

THE CONCEPT OF FORMATION OF A COMFORTABLE LIGHT ENVIRONMENT, ELECTRIC LIGHTING OF ARCHITECTURAL OBJECTS

Kirill Kondrashin^{1,*}, Sergey Strelkov¹, Tatiana Kurbatova¹, Nadezhda Raktovich¹

¹ Astrakhan State University of Architecture and Civil Engineering, Astrakhan, Russia

* Corresponding author. Email: astrakhan_kirill@mail.ru

ABSTRACT

In this work, the central aesthetic problem of the process of forming the light environment of the city and the light architecture of objects was investigated - the interaction of artificial light with an architectural form in its four main types or categories, which results in the formation of light space, traffic lights, light plastic, light colour with new, different than daytime, visual qualities. The idea of the project is to create a normal light environment for the Astrakhan embankment. It must meet all norms, have a single stylistic solution, maintain the integrity of the compositional structure, and also solve a number of problems associated with the perception of the urban environment day and night.

Keywords: *design of light environment, comfort of urban environment, city embankment.*

1. INTRODUCTION

The urban environment is an artificial habitat constructed by man, simultaneously including static and dynamic components, and is a system in which there are material (architectural structures, objects, things, etc.) and spiritual objects (norms, values, rules etc.) [1].

The more detailed the information about the urban environment, the more effective the processes for the formation of comfortable living for urban residents [2]. In the process of intensive urbanization, increasing population density and a significant increase in the periods of daily activity, it is necessary to develop approaches to increasing human potential. First of all, this is an increase in life expectancy and the index of happiness [3-5].

In the theory and practice of urban planning, outdoor lighting in all its types is included in the section of the engineering equipment of urban areas [6-8]. This circumstance plays a decisive role in a clear underestimation of the aesthetics of outdoor lighting, its richest possibilities and creative potential in the artistic interpretation and humanization of the architectural

environment, traditionally designed and calculated for the conditions of its visual perception, and assessment only in the daytime [9-12].

At the same time, the spectacular implementation of electric lighting of landmark objects in many cities of the world, at international exhibitions and in the natural landscape has always attracted the interest of the general public to new opportunities for improvement and new, generated lighting, environmental standards [13]. The quantity and quality of these capabilities, standards and expectations is steadily increasing due to the progress in the field of lighting technology [14-15].

2. OBJECTS AND METHODS

Interdisciplinary studies of urban issues are an important part of his ecological design. This comes from the overall vision and perception of the city as an organization. A complex system consisting of many interacting elements - objects, processes, phenomena, events, etc. - forms the appearance, physical structure, and dynamic characteristics of the city.

The site for the development of the light design of the embankment was selected taking into account the general plan of the city of Astrakhan. The site occupies an area on the border of Kirovsky and Sovetsky districts, relative to the city center in the southwestern part. According to the general plan, the territory is recreational, it is limited from the north - st. General of the Army Epishev, from the west - st. Privolzhsky backwater, from the east - st. Privolzhsky backwater, and from the south - st. Donetsk.

Table. Technical and economic indicators

№	Denomination	Value, m ²
1	Land area	12 027
2	Built-up area	11 137
3	Hard surface area	6 704
	Paving slabs	4 293
	Spec. coverings	2 411
4	Landscaping area	4 433

The embankment is a canal with two banks (western and eastern). Residential buildings are located on both sides of the canal. On the western bank there is an industrial area, parking lots and a city highway.

The artificial light environment of the city has a pronounced specificity, which is obvious when compared with the natural light environment. It is due to the four main components of this environment - lighting, visual, functional, and architectural and urban planning [16]. Two of them, functional and architectural and urban planning, represent a constant urban basis of the environment, the other two, lighting and visual, are changing factors. The lighting component is the main "actor" in the formation of the light environment, created by man and constantly modified due to the progressive development of lighting engineering science, production, and practice. It is completely manageable and, in comparison with the urbanistic basis, is mobile, changeable in time and space.

Illumination of the urban environment, that is, urban spaces, objects that form them and the surface of the earth, is fragmentary, selective and will not fundamentally change in the near future. It is carried out by a variety of light sources, which are primary emitters, and light reflecting surfaces (as secondary emitters) with different brightness, colour, light distribution and radiation kinetics. Each of the primary sources forms a visually perceived space, which can be called an elementary light space, with more or less clear boundaries, which, under certain conditions, are read in the air as light cones, spheres, cylinders, etc. (luminous flux at a certain solid angle at a reduced transparency of air - in case of rain, snow, fog, etc.). The shape and size of such a light space can be characterized by the photometric body of the lighting device that created it.

Each elementary light space, optically merging with neighbouring (if any), forms a more complex in structure, relatively unified utilitarian light space with varying

degrees of heterogeneity - continuous within linear planning elements (streets), discrete in certain areas of the territory (in squares, in residential courtyards, in parks) or "patchwork" - discontinuous, which is the light space within the city. His drawing can be read from the illuminated fragments of the earth, along the "light tunnels" of the streets on the "light plan" of the city from high vantage points and from airliners.

Real architectural light space also includes the effects of secondary emitters - illuminated objects that form a three-dimensional environment - buildings, structures, trees. Visually, they are more significant in the aesthetic assessment of the light environment, although their "specific gravity", characterized by the photometric parameters of the generated light field, is usually less than that of streetlamps. Ultimately, the creation of lighting is the optical formation of an urban space with predictable light-compositional parameters.

3. RESULTS AND DISCUSSION

As a result of the visual analysis, the following was revealed:

- Low level of illumination of the territory;
- Insufficient space to create a comfortable recreational area;
- Violation of stylistic unity in the design of the embankment;
- Loss of the main compositional elements of the connection between the city and the embankment.

The concept of the formation of an artificial light environment in the city proceeds from the goal-setting tasks of a utilitarian, technological and psychoaesthetic nature, which should be solved at different stages of design and in the process of implementing a complex of lighting installations:

- Creation of comfortable, environmentally friendly visual conditions for pedestrians and transport drivers;
- Providing architectural and artistic expressiveness of urban ensembles and objects for all people whose attention is drawn to the evening city;
- Formation of a favourable "psychological atmosphere" in the evening city, mainly for pedestrians.

These general tasks in specific urban planning conditions are transformed, acquiring an individual colouring, reflecting the peculiarities of the situation and the creative credo of the authors.

The idea of the project is to create a normal light environment for the embankment. It must meet all norms, have a single stylistic solution, maintain the integrity of the compositional structure, and also solve a number of

problems associated with the perception of the urban environment day and night.

At the moment, the territory of the embankment is in good condition. But it has a number of specific problems. They are associated with a violation of the stylistic integrity of the embankment design, insufficient territory for the recreation zone. Poor illumination level and inaccurate construction of functional zoning zones.

The basis for building the image of the new embankment was the visualization of the number three in our concept of organizing the embankment space. The number three is a conventional designation of the number of basic types of perception of the territory. There is also a semantic image of this number associated with a person's lifestyle, the average number of days per week, the number of months in one annual season. Based on the number three, we create three levels of lighting, the type and degree of brightness of our light environment. In the same way, we use three planes of human volumetric perception of the environment.

It was decided to divide the embankment into three main levels, united by a single style solution. By means of light, the image of the projected embankment is organized on three levels, accents and dominants are brought out here.

The main task of the project is to create a favourable environment for a person's stay. "Closer to the stars" is the main slogan of the concept under study. The light will help you navigate in space. The planning solution distinguishes three pedestrian directions at three different levels, each with their own specific lighting. At the same time, the task was set for both functional and decorative solutions of the light space.

Similar solutions are applied to the other side of the Volga backwater. However, here it is necessary to take into account the objects of cultural heritage, the main pedestrian directions and viewpoints, on the basis of which the concept was built. Much attention is paid to the details of the embankment filling.

Each element should be part of the whole and have an echo in the form of a bright light on the embankment map. The objects will create a general image of the embankment, both at night and during the day.

When developing the concept on the basis of architectural, planning, coloristic solutions of buildings, structures and areas of the embankment, including small forms and landscaping elements, the search for artistic imagery of the light environment was carried out - from the main entrance to the embankment area and ending with individual buildings and fragments of urban development. The transmitted imagery is united by a common leading concept of lighting organization, which, in turn, is divided into separate blocks according to the principles of the formation of the light environment, the light-colour solution, the design of small light forms and lighting devices.

In the planning structure of the embankment, it was decided to make a number of changes to facilitate the normal perception of space and the organization of traffic along the canal territory. The main solution to the lighting environment was the ability to highlight the main objects of the embankment territory, create a favourable environment for a person's stay and solve a number of problems associated with the integrity of the perception of the territory.

Filling the space with small architectural forms allows you to create a comfortable environment. There are benches along the pedestrian directions, the directions have artificial lighting, there are drinking fountains throughout the territory, allocated due to their own lighting, and the organization of comfortable places for quiet rest with warm, calm illumination. Also available communication links, presented in the form of stairs and illuminated ramps, allow you to travel smoothly along the embankment.

The centre of the entire structure are open areas for exhibitions, small festivals, or the usual gatherings of small groups of people.

Everything in the embankment light design project is aimed at creating a light space. The projected embankment consists of two terraced banks. The difference in the heights of the terraces of the western bank is 1.2 m, that of the eastern bank is 0.9 m. On the basis of the difference in heights of the terraces of the embankment, illumination of three levels was built.

The first level is the illumination of the coastline. It is located along the entire length of the bank of both sides of the channel, it is presented in the form of directional light sources submerged in the water. Serves to give the greatest expressiveness to the coastline and emphasizes the boundary of the watershed of the canal.

The second level of lighting is located on the lower terraces of the embankment. It is presented in the form of low lanterns and is located along the entire length of the coast. Serves to create accents on the lower level of the embankment and highlight the main walking area.

The third level completes the overall composition, emphasizes significant places on the territory, sets the direction of movement of pedestrians and creates a colour background for the general lighting of the coast. The level is presented in the form of lanterns of different heights, different power heights and colours.

The coloristic solution of the environment as a whole depends on the lighting and the materials used. In the project, it was decided to use light colours of materials and light of a warm shade. The abundance of landscaping goes well with natural woody tones. Visually, such a solution gives stability and balance, and a warm shade of light gives cosiness and comfort. It is customary to highlight the accent with light of a different shade, brighter and colder. The coloristic solution harmoniously matches the environment of the embankment and urban development.

The existing power supply on the construction site is centralized from the city power grid. Installed power: $220 \text{ v} \times 62 \text{ kW}$.

It is planned to place 386 artificial lighting sources on the embankment territory, of which 256 will be directed to direct illumination of the embankment area as the main one and 130 as auxiliary ones. As a basis for this equipment, it was decided to take the Super Street lights (Fig. 1) as the main ones for the main connections and directions, and the L-Park 32 type (Fig. 2) model as background lighting

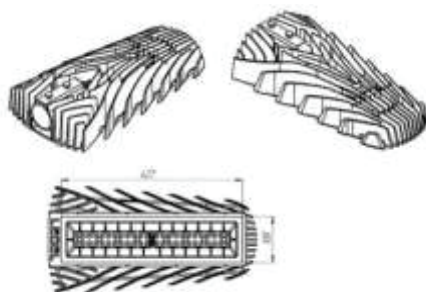


Figure 1. Super Street Lantern.



Figure 2. Lantern type L-Park 32.

On the basis of these two types of lighting equipment, a new one is being designed in accordance with the adopted design plan, but having the same technical indicators. Super Street model 110 has an efficiency of 95%, a luminous flux of 12,780 lm, similar to the DRL-250 and DNaT-15 flashlights. The DC supply voltage to the network from the Super Street lamp is 200-250 V, the power consumption is 110 W.

Power consumption of L-Park 32 lights is 32 W, Super Street lights - 110 W.

We can determine the power consumption of this system by the formula:

$$P = nNP_i, \quad (1)$$

P - Total power of the lighting installation

Pi - Power consumption of one lamp

N - Number of luminaires

n - Number of lamps in the luminaire

Therefore, P for L-Park = $60 \cdot 179 \cdot 1.875$,

$$P = 5728 \text{ W} = 5.728 \text{ kW},$$

For Super Street 110, $P = 36 \cdot 77 \cdot 3.437$,

$$P = 8470 \text{ W} = 8.47 \text{ kW}.$$

Thus, the total load on the lighting system is 14.198 kW. According to calculations for the last year, the cost per 1 kW / h is on average 4.68 rubles. The total working period of the main form of embankment lighting is considered to be 10 working hours of operation of the lighting equipment. From this we get the cost of one working hour of the entire system as 66.44 rubles, and 664.4 rubles. for a whole day of operation of the lighting installation.

The developed project to improve the comfort of the study area is presented below (Fig. 3).



Figure 3. The project to improve the comfort of the Astrakhan embankment.

The quality of the project is determined not only by progressive technical solutions, but also by the reliability of the estimate documentation. The estimated cost of the construction of enterprises, buildings and structures is the amount of funds determined by the estimate documents required for its implementation in accordance with the project. The estimate is used to plan and finance construction, to determine the technical and economic indicators of the projected facility and the feasibility of its construction, organize construction production, conduct economic work in construction and installation organizations and control their activities.

The project includes the design of pedestrian routes along Privolzhsky Zaton Street, and along the Privolzhsky Zaton Canal in the city of Astrakhan. This section of the territory is limited by General Epishev street from the north and Donskoy street from the south. The destinations are located on two levels of the embankment, along the canal there are different zones for different types of recreation and leisure. The canal itself serves as a means of renting various light boats and recreational facilities on the water surface. From an economic point of view, the concentration of a large

number of people in this area will allow the development of a tourist business, increase the popularity and sale of various types of water transport, in winter it is well suited for renting skates and holding small competitions on the territory of the backwater. Also, near the backwater is one of the main architectural monuments of the city of Astrakhan, the temple of Prince Vladimir. This fact leads to the fact that the tourism business will develop well on the territory.

The estimated costs determined in the budget form the basis for planning capital costs, financing construction, paying for construction and installation work, as well as compensating for other costs at the expense of funds provided for in the consolidated estimate. According to the structure of capital investments and the order of implementation of the business plan of the construction company, they are divided into types of work and the following costs: Installation work; the cost of equipment, furniture, inventory, and other expenses.

Based on the data received, the cost of the project was calculated. The object of construction is an embankment, consisting of two levels, with an area of 6,238.842 m². The average cost per 100 m² (according to the enlarged estimate norms of the NCS 81-02-04-2014 for paths, platforms and sidewalks made of paving slabs on a sandy base) is 237.59 thousand rubles. In 2020 prices, $237.59 / 5.4 \cdot 5.64 = 248.15$ thousand rubles. The cost of the construction of the pedestrian directions of the embankment according to the enlarged estimate norms is $62.39 \cdot 248.15 = 15\,428\,078$ rubles.

The concept of lighting the Astrakhan embankment presented by the author includes the following series of light compositional solutions:

- Programming brightness. The most important buildings bordering the facades are highlighted with maximum brightness and lighting. In this case, the intermediate object can only contain minor local lighting.
- Light determination of the depth of space, that is, the principle of illumination of deep spaces. Designing street lighting requires defining architectural rules, modeling and positioning the maximum and minimum brightness that shapes the light, and creating a deep, flat light space.
- Light detection or highlighting of eclectic plastics and colour of complex facade architecture.
- Using coloured light as a means of creating an artistic expressive image of a building;
- Inclusion of multidirectional transverse light fluxes.
- Artistic inclusion of functional light in the overall light composition of the facade or street space.
- Allocation of silhouettes of facades.

- Detection of the contrast of openwork patterns of countercurrent forged elements (reception of illumination).
- Creation of light rhythmic of plastic elements, window sills, front windows.
- Light accents of axial elements-arches and niches in the composition of facades-light arches and light niches.
- Highlighting domed corners in 3D building configurations.
- The use of media facades.

The practice of light modeling has shown that a light composition is harmonious if it contains no more than two different-spectral light sources. The artistic effect is enhanced by using luminance (light-shade) and colour contrast (cool hue-warm hue).

For cleanliness and comfortable perception of the embankment in the dark, the lanterns are made at different levels and have a warm temperature spectrum. This technique allows you to create a cosy atmosphere and does not strain the visual perception of a person while walking along the embankment. The images become warmer, more cosy, an atmosphere of comfort and tranquillity is created.

Despite the fact that the "Culture of Light" is divided into different disciplines, the tasks that it solves and the principles that it embodies convincingly indicate that all the activities of a lighting designer, including the period of study, makes the object of the idea of creating new meanings and value culture.

The results of the analysis of existing approaches to urban lighting in relation to a specific object of research do not limit the field of research, bring scientific and practical problems to a new level, and open up new prospects for studying the complex organization of the light environment.

AUTHOR'S CONTRIBUTION

The authors carried out work on the analysis of the components of a comfortable urban environment and also created a project for a comfortable light environment for the embankment of the city of Astrakhan.

ACKNOWLEDGMENTS

The authors express their gratitude to the Astrakhan State University of Architecture and Civil Engineering for the equipment and materials provided

REFERENCES

- [1] Ch. Santen, Light Zone City. Light planning in the Urban Context, Brikhäuser Publishers for Architecture, 2006, 127 p.

- [2] G.S. Matovnikov, N.I. Shhepetkov, Lighting new pedestrian streets in Moscow, in: *Light & Engineering*, 2015, vol. 2, pp. 11-17.
- [3] V.E. Karpenko, Coastal cities light panoramas, Far Eastern Federal University, School of Engineering, Vladivostok, Far Eastern Federal University, 2015, 116 p.
- [4] G.S. Matovnikov, Principles of the formation of the light environment of pedestrian streets of the city (on the example of Moscow). Book Publisher of Moscow Institute of Architecture (State Academy), Moscow, 2017, 31 p.
- [5] A.V. Efimov, V.E. Karpenko, N.I. Shhepetkov, Illumination of embankments of Vladivostok and the city, in: *Light & Engineering*, 2016, vol. 5, pp. 62-68.
- [6] O.V. Maslovskaya, G.E. Ignatov, Sovremennye tendentsii sozdaniya i preobrazovaniya gorodskikh ploshchadey, in: *Territoriya novykh vozmozhnostey. Vestnik Vladivostokskogo gosudarstvennogo universiteta ekonomiki i servisa*, 2015, no. 1 (28), pp. 91-95.
- [7] N.V. Meseneva, Vizualnaya kultura sovremennoy gorodskoy sredy na primere goroda Vladivostoka, in: *Territoriya novykh vozmozhnostey. Vestnik Vladivostokskogo gosudarstvennogo universiteta ekonomiki i servisa*, 2019, no. 1, pp. 112-120.
- [8] N.V. Meseneva, K voprosu ispolzovaniya malykh arhitekturnykh form v dizayne gorodskoy sredy, in: *Sovremennye naukoemkie tekhnologii*, 2016 no. 8 (2), pp. 256-260.
- [9] S.V. Stetskiy, Comparative analysis of the functional characteristics of sunscreens for civil buildings in a hot sunny climate, in: *Light & Engineering*, 2017, no. 3, pp. 29-33.
- [10] S.V. Stetskiy, A.I. Gerasimov, Sound insulation of external enclosing structures of civil buildings in large cities of countries with a hot climate, in: *Roofing and insulation materials*, 2009, no. 1, pp. 60-61.
- [11] A.K. Soloviev, *Physics of the environment*, DIA, Moscow, 2014, 341 p.
- [12] U. Norsidah, Z. Khalilah, The Notion of Place, Place Meaning and Identity in Urban Regeneration, in: *Procedia - Social and Behavioral Sciences*. Elsevier, 2015, January, pp. 709-717.
- [13] N.I. Shchepetkov, Open letter to the Chief sanitary doctor Yu. Popova, in: *Light Engineering*, 2017, no. 6, p. 100.
- [14] O.V. Bogdanova, Y.D. Filatova, Determining the role of color and light in architecture, in: *Tendentsii razvitiya nauki i obrazovaniya*, 2016, no. 17-1, pp. 6-8. <https://doi.org/10.18411/lj2016-8-1-02>
- [15] D. Jackson, *Superlux: smart light art, design and architecture for cities*, Thames & Hudson, London, 2015, 272 p.
- [16] V.G. Chudinova, O.R. Bokova, Possibilities of Architectural Lighting to Create New Style, in: *IOP Conference Series: Materials Science and Engineering*. International Conference on Construction, Architecture and Technosphere Safety (ICCATS 2017), 2017, vol. 262, 012147. <https://doi.org/10.1088/1757-899X/262/1/012147>