardens of Perfect Brightness'), destroyed in 1860, and exist only in illustrations, as well as a large number of destroyed small pavilions of those architectural types that are not represented by the existing pavilions, which as a result greatly complicates their analysis. That is why the views expressed in the sources on the problems of preserving cultural heritage correspond to the author's views on the issue of preservation of the authentic environment of historical Chinese gardens [2]. The points of negative impacts on the cultural landscape expressed in the articles are also connected with the problems of protecting historical Chinese gardens [3].

The opinions expressed by scientists who dealt with the problems of degradation of the cultural heritage and cultural landscape, opinions on the causes, manifestations and ways of overcoming these adverse trends were projected by the authors of the presented article to the specific object of the research – historical Chinese gardens. Based on the existing publications on this topic, the problems of protecting objects of landscape architecture were identified, and their value for the world community was determined.

The authors set the task of investigating the general and regional features of small-scale architecture; the influence of natural and climatic conditions on the development of landscape architecture in different regions; highlighting the significant role of historical Chinese gardens as those that best preserve the original national peculiarities, and have not experienced a large number of rearrangements, which allows determining their original appearance. For solving the tasks, the following methods were used: the method of historical analysis; the method of comparative analysis; the graph-analytical method; the iconographic method and the method of system-structural analysis. For the study, the archival base of sources and materials of the plain-air images of the historical pavilions of China were used. In the conclusions, it analyzed the correspondence of modern small-scale forms in the Chinese style to historical models.

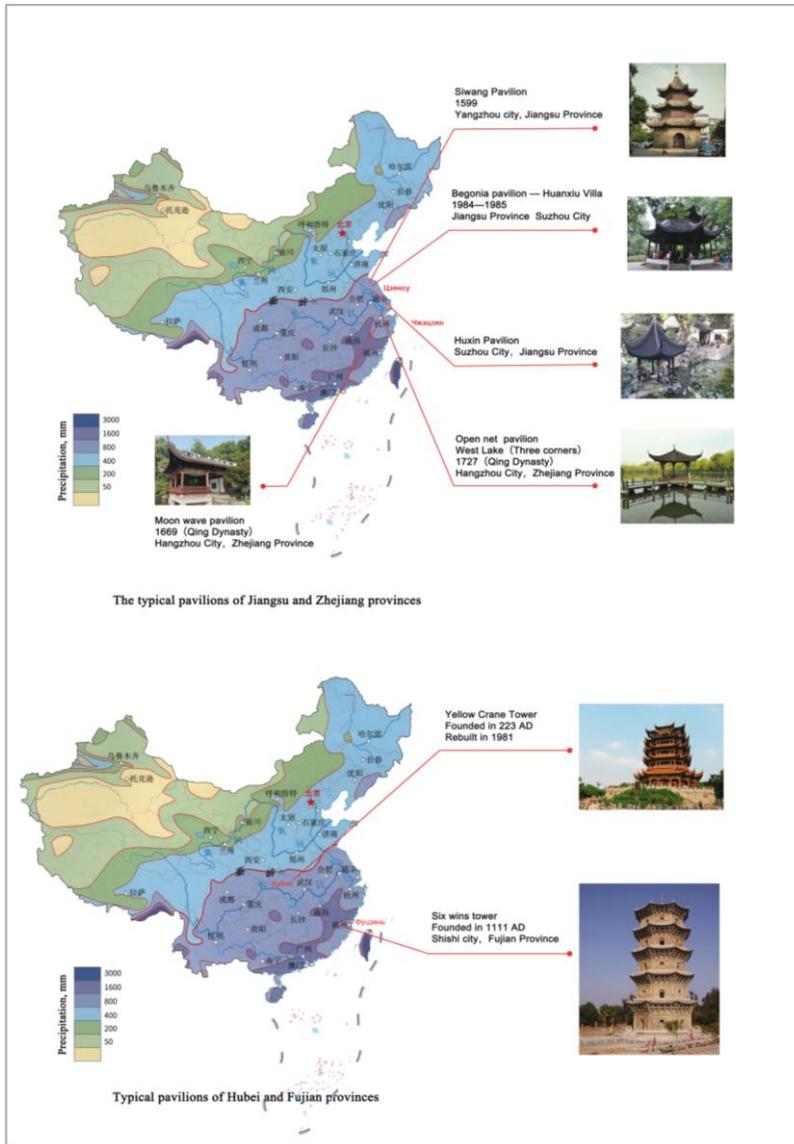
Results and discussion

Main aspects of studying

Based on the analysis of the source base, we identified the aspects that require further research, as well as poorly studied aspects. They are as follows: the determination of the dependence of the type of pavilion on the natural and climatic zoning by comparing it with a precipitation map; compiling the characteristics of small pavilions as a specific type of building

and the place of garden pavilions among them; comparing the most famous gardens of Suzhou with existing pavilions; analyzing and directed definition of the principal landscape techniques and the sites in Suzhou gardens, where they were applied; comparison of proportional construction of historical and modern pavilions.

The authors drew attention to the aspect of the direct dependence of the appearance of small pavilions on the climatic conditions of various regions of China, creating four corresponding maps, one of which are given in the article (Fig. 1), and one table with different types of roofs (Fig. 2).



Influence of climatic conditions on types of pavilions in different regions of China

Fig. 1. Studying the connection between climate conditions and types of pavilions. Scheme composition by Peng Chang. Sources of maps and photos: <https://baike.baidu.com/item/%E5%9B%9B%E6%9C%9B%E4%BA%AD/1273356> http://blog.sina.com.cn/s/blog_5ea767ba0102wj8i.html <http://www.nipic.com/show/7581873.html>

Although the fact of the spread of pavilions with upwardly concave roofs of large outflow in regions with a large amount of precipitation is known, the authors confirmed this hypothesis by comparing the corresponding climatic maps of China with the types of pavilions in these territories and also extending these conclusions to the characteristics of pavilions in Suzhou gardens, most of which have a concave upward roof with a large outflow. The problem of the lack of dimensional drawings of many historical small pavilions, as well as drawings that determine the principles of proportional, metro-rhythmic construction, types of silhouettes, the morphology of characteristic forms, is also common in China; and this task was posed in this article, and also a comparative analysis was carried out of historical Chinese pavilions and modern pavilions, which are massively designed by architectural firms in China for installation in recreation areas.

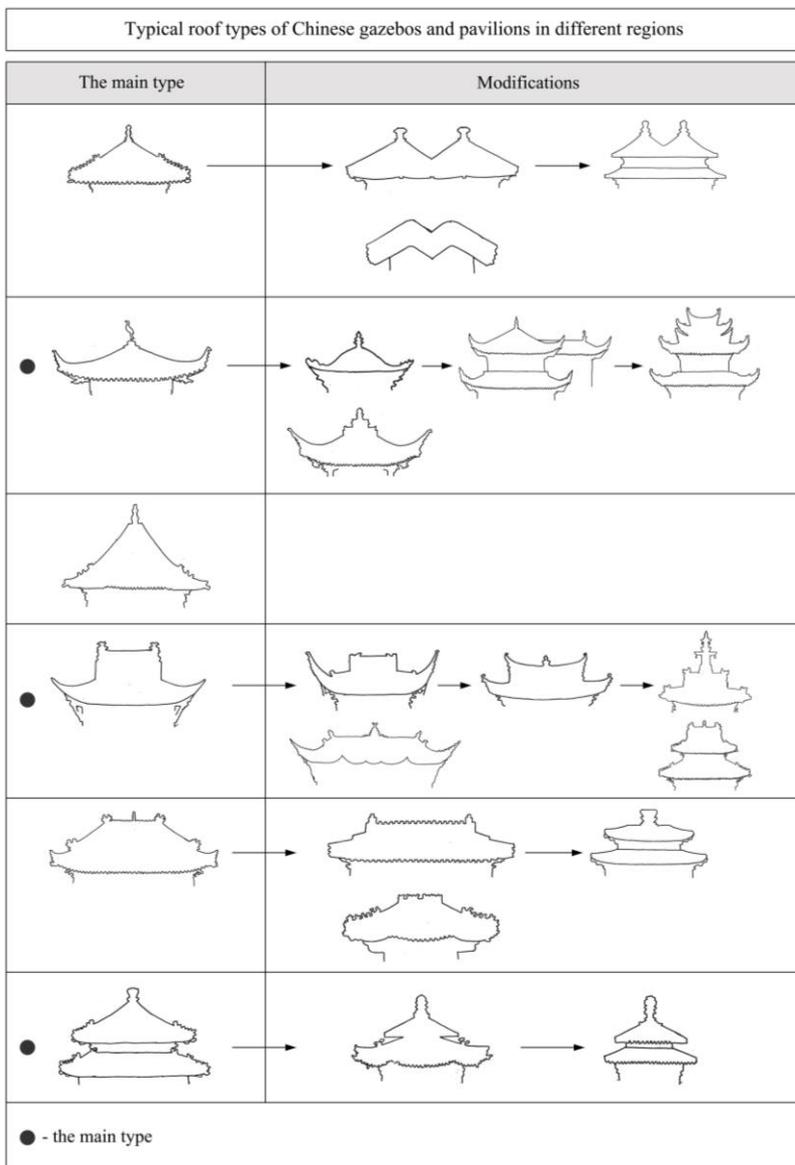


Fig. 2. Types of the roofs of small Chinese pavilions. Drawings by Peng Chang, 2020

The study shows that, despite their aesthetics and sophistication, the old pavilions were quite simple in silhouette and function, and their functionality was regulated, among other things, by the properties of the "dou-gun" constructive scheme. On the other hand, modern opportunities have been opened in the field of building materials and technologies, which have significantly simplified and accelerated the pace of construction and can increase the life of the pavilions; however, they also had negative consequences, which were mentioned in the previous paragraph. Besides, the tradition of erecting modern Chinese-style pavilions in new public parks today is most widespread in the east and southeast of China, where the type of concave roof with a large overhang is optimal.

This approach made it possible to determine the principal and derived types of pavilions, regional features of pavilions in various regions of China with a dominance of a particular type, often due to natural and climatic conditions. It makes it possible to compare traditional Chinese pavilions with their modern designs in parks of China.

At the same time, if the known pavilions on the territory of world-famous sites such as the Gugong Palace in Beijing or the private gardens of the Zhuōzhèng Yuán Garden and the Liú Yuán Garden in Suzhou are in proper condition and are being restored, then the attention paid to little-known pavilions in villages or the mountains is much less, and therefore, financing their maintenance in its original form. It requires some additional complex measures aimed at the preservation and planned restoration of the ancient architecture of the small-scale forms (Fig. 3). The basic principles and methods of preserving and restoring the historical pavilions of China provide for the certification of objects with the performance of field surveys, the recreation of lost elements and restoration following the international legislative documents.



Fig. 3. The imperial garden of Forbidden City. Beijing.

The Chinese Garden, in contrast to the European garden, never represented the true-life landscape of the area. It was an ideal man-made view with embodying features of numerous landscapes from different parts of China at once; and the variability of the scenery symbolized the variability of the Universe [8].

The gardens of Suzhou, listed in the UNESCO register, are material evidence of the landscape traditions of the Song, Yuan, Ming and Qing eras, where water bodies, artificial mountains and hills, greenery, flower beds and small pavilions are harmoniously combined to create an ideal microcosmos of positive emotions, protected from the real world with the outer wall.

An analysis of the most famous gardens in Suzhou should start by comparing their layouts. The biggest "Zhuōzhèng Yuán" garden is horizontally elongated and irregular in shape; most of the territory is occupied by water bodies. Here is the largest number of small pavilions, concentrated evenly throughout the entire territory – both in the centre and along the borders of the garden. In contrast, in smaller gardens, the pavilions are shifted from the central parts to the borders of the garden.

The garden "Shī Zǐ Lín" (The Lion Grove Garden) has an irregular crooked shape, close to a rectangle; it is stretched horizontally and is surrounded by buildings on two sides, and fenced on the other two sides. An artificial lake is located in the centre; pavilions are situated mainly along the borders of the garden, close to the fence. The "Cāng Làng Tíng" garden has an even more irregular shape, the pavilions are also located along the borders of the garden, and they are less numerous in comparison with the number of pavilions in the gardens of "Zhuōzhèng Yuán" and "Shī Zǐ Lín". These facts indicate that despite some canonical Chinese landscape design, some variation was also allowed in it; for example, there could be no ponds in the garden at all. Also, the pavilions were not always located along the borders of the garden; everything depended on the size of the garden and the design. Landscape designers deliberately avoided the correct geometry of the outlines of the garden; the paths always had an irregular character in contrast to the European regular parks of the 18th – 19th centuries with pavilions "in the Chinese style". Such irregularity was due precisely to the specificity of the ancient Chinese worldview, the peculiarities of the religions of Taoism, Buddhism, the principles of Feng shui, as it was mentioned earlier. That is why the Europeans failed to achieve a sense of authenticity and kinship with real China in the chinoiserie style: the European design principle began by designing an aesthetic artificial form, which should be nice in compositional and morphological characteristics and dominate the environment, but the Chinese design principle (in this case, the design of the small-scale forms) began with an analysis of how an artificial form can harmoniously obey the environment and what its size, compositional and morphological characteristics should be, which should correspond to a specific landscape environment and complement it. In contrast to the monarchical European parks with pavilions "in the Chinese style" that are emphatically bright or oversaturated with gilded decor, the Chinese gardens testified to the status of the owner mainly by the scale of the site and large-scale landscape pictures, both in the imperial garden and in the garden of an official, philosopher or wealthy merchant. Those paintings could be the same in content, as well as the list of landscape techniques, the number of which could be more or less. At the same time, even in the imperial garden, if it was not the garden of the official imperial residence of the Forbidden City or a unique pavilion of the great importance, the pavilions could look quite modest in form and decoration, and the pavilions of the private gardens of Suzhou could become a model for pavilions in the country imperial gardens.

In the case of a large private garden – as "Zhuōzhèng Yuán" Garden – at different times it could be divided into several pieces that belonged to various owners, so each part had a unique layout. The garden has preserved 13 pavilions, which are marked by diverse traditional forms of plans, among which are square, rectangular, faceted with a different number of corners. Besides, among them, there are bigger and smaller pavilions. The continuity with the

developed traditions of the construction of small pavilions is testified by the fact that here there are in full open pavilions on pillars, partially open pavilions and the pavilions fenced by the walls.

The original name of the main, now the newest part of the garden – Western – used to be "Guiyuan Tianzi" and in this part images of mountains in Pinggan, lawns, bamboo thickets, pine forests were embodied. In the Western part, there are five pavilions: With Whom Shall I Sit? Pavilion, the Bamboo Hat Pavilion, the New Circumstances Arose Pavilion, the Do good for Both Families Pavilion, the Where you can see the shadow of the tower Pavilion.

The most perfect is the Central part, which was called Zhongyuan. A third of its area is occupied by reservoirs, on the banks of which there are picturesquely scattered pavilions of different sizes and various purposes. There are eight pavilions in the Central main part: the pavilion of Emerald Lake (Fig. 4); the pavilion of Plane tree and Bamboo (Fig. 5), the Pavilion Life in solitude; the Waiting-for-the-Frost Pavilion; the Pavilion of Fragrant Snow and Azure Cloud (Fig. 6); the Lotus Breeze Pavilion; the Embroidered Silk Pavilion; the Pavilion of Pleasant Fruits, the Wind-in-the-Pines Pavilion.



Fig. 4. The Pavilion of Emerald Lake. Watercolor by Chang Peng, 2020



Fig. 5. The Pavilion of Plane tree and Bamboo. Watercolor by Chang Peng, 2020

In many cases, the pavilions defined or served as a symbolic partition separating the Western Garden from the Central (as the New Circumstances Arose Pavilion). In some cases, the pavilion names express traditional Chinese cultural and artistic symbols, often associated with sacred trees and plants.



Fig. 6. The Pavilion of Fragrant Snow and Azure Cloud. Watercolor by Chang Peng, 2020

Most of the Suzhou private gardens with no mountains have artificial stone hills with several "peaks" and slopes with flowers and trees for more naturalness. The favourite material for those artificial hills was stone from the bottom of Lake Taihu in the vicinity of the city. So, one of the classic gardens of Suzhou – "Shī Zǐ Lín" (The Lion Grove Garden) – was called the "Kingdom of artificial hills". Those hills were low but amazed with a variety of contours of artificial relief and deep caves, since the main task was to create, on a reduced scale, the impression of being in a real mountain environment.

The Shī Zǐ Lín Garden (The Lion Grove Garden) in the northeast of Suzhou got its name since on its territory there are many compositions made of natural stone, which in their silhouettes resemble lions in different poses, so the other name of the garden is "Lion Forest". The garden occupies a rectangular area with a combination of stone compositions, picturesque reservoirs and irregularly scattered pavilions.

There are six pavilions on the territory of the Shī Zǐ Lín Garden: Fan Pavilion, Mid-Pond Pavilion, Pavilion of Real Interest, Flying Waterfall Pavilion, Pavilion in memory of Wen Tianxiang, Imperial Monument Pavilion/Imperial Stele Pavilion (Fig. 7).



Fig. 7. The plan of the Shī Zi Lín Garden (The Lion Grove Garden) with pavilions.
 Drawings and watercolors by Peng Chang, 2020

A significant part in landscape design is played by the orientation of the pavilions and the presence of two axes – the main north-south with the orientation of the main facades to the south and west-east. For example, the main square building of the Western Garden, the Pavilion of 36 Mandarin Ducks, is divided into the northern and southern halves, where the southern half is the main one and is called the Flower Hall of 18 Mandalas, and the bedded camellia is considered to be a mandala flower. The northern half is called the 36 Mandarin Ducks Pavilion. If we trace the orientation of the small architectural forms of the Western and Central parts, then most of them are oriented along the north-south axis, like other large houses in the garden.

The technique of transforming a landscape into a picture in a frame can be illustrated by the examples of two original pavilions – the Pavilion of Plane Tree and Bamboo, the Secluded Life (Wuzhu Youju) in the Central part, and the Fan Pavilion, the With Whom Shall I Sit? Pavilion in the Western part of the garden. Through the Yuedong Gate, the Plane Tree and Bamboo, Secluded Life Pavilion can be seen as if framed in round frames when they overlap, providing a landscape view of the painting.

The semi-open With Whom Shall I Sit? Pavilion on the water does not have a front wall; there are two slots in the side walls opposite each other and a fan-shaped hole in the central wall. It allows a full view from the front and fragmentary perception of landscape paintings through the slots and the hole in the wall.

Another classic technique is "borrowing the landscape" when one landscape image becomes part of the scene of the second picture, which is demonstrated by the Pavilion Where can you see the shadow of the tower, when the Northern Temple Pagoda becomes a part of the landscape outside the garden.

On the hill of the Western Garden, there is a Pavilion of Do Good for Both Families, from where a beautiful view opens up to the west – to the landscapes of the Western Park, and the east – to the mountains and water surface of Central Park, which means the technique of "borrowing the landscape" is also applied here.

One of the techniques of a classical Chinese garden is "garden within a garden" when, while walking through each landscape picture a person sees the next landscape, as well as the impossibility of viewing the garden from distant perspectives. This technique is applied in a small separate orchard surrounded by its walls in the southeast of the Central part. A special place in this garden is occupied by the loquat tree which has a lot of yellow fruits at the beginning of summer, therefore it is said about it: "pluck a handful of gold from the medlar." In the closed orchard area, some pavilions divide the space into three small separate zones with small courtyards of different sizes. This Chinese landscaping technique is called "partition of landscapes." The Pavilion of Pleasant Fruits, although it is located outside the fence from the south, nevertheless substantively refers to the territory of a small fruit garden, underlined by its name. According to the legend, Li Xiucheng, the King of the Taiping Heavenly Kingdom, planted the trees around this pavilion with his own hands, as an expression of his gratitude.

The "garden in the garden" technique applied in the Zhuōzhèng Yuán Garden is also used in the Liú Yuán Garden, which has received recognition for its layout: the garden opens with a zigzag gallery presenting several views at once, which divide the garden space into several territories, separated and simultaneously flowing one into another. In the central part, there is a landscape based on the principle of "one lake, three mountains"; in the eastern part, there is an architectural ensemble with the inclusion of bizarre stones in the composition; in the north-western part, there is an imitation of a mountain forest with a combination of lush vegetation and a stream between artificial gorges. The natural elements – artificial hills, midwood of plants and trees, sometimes small architectural forms, play the role of screens, preventing considering the long distance.

The impossibility of long-range views of a private garden is compensated by the picturesque and detailed landscape images, their diversity and variability, which contributes to the creation of different moods – poetic, vague, soothing. The main thing is to achieve the maximum fusion of nature and man through being in an environment that is given the features of maximum naturalness. The openness of the pavilions-arbours also had underneath the ancient philosophy of maximizing the merging of a person with the surrounding landscape in the pavilion. That is why most of the garden pavilions have no walls, and the fancy roof "hovers" on graceful high supports.

There are six pavilions in the Liú Yuán Garden: Pavilion of Greatest Joy; Pavilion of the Gardener's Dreams of forty weather and rain conditions, a luxurious house and lush flowers in the garden; Pavilion for Relaxation and Admiration; Cloud Capped Pavilion; Pavilion Whoever enters the pavilion becomes a Buddha; Pavilion That Whistles; Pavilion Contemplation of ancient people for fish. A feature of the Pavilion of the Gardener's Dreams about forty weather and rain conditions, a luxurious house and lush flowers in the garden, is that in fact these are two pavilions, one in the east, the second in the west. The Pavilion for Relaxation and Admiring is traditionally hexagonal in plan, known as the best place, to enjoy winter landscapes and

blooming plum trees around. After refurbishment in 1953, it obtained a sharper rooftop and crowning.

In the most ancient garden of Suzhou – "Cāng Làng Tíng", – there are significantly fewer pavilions than in the gardens of Zhuōzhèng Yuán, Liú Yuán and Shī Zǐ Lín Yuán. There are only four of them: the Canglang Pavilion (by the name of the garden), the Fish Watching Place Pavilion, the Reverence Pavilion, and the Imperial Stele Pavilion (Fig. 8).

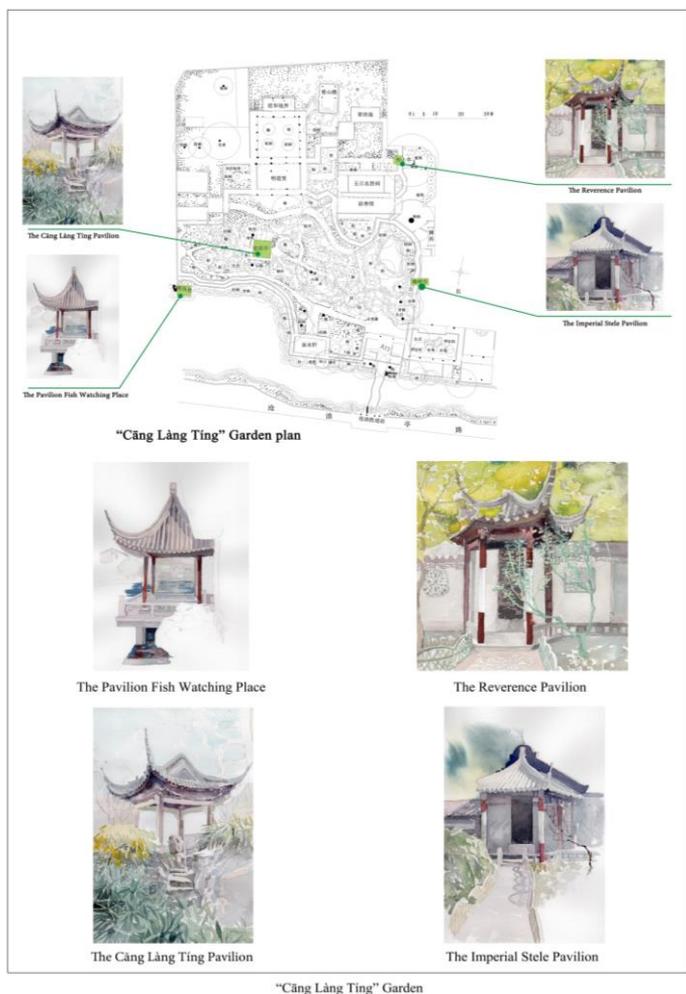


Fig. 8. The plan of Cāng Làng Tíng Garden with pavilions. Drawings and watercolors by Chang Peng, 2020

The main principle of the historical Chinese garden is the understanding of the garden not as a literal reflection of a real landscape, but an ideal landscape in which there is nothing imperfect, a landscape as a work of art, where architecture is merged with the natural environment, thereby confirming the unity of the three main ontological components of the world: Heaven, Earth and Man, and it was the natural, not man-made elements of the garden that were considered real perfection. According to the well-established traditions, a special role was assigned to the elements of mystical meaning associated with ancient legends – reservoirs, which occupied more than half of the site, and natural or artificial hills and mountains.

The second rule of the Chinese garden is the impossibility of inspecting the entire garden at the same time, and instead, the constant watch of disparate landscape pictures, each of which exists separately, and together they create the effect of infinite space, symbolizing the changeable Universe. At the same time, some natural and artificial elements blocked distant vistas, according to "feng shui" traditions. Here it is worth drawing an analogy with the interiors of traditional Chinese pavilions, where a similar "overlapping" protective role was played by the parts of the screen and shields.

The third rule declared the thematic artistic commonality of the technique of landscape design and traditional painting "Shang-Shui" ("mountains-water") (presented in garden of Suzhou – "Cāng Làng Tíng").

The fourth rule is a deliberate "miniaturization" and idealization of a real known landscape, where there are mountains and water bodies. Such a smaller copy gave the impression of being in a natural mountain environment (presented in the Shī Zǐ Lín Yuán Garden in the city of Suzhou).

The fifth rule is associated with the mandatory presence either in the imperial, or in private gardens of a particular list of landscape design techniques, namely: 1) "shang-shui"; 2) "one lake, three mountains"; 3) "borrowing a landscape", or a combination of foreground and distant plans; 4) "partition of the landscape", or deliberately dividing the garden space into separate spaces; 5) "garden in the garden"; 6) "landscape as a picture in a frame".

The sixth rule demonstrates the connection between landscape design and art since the garden was considered not so much a means of comfort as a means of getting into the ideal world of harmony. It was achieved by actively emphasizing the poetry of the pavilions with the help of a romantic name or poetic lines on tablets.

The seventh rule of landscape design concerns compliance with a particular orientation of the pavilions along the north-south axis with the orientation of the chief premises to the south.

The eighth rule is consonant with the sixth because it considers the garden as the art of creating positive emotions through the contemplation of perfect landscape paintings.

Despite the use of the same landscape techniques in different gardens, the artists diversified them, as can be seen when comparing the four plans of the gardens of Suzhou – Zhuōzhèng Yuán, Liú Yuán, Shī Zǐ Lín Yuán and Cāng Làng Tíng Yuán.

Problems and methods of restoration of wooden pavilions in China

Raising the issue of restoration of the historical heritage in China is attributed to the overall policy of educating the population in respect to the cultural traditions, and the transformation of historical cities, towns and individual buildings into tourist objects and the world heritage sites.

In this article, we refer to the "Principles for the Conservation of Wooden Built Heritage". It is the Resolution adopted by the 19th ICOMOS General Assembly (11-15 December 2017, New Delhi, India). This document attracted attention, in particular, by the fact that the state of the structure and its elements, including previous works, should be documented in detail before taking any action. The first step of the intervention, according to the document, should be developing a general strategy for maintaining the facility. The Resolution highlighted those modern materials and technologies should be selected and used with the utmost care.

The legislative document for the restoration work in China is GB50165-92 "Technical conditions for the maintenance and strengthening of wooden structures of ancient buildings". It envisages the restoration and strengthening of ancient buildings on the principle of the invariability of the initial state of cultural relics and preservation of the original shape of the

building, the original structure, the original building materials and work technologies. That is, you should preserve the original style of the building without changing it.

Timber structures are susceptible to deformation, decay and loss of bearing capacity. The degradation of historical wood material, regardless of its function and purpose, can be caused by the following: atmospheric factors (such studies were carried out on a large scale, for example, in Norway and China) and biological factors (fungi, algae, insects). Every case of the degradation of historical wooden material should be considered on an individual basis. It makes it possible to correctly diagnose the causes of destruction and, thus, to select the appropriate conservation procedure. In China, the issue of scientific restoration of monuments is very acute: a large number of old wooden buildings are in urgent need of emergency liquidation, but there is a shortage of professional restorers who can determine the principal causes of destruction, select optimal methods, predict the use of new building materials in conditions of the lack of dry wood in the country.

In the procedure of preservation of historical wooden buildings, the following working phases can be categorized: diagnostics and necessary tests; the inventory of the whole object or its fragment or part; choosing the appropriate conservative methods; conservation; monitoring the consequences of conservation.

At the stage of diagnostics, construction, architectural and chemical-biological studies are performed. They help with diagnosis and subsequent selection of maintenance. In the case of the wooden material, the intervention in preservation may consist in strengthening its structure, and if it is not possible, in replacing the given element or using chemicals.

The control step of the applied preservation method is also very significant, even over a long period, as it allows adjustments in subsequent preservation works with the wood matter.

It should be said that one of the most frequent causes of the destruction of old wood is the presence of various types of fungi, which cause decomposition of the substance and the loss of its dimensional and structural stability.

The main reasons for the destruction of architectural monuments in China are the adverse atmospheric effects (natural disasters - floods, hurricanes, earthquakes, landslides; fires, rains, rising groundwater) and anthropogenic factors (results of human activity).

In China, there are the following main approaches to the restoration of architectural monuments:

- 1) the correspondence of authentic and restored or supplemented parts;
- 2) the difference between authentic and supplemented by modern materials and technologies fragments;
- 3) maximum preservation of the authenticity of the building and its parts.

Restoration methods for historical buildings in China are determined by the value of the building, the intensity of damage, the general state of the historical environment of the protected object. These methods are grouped into two categories:

- 1) maximum preservation of the authenticity of the building and restoration of the original appearance (in temples and residences)
- 2) visual contrast between authentic and augmented parts (rare in China).

The main problem in the restoration of most ancient buildings in China is the lack of dry timber. Another issue concerns the fact that, despite a noticeable improvement in the quality of restoration work over the past 30 years, not all restoration activities are carried out at a high level, and there is a shortage of personnel.

The reasons for the emergency state of the historical Chinese pavilions should be considered separately. First of all, the state of the footings and foundations is analyzed, then the podium with stairs, then the walls or supports, then the roof and finally the decor. A special feature of wooden pavilions is that in many cases a wooden building stands on the stone foundation with a plinth or a podium with the staircase.

The first block of restoration problems is associated with the examination of the condition of footings and foundations as they are damaged by groundwater, overgrown tree roots (which is especially important for buildings in historical gardens), and underground utilities. When restoring foundations, successive disclosure of the foundation sections is performed in parts, each of which should not exceed 1 m and should not exceed 20% of the basement area (the method by plots); there is also a method of strengthening with separate posts, jacked and root piles. At this stage, the foundation and walls are maintained and strengthened.

Traditionally, above the foundations of the Chinese pavilions, there is a stylobate platform of various outlines in plans and heights, with several steps. The danger to this part is associated with loosening and displacement of stone stairs, peeling and weathering of slabs, weathering of stone stairs, looseness and loss of individual stones. Cracking of the stone occurs due to the temperature drop when the cycles of freezing and thawing of water in the pores of the stone alternate. During the restoration, it is allowed to replace a lost or damaged stone with a new one and erase the difference between an authentic and augmented part, use the "ageing" method of a new stone.

The main problems of wood are associated with excessive wetness. It leads to decay of the wooden foundations of columns and walls, the appearance of cracks in the columns and their splitting, violation of the static nature of the wooden frame, sagging of the girders. Moistening of wood may lead to fungal attacks, damage to wood structure and its biodegradation.

In China, in case of decay of the wooden base of the column, the method of bandages is often used. If the depth of destruction of a wooden column exceeds half the section of the column or the core of the column collapses and the destruction affects from 1/5 to 1/3 of the column height, the method of joining supports is required. After connecting the supports, the joints are planed and smoothed, and two iron hoops are used to secure them to increase their integrity. The height of the connection of the column supports, if it is an open column without walls on all sides, should not exceed 1/5 of the column height; if it is a column wrapped in a wall, it should not exceed 1/3 of the column height; otherwise, it will affect its stability. All of these reinforcements are made according to engineering calculations.

If the column shaft is too long or broken, the entire column must be replaced with preliminary strengthening, reinforcement and raising of the elements that are connected to the column; after that the emergency column is removed and replaced with a new one. At the same time, there are limitations: the central pillars are not subject to such replacement, which can only be strengthened by adding auxiliary pillars and using iron hoops to form a single load-bearing structural system.

In China, some technologies deal with the restoration of rotten beams. If the rotten part does not exceed 1/3 of the cross-sectional area of the beam, you can use the pick-up method, in which the rotten parts are firmly fastened and fixed with iron nails, and if necessary, iron parts are additionally used for strengthening (bolts, iron hoops, etc.), again with the aim of creating a single load-bearing structural system. If the degree of damage to the purlin section exceeds 1/3, the section is removed and replaced.

A specific type of emergency state of wooden structures in China is the inclination of the frame and the fastening spikes, with the general preservation of parts of the wooden frame. In this case, it is necessary to ensure the static structure of the building by levelling it. For this purpose, initially, the tilted rafters are held to prevent the danger of overturning caused by external structural forces. Thereafter, the wooden wedge, iron nails and iron parts in the thorns and in the wooden frame are removed. The column and the upper support rod ensure the verticality of the frame; then the wooden wedge is pushed again and iron parts are added to secure it, and then the wall is erected for the installation of the roof structures; and only after the completion of the work the temporary supports are removed.

Minor damaged or lost wooden elements, such as wooden arches or door frames, can be easily replaced, and the main difficulty is only in the accurate reproduction of the stylistic features of the details of each dynasty.

Despite the general line of preserving the authenticity of the wooden structures of historical buildings in China, along with the traditional methods of restoring the damaged wooden structure, they use the modern methods with application of the new, more effective materials. It is justified in cases where large arrays of constructs are damaged, or the wood that is especially rare and difficult to replace is damaged. In this case, preference is given to the partial restoration of damaged parts of wooden elements and strengthening of nodes.

Today, the restoration practice in China has introduced new materials such as carbon fiber reinforced materials, fiber glass reinforced materials, basalt fiber and chemical reinforcement.

The use of carbon fiber fabric (mainly in the form of cloth for the repair and reinforcement of wooden structures), is justified by its mechanical properties, corrosion resistance and specific strength, which is approximately 20-50 times higher than that of HRB400 steel, that is the use of such fiber material significantly reduces the negative influence of its own weight on the structure, and in combination with the wooden structure can significantly improve the mechanical properties of wood. First, the surfaces of the wood elements are cleaned, the base resin is painted, and then a carbon fiber fabric is glued to the surface of the wood elements and used with a roller. Then the air bubbles are squeezed out; the protective layer is applied to the outer surface of the repaired reinforced carbon fiber fabric.

Glass fiber reinforced materials (GFRP) are also used; they are similar to carbon fiber reinforced materials (CFRP). The glass fiber material is glued to the surface of wooden elements (the technology is the same as for carbon fiber), thereby improving the mechanical properties and durability of the wooden elements.

For the restoration, repair and reinforcement of wooden elements, a modern type of inorganic fibrous material is used – continuous basalt fiber (CBF). It has good mechanical properties, resistance to acid and alkali corrosion, ductility, lightness and thinness, and is easy to cut.

The use of basalt fiber fabric (BFS) to improve the quality of the restored wood is characterized by simplicity of the technology; it does not change the original appearance of the wooden element, which explains its widespread use. First, the wooden surface is processed and levelled; then the basalt fiber fabric is glued to the surface; then the fiber is compressed in the direction of the force. To prevent damage to wooden parts due to the penetration of harmful substances and to extend the service life, it is necessary to apply the resin to the surface of the last layer of fibrous fabric.

The Chinese pavilions (for example, the gazebos mentioned in the article) have wooden roof structures and often roof tiles; therefore, their restoration involves the simultaneous restoration of wooden structures and tiles. First, the places of roof leakage, biofouling and damaged tiles are recorded. Then the roof is cleaned using a knife, a short, bristled brush, a hemp brush dipped in the green paste, and a polishing spatula. The tightness of the tiles is checked particularly carefully. Cracks and potholes are covered with ash and levelled; then a layer of ash is applied to the ridge. If the entire roof or half of it is damaged, it is necessary to remove the roof tile and re-install it. In addition to eliminating the leakage of the roof, the corners of the roof, the cornices are repaired; the ridge is reinforced and repaired, paying special attention to the inspection of the vertical protruding parts, since if water leaks in this part, the damage to the gable and the wooden frame becomes very large.

As in similar buildings in other countries, damage to the wood of roof structures is associated with roof leakage and soaking of wooden parts. If the rotting area of structures is small and does not affect the safety of the structure, only the rotting parts must be cleaned. Old and new parts are impregnated with tung oil, which protects against decay and insects, without

changing the color of the wood; if necessary, they are additionally impregnated with insecticides. As an example of the Chinese experience in the restoration of wooden structures, we will cite the one described in a specialized publication on the protection and restoration of rotten wood in the buildings of the Shuiyu Village in Beijing [31]. The main challenge was to preserve and restore authentic elements without replacing them with modern wood, even if the wood elements were damaged.

Based on preliminary experiments, Chinese restorers chose ethyl orthosilicate and methyl triethoxysilane as proposed for applying chemical materials to rotten parts. The results of the preliminary studies made it possible to establish the mechanism to counteract damage: an organosilicon layer on the walls of wooden cells was applied by a condensation reaction, where SiOSi bonds were formed among the alkoxy groups, and SiOC bonds were formed between cellulose fibers and an organosilicon compound. As a result, the organosilicon layer further improved the physical and mechanical characteristics such as hydrophobicity, mechanical properties, the thermal stability of treated wood components, except for slight color deviation. It was found out that the combination of ethyl orthosilicate and methyl triethoxysilane helps to retain the decomposed part of the wood components and keep it in a satisfactory state.

Another technique is related to the removal of damaged parts and subsequent strengthening with chemical reagents using unsaturated polyresin. An example of the successful use of chemicals with good corrosion resistance for the restoration and reinforcement of wooden structures is the Fengyuan Pavilion at the Xuzhou Simantai Complex, where the wooden pillars were restored and no further damage was found ten years later.

Since there are also many historical wooden buildings in Japan, for comparison, it should be mentioned which antiseptics and fire retardants are used there: these are pentachlorophenol (oil) C_6Cl_5OH or pentachlorophenolate (aqueous, nonflammable) C_6Cl_5ONa , a 2-5% solution is used, and to increase the hydrophobization of structures, add aluminum sulfate.

The Restoration Experience of the "Ukrrestavratiia" corporation

Since, as mentioned above, one of the main problems of restoration in China is the lack of the required number of professionals-restorers, it makes sense to share the experience of restoration of wooden architectural monuments in Ukraine.

The professionals of the "Ukrrestavratiia" Corporation through long-term practical and scientific restoration activities have identified the essential problems of the emergency state of wood of architectural monuments, which are international since they are associated with a change in the statics of the state of the system "base-foundation-monument of architecture"; hydrogeological conditions of the building; subsidence of the foundation; lack or damage to waterproofing; excessive moisture of structures (more than 25%); damage by wood insects that as a result leads to decay of structures and their deformation; unsatisfactory operation and non-observance of the normal temperature and humidity conditions of the building.

Primary attention is paid to the condition of the footings and foundations; the soaking of foundations and walls is eliminated with the provision of an optimal temperature and humidity regime inside, which is especially important for the eastern and southeastern regions of China with a large amount of precipitation. According to the experience of restoration of objects in Ukraine, the professionals of the "Ukrrestavratiia" Corporation have repeatedly confirmed that it was precisely the capillary absorption of soil moisture that was the main reason for the soaking of wooden structures of foundations and walls, and led to rotting wood and damage by wood insects, loss of bearing capacity of beams and supports, especially in those cases when, as a result of unprofessional repairs, the interior walls were painted with oil paint, that is, the wood was covered with an impervious layer.

The main problems of the critical condition of roof structures are the emergency state of foundations and roof frames. In the case the roof becomes soaked, it is opened, the damaged

areas are cleaned from rot and insects, injecting with antiseptics and insecticides, and in the presence of large damage, the frames are strengthened by coating and pumping through holes; strengthening wooden structures and unloading wooden structures, point support on damaged rods, replace the damaged parts of the roof and reinforce the deformed outline with double boards on bolted joints, reinforce the struts of the central column and cornice, with the manufacturing of a protective coating for the wooden tiles.

After examining and drawing up an act of the technical state of the monument of wooden architecture and following carrying out of all the necessary scientific and restoration, architectural, chemical and biological, mycological studies, the high-priority emergency response and recovery operations are determined.

The technology for carrying out urgent conservation work on monuments of wooden architecture includes the following principles and stages of work: before starting the restoration and conservation work, it is necessary to eliminate the reasons that led to the unsatisfactory or emergency state of the monuments of wooden architecture (balancing the system "base-foundation-building-monument of architecture", eliminate roof leaking, soaking of wooden walls, waterproofing, blind areas from excessive moisture of wood).

Excessive moisture of wood (over 20%) is the main reason for its destruction (rot, fungi, biodegradation). Oxygen-free underwater wood is well preserved, under the following conditions:

- 1) To eliminate over-moisturizing of wood, impregnation with acetone, butyl methyl acrylate monomer and a benzene catalyst with a solution temperature of 80°C is performed. The solution is left for 10 hours, impregnated with alcohols, followed by coating with a polyethylene glycol solution. If the walls are excessively damp, it is recommended to paint the outside with lime paints. When the air humidity is less than 20%, the tree does not rot if it does not come into contact with the ground in the basement or with the foundation without waterproofing. Compliance with normal temperature and humidity conditions during the operation of a monument of wooden architecture is the guarantee of its durability.
- 2) Based on the results of the examination of the monument of wooden architecture, its elements can be divided into several groups: a) the elements of the monument that are in the satisfactory condition – only conservation measures are carried out with them; b) the partially damaged elements, which can be used after clearing from strongly affected by rot and corresponding structural strengthening with the help of polymer compositions and prosthetics; c) the elements that cannot be reused due to the absolutely lost structure.
- 3) The stages of work on the preservation of wooden structures and elements are as follows:
 - a. Mechanical cleaning of existing historical wooden structures, parts from dirt, rot and layers.
 - b. Disinfection treatment of damaged wood (sodium fluoride, concept FBA or concept FBG use a 0.5-1% aqueous solution of these preparations produced by the laboratory of the SE SSTC "CONREST" "Ukrrestavratsiia");
 - c. Antiseptic treatment of the entire cleaned surface of old wood using the FBA concept or the FBG concept. The recipe of old antiseptic compositions BS-11, BB-32 based on technical borax 2.5%, boric acid 2.5%, and water 95% do not change the color of the wood but require hydrophobization of the surface, which is performed after applying antiseptic compositions with a GIS solution on based on liquid glass and sodium methyl ethyl silicate. At present, Ukrainian restorers use Ukrainian broad-spectrum biocides "Ambisol IS", "Carbocide", "Phytoside", a solution of sodium dichromate, sulfuric, acetic acid and water as antiseptics. "Ambisol IS" is a mixture of dithiocarbamic acid derivatives of sodium hydroxide and urotropin in water to protect

against fungal biological damage, a 5% solution of the product in water is used to apply on wooden surfaces. Substances from Remmers from Germany and MIPA from Sadolin, Estonia have also proven themselves well.

d. Strengthening, prosthetics and replacement of individual structures. The basic principle for the conservation and restoration of wood structures is to use wood of the same species as in the original version. The wood is used dry and disinfected.

e. Fire and bio-protection of all historic and new wood by fireproofing. A common problem with wooden monuments is their susceptibility to fire. Any restoration work on such objects begins with field examinations of the state of the monument and its parts, determining the degree of destruction and those areas where old wood can no longer be restored. Such buildings are protected with antiseptics, fire retardants and bioprotective substances. Ukrainian broad-spectrum biocides "Ambisol IS", "Carbocid", "Fitoside", a solution of sodium dichromate, sulfuric acetic acid and water are used as antiseptics. They use Ukrainian preparations BB-11, BB-32 based on technical borax, boric acid and water, which have good penetration with antiseptic properties and are harmless. Ukrainian Endotherm, consisting of a suspension of fire-resistant pigments and fillers in a solution of vinyl chloride copolymer, should be called as fire-retardant substances that are successfully used in the Ukrainian restoration practice of the Ukrrestavratsiia Corporation; it transforms wood into a low-flammable state. Among foreign fire-retardant substances, one should mention the preparations of Remmers and Caparol, Germany.

f. Insecticidal treatment (coating, injection of insect damage to wood). Preparations: concept of IS, concept of IFI produced by SE SSTC "CONREST" "Ukrrestavratsiia". The treatment is carried out with a 0.5% solution several times, gradually applying it to the wood with brushes and syringes, followed by wrapping the wood with a film for 5-6 hours.

g. Structural strengthening of destructive wood. Solutions of acrylate or urethane polymer are used (repeated coating and injection into drilled holes). Putting of cracks, checks, areas of loss is carried out with wood flour, sawdust, adhesive solution of acrylate or polyurethane. Acrylate solution "Akrylakma" (Ukraine) – aqueous liquid, odorless, well penetrating into wood and forming a stable surface film, water and frost resistant. Indigenous polyurethane adhesives RK-30 I "Desmokol" and imported preparation "Hemilan" are also water- and frost-resistant.

An example is the creation of information application (the knowledge base) of the expert system "restoration of architectural monuments" – "wooden walls", which is directly related to the topic of the study presented by the authors (Fig. 9) [18]. Such an expert system helps to solve the problem of eliminating the emergency state of the walls in a complex manner, since the aspects of visual examinations, fixing the causes of the emergency state and methods of their elimination, are combined in one algorithm of actions; that is, all restoration measures are grouped according to the existing problem, and you can immediately go to a specific problem developed and proven by practice algorithm of restoration measures.

A brief review of the emergency state of wooden buildings in China, Ukraine and Poland, has proved their commonality. It is necessary to observe the state of the architectural monuments after the restoration for a particular time to compare the effectiveness of the results obtained in different countries. Each country uses its restoration methods to eliminate the emergency state of such facilities.

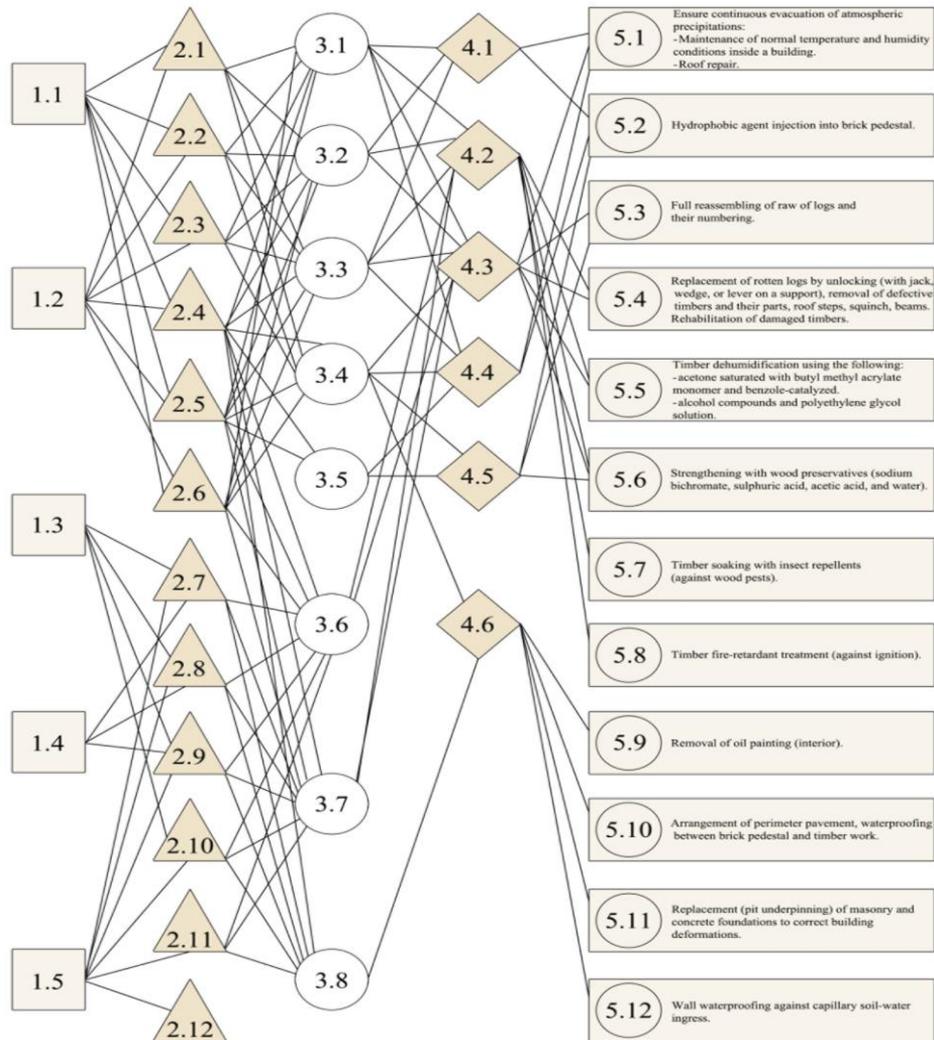


Fig. 9. Expert system "Timber Wall Strengthening Procedure": 1 – visual signs of critical conditions: 1.1 – wet spotting; 1.2 – fungoid growth; 1.3 – deflections; 1.4 – timber flooring deformations; 1.5 – depressions; 2 – critical condition reasons: 2.1 – roof leaks; 2.2 – squinch wetting; 2.3 – roof step wetting; 2.4 – wetting of logs row; 2.5 – wall covering (ceiling) wetting; 2.6 – wood-freeter invasions; 2.7 – shipworm attacks; 2.8 – beams (joists) wetting; 2.9 – flooring wetting; 2.10 – foundation (wooden, masonry, brick) deformation (subsidence); 2.11 – footpath damage; 3 – critical condition reasons 3.1 – roof sealing failure; 3.2 – drop apron damage; 3.3 – rainwater heads (on the roof) damage; 3.4 – rainwater pipes (downpipes) damage; 3.5 – wall waterproofing failure; 3.6 – pedestal waterproofing failure; 3.7 – capillary moisture ingress from pedestal; 3.8 – foundation seal failure; 4 – critical condition reasons: 4.1 – roof structural failure; 4.2 – framed wall structural failure; 4.3 – self-bearing wall structural failure; 4.4 – performance failure of lining; 4.5 – structural failure and loss of aesthetic properties of painting and gold; 4.6 – foundation structural failure; 5 – remediation techniques: 5.1 – ensure continuous evacuation of atmospheric precipitations: maintenance of normal temperature and humidity conditions inside a building; roof repair; 5.2 – hydrophobic agent injection into brick pedestal; 5.3 – full reassembling of logs row and their numbering; 5.4 – replacement of rotten logs by unlocking (with jack, wedge, or lever on a support), removal of defective timbers and their parts, roof steps, squinch, beams; rehabilitation of damaged timbers; 5.5 – timber dehumidification using the following: acetone saturated with butyl methyl acrylate monomer and benzole-catalyzed; the solution to be heated up to 80°C and applied to a surface for 10 hours; alcohol compounds and polyethylene glycol solution; 5.6 – strengthening with wood preservatives (sodium bichromate, sulphuric acid, acetic acid, and water); 5.7 – timber soaking with insect repellents (against wood pests); 5.8 – timber fire-retardant treatment (against ignition); 5.9 – removal of oil painting (interior); 5.10 – arrangement of perimeter paving, waterproofing between brick pedestal and timber work; 5.11 – replacement (pit underpinning) of masonry and concrete foundations to correct building deformations; 5.12 – wall waterproofing against capillary soil-water ingress

The Polish Experience in the Restoration of Wooden Architecture Monuments

In Poland, in the process of wood preservation, high-quality synthetic resins (in the form of liquids or granules) are used, which strengthen its structure regardless of the cause of its damage – weather conditions, microorganisms or insects. These resins can also be used to repair wood fragments by mixing them with wood flour and then filling the voids.

In the case of the presence of microorganisms in historical wood, the frequently used preparations are a combination of the following compounds: 2,2'-hydroxydiethanol (diethylene glycol); quaternary ammonium compounds, benzyl (C12 - C16) alkyldimethyl, chlorides and 2-octylisothiazol-3 (2H) – (for example, Altax); or preparations based on the following components: quaternary ammonium compounds, benzyl-C12-16-alkyldimethyl, chlorides; Boric acid and (2-methoxymethylethoxy) propanol (e.g. boramone), which when applied to historic wood can protect it for up to several months after application without altering the color and brightness of the wood. The method of assessment of the effectiveness of the applied technique is also significant. For example, the combination of digital radiography and image analysis can be used for this purpose. It enables rating the degree of penetration of the consolidator and determining its location within the preserved historical material.

Conclusions

The scientific novelty of the research consists of two aspects – the aspect that concerns the protection of historical gardens of Suzhou on the basis of their comprehensive analysis and the aspect that concerns the experience of the restoration of wooden monuments in different countries – in China, Japan, Ukraine and Poland and the presentation of restoration activities as a system. The scientific novelty of the research consists in identifying a list of the main techniques of traditional Chinese landscape design and argumentation of the revealed techniques with specific examples of gazebos in the gardens of Suzhou. The methods of figurative expressiveness of pavilions in different regions of China are systematized. Comparison of historical and modern Chinese pavilions demonstrated the narrowing of figurative means, the use of a narrow range of historical prototypes (mainly in the east and southeast), in which the national features of the small-scale architecture are vividly pronounced.

The Ukrainian restoration school is based on the integrated systematic approach to solving the problems of restoration. The experience of the corporation formed the foundation of the expert system (ES) for restoration and renovation works, in particular for information and methodological support of the restoration activities.

Mykola Orlenko has developed four groups of expert systems:

- "observation" – "monitoring" of architectural monuments;
- "diagnostics" – the establishment of causal relationships, predicting the damage detected, recommendations for eliminating the consequences;
- "design" of restoration objects for individual components and elements of buildings and approval of decisions;
- "planning" – the execution of restoration work.

Technological development of expert systems in the field of restoration of architectural monuments consists of procedures that include: information retrieval (creation of information retrieval systems), complex calculations (checking the stability and strength of load-bearing structures), searches for graphic and other elements, and text processing.

As a tool for developing information support (creating a knowledge base), it is possible to recommend applying the principles and methods of forming relational databases (knowledge base). The effectiveness of the expert system is achieved due to reducing the time spent on development and decision-making.

There are the causes of the destruction of wooden walls as specific reasons and the sequence of restoration actions in each particular case. It means that such a scheme is essentially an algorithm for carrying out work. Our algorithm was developed on the basis of the Ukrainian restoration experience. The subsequent in-depth analysis of the applied foreign techniques and chemicals makes it possible to fill up the algorithm with successfully proven

external methods. It should be added to that part of the information application of the expert system, which describes the specific technologies for eliminating the emergency state of the monument.

References

- [1] P. Spiridon, I. Sandu, *Muselife of the life of public*, **International Journal of Conservation Science**, 7(1), 2016, pp. 87-92.
- [2] P. Spiridon, I. Sandu, L. Stratulat, *The conscious deterioration and degradation of the cultural heritage*, **International Journal of Conservation Science**, 8(1), 2017, pp. 81-88.
- [3] L. Pujia, *Cultural heritage and territory. Architectural tools for a sustainable conservation of cultural landscape*, **International Journal of Conservation Science**, 7(1), 2016, pp. 213-218.
- [4] V. Petrušonis, *Symbolic potential of place and its modelling for management needs*, **Landscape Architecture. Scientific Journal of Latvia University of Agriculture**, 13, 2018, pp. 39-49.
- [5] Yu. Ivashko, T. Kuzmenko, S. Li, P. Chang, *The influence of the natural environment on the transformation of architectural style*, **Landscape Architecture. Scientific Journal of Latvia University of Agriculture**, 15, 2020, pp. 101-108.
- [6] Yu. Ivashko, D. Kuśnierz-Krupa, P. Chang, *History of origin and development, compositional and morphological features of park pavilions in Ancient China*, **Landscape Architecture. Scientific Journal of Latvia University of Agriculture**, 15, 2020, pp. 78-85.
- [7] L. Qin, **Chinese Pavilions**, China Architecture and Building Press, 2019.
- [8] R. Lu, **Garden Analysis Pavilion**, China Forestry Press. 2004. (in China), (《园林析亭》中国林业出版社 2004年 卢仁).
- [9] Yu. Ivashko, D. Chernyshev, P. Chang, *Functional and figurative and compositional features of traditional Chinese pavilions*, **Wiadomości Konserwatorskie – Journal of Heritage Conservation**, 61, 2020, pp. 60-66.
- [10] L. Zhang, *La PKU'S research on China's traditional eco-wisdom and related application in contemporary landscape planning and design*, **Landscape Architecture Frontiers**, 6(3), 2018, pp.12-27.
- [11] M. Orlenko, Yu. Ivashko, *The concept of art and works of art in the theory of art and in the restoration industry*, **Art Inquiry. References sur les arts**, XXI, 2019, pp. 171-190.
- [12] M. Orlenko, M. Dyomin, Yu. Ivashko, A. Dmytrenko, P. Chang, *Rational and Aesthetic Principles of Form-Making in Traditional Chinese Architecture as the Basis of Restoration Activities*, **International Journal of Conservation Science**, 11(2), 2020, pp. 499-512.
- [13] I. Sandu, M. Orlenko, M. Dyomin, O. Ivashko, Y. Ivashko, C.G. Lazareanu, K. Paprzyca, I.G. Sandu, P. Sztabinska-Kalowska, *Scientific Conservation of the Outstanding Theaters of the 19th Century and Their Influence on the Creation of Modern Art-Space*, **International Journal of Conservation Science**, 12(2), 2021, pp. 361-390.
- [14] K. Yu, *The conflict between two civilizations of nature-based solutions*, **Landscape Architecture Frontiers**, 8(3), 2020, pp. 4-9.
- [15] J. Jiang, M. Chen, J. Zhang, *Analyses of elderly visitors' behaviors to community parks in Shanghai and the impact factors*, **Landscape Architecture Frontiers**, 8(5), 2020, pp.12-31.
- [16] P.V. Alfieri, R. García, V. Rosato, M.V. Correa, *Biodeterioration and biodegradation of wooden heritage: role of fungal succession*, **International Journal of Conservation Science**, 7(3), 2016, pp. 607 – 614.
- [17] J. Abbasi, K. Samanian, M. Afsharpor, *Evaluation of polyvinyl butyral and zinc oxide nanocomposite for consolidation of historical woods*, **International Journal of Conservation Science**, 7(2), 2017, pp. 207 – 214.

- [18] M. Orlenko, **Problems and Methods of Conservation of Architectural Monuments in Ukraine**, Kyiv, 2018.
- [19] M.S. Austigard, J. Mattsson, *Monitoring climate change related biodeterioration of protected historic buildings*, **International Journal of Building Pathology and Adaptation**, **38**(4), 2020, pp. 529-538.
- [20] R.Y. Yang, Y.F. Sun, X.F. Zhang, *Application and Progress of Reinforcement Technology for Chinese Ancient Buildings with Wood Structure*, **Geotechnical and Geological Engineering**, **38**(6), 2020, pp. 5695-5701.
- [21] A. Blanchette, *A review of microbial deterioration found in archeological wood from different environments*, **International Biodeterioration and Biodegradation**, **46**, 2000, pp. 189-204.
- [22] G. Chidichimo, F. Dalena, A. Rizza, A. Beneduci, *Insect-Infested Wood Remediation by Microwave Heating and Its Effects on Wood Dehydration: A Case Study of *Hylotrupes bajulus* Larva*, **Studies in conservation**, **63**(2), 2018, pp. 97-103.
- [23] Y. Yuzhakov, A. Belkin, *Construction strengthening in historical wooden cupolas restoration*, **XXI International Scientific Conference on Advanced in Civil Engineering Construction – the Formation of Living Environment (FORM 2018)**, (Editors: A. Askadskiy, A. Pustovgar, T. Matseevich and A. Adamtsevich), IOP Conference Series – Materials Science and Engineering, Volume: **365**, 2018.
- [24] G. Frunzio, L. Di Gennaro, *Seismic structural upgrade of historical buildings through wooden decks strengthening: the case of study of Palazzo Ducale in Parete, Italy*, **XIV International Conference on Building Pathology and Constructions Repair**, (Editors: G. Bartoli, M. Betti, M. Fagone and B. Pintucchi), Volume 11, 2018, pp. 153-160.
- [25] G.F. Qiao, T.Y. Li, Y.F. Chen, *Assessment and retrofitting solutions for an historical wooden pavilion in China*, **Construction and Building Materials**, **105**, 2016, pp. 435-447.
- [26] J.V. Oliver-Villanueva, J.E. Benitez-Telles, M.V. Vivancos-Ramon, J.V. Grafia-Sales, *Wood Consolidation Assessment by Fundamental Frequency Method in Cultural Heritage Preservation*, **Wood Research**, **57**(2), 2012, pp. 331-338.
- [27] E. Pokrovskaya, D. Adapov, Yu. Kavalchuk, *Mycological Investigation of a Wood Substance of Historic Cultural Heritage*, **Lesnoy Zhurnal – Forestry Journal**, **4**, 2019, pp. 212-220.
- [28] M. Lisinska-Kusnierz, M. Krupa, K. Paprzyca, J. Sygula-Cholewinska, K. Kusnierz, O. Ivashko, *Deterioration of Wood by Microorganisms in a Historical Building on the Example of a Historical Health Resort Villa*, **International Journal of Conservation Science**, **11**(4), 2020, pp. 905-916.
- [29] J. Sobczyk, P. Fraczek, M. Obarzanowski, J.M. del Hoyo-Melendez, L. Bratasz, *Digital radiography (DR) and imaging analysis for evaluating the penetration and distribution of organic substances used in wood conservation*, **Wood Science and Technology**, **48**(5), 2014, pp. 981-994.
- [30] S.F. Jiang, N.L. Li, S. Shen, M.H. Wu, Y. Zhang, *Damage prognosis of China ancient wooden buildings based on structural health monitoring system*, **Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems 2018**, (Editors: H. Sohn, J.P. Lynch and K.W. Wang), 2018, Article Number: 10598.
- [31] Z. Kunpeng, L. Aiqun, X. Linlin, W. Chong-Chen, W. Peng, W. Xiufang, *Mechanism and effect of alkoxysilanes on the restoration of decayed wood used in historic buildings*, **Journal of Cultural Heritage**, **43**, 2020, pp. 64-72.

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