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RESEARCH INTO LUMINANCE CHARACTERISTICS OF OBJECTS WITH ARCHITECTURAL LIGHTING OF CENTRAL STREETS OF TULA

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ABSTRACT

The study of luminance distribution over the facades with architectural lighting allows us to estimate the perception of architectural objects, to analyse the quality of light solutions. The relevance of luminance characteristics estimation in night-time urban conditions has been increasing over the years, in particular, for cities where the development direction of lighting environment aims at increase of the number of illuminated objects and where there is no developed strategy of lighting environment development. Using the example of 11 central streets of Tula, the article describes the comprehensive approach to analysis of the quality of architectural lighting. Using a CCD matrix-based luminance meter, the luminance characteristics of facades were estimated.

Keywords: architectural lighting, luminance distribution, lighting environment, luminance measurements, lighting quality

1. INTRODUCTION

Nowadays, the lighting environment of Russian cities has been forming spontaneously, without taking the hierarchy of objects in the urban environment into account [1–3]. The luminance characteristics of applied lighting installations are often overestimated, which causes negative impact on visual perception [1–3]. Increase of the number of architectural lighting solutions based on local lighting method causes visual destruction of perception integrity of buildings, in most cases, the relations between minimal and maximum illuminance values do not comply with the requirements of SP 52.13330.2016 and exceed 1:30 [4].

The lighting composition of an evening city should be based on compliance of all elements of lighting environment in the entire solution. The requirements imposed on architectural lighting are: identification of building mass, expression of the structure and plastics of architectural forms. The projects of exterior architectural lighting should be the part of general urban design and lighting skylines of an evening city [1–4].

In terms of qualitative estimation of the implemented lighting solutions, there are the following challenges today:

- Formation of exterior of night cities without a developed lighting strategy in Russia causes appearing of separated objects;
- Urban hierarchy of the objects within the urban environment is not taken into account;
- The implemented objects do not comply with the requirements of standard regulations in terms of luminance level;
- There are no quality control mechanisms of the implemented objects;

Lack of attention to the said problems causes destruction of integrity of urban environment during evening time, irrational consumption of energy resources, negative impact on visual perception and psychoemotional state of a person [1–4].

Tula is a small city with area of 145.8 km^2 located at 200 km from Moscow. For small towns,

Fig.1. Mapped objects with architectural lighting

specialist design lighting of objects remotely, which also affects the quality of the implemented solutions.

Application of the methods of luminance distribution study within the field of view is a relevant challenge which allows qualitative objects to subsist in the urban structure and to plan modifications of the lighting design structure of the city. The analysis of luminance characteristics of existing lighting may be conducted as a preliminary phase before developing the lighting strategy, the lighting master plan of the city [5–7].

The goal of the study was to investigate the luminance distribution over the illuminated facades by optoelectronic instruments using the example of central streets of Tula. In the course of the study, the existing lighting environment was evaluated, which allowed the most common problems to define. The luminance distribution was estimated by means of a direct method in accordance with GOST 26824–2010 and GOST R55707–2013 using LMK Mobile Advanced luminance meter on the basis of a CCD matrix. Application of the specialised LMK LabSoft software for analysis of the acquired results allows process, analyse and display the values of luminance of the measured surfaces. The measurements were conducted in August 2017, prelim-

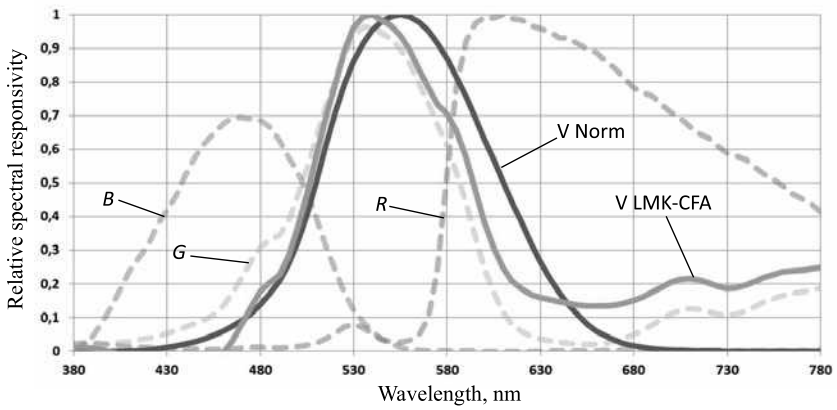


Fig.2. Relative spectral responsivity of the luminance meter (black curve)

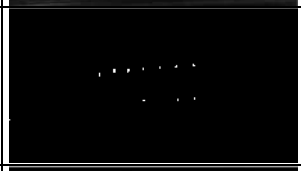
2, Mosina st.			THE OBJECT Buildings with AHL Arch. Dominants: Level 2 Level 3	The building of the Ryabikov Tula Machine-Building Plant is not a dominant. The architectural lighting fully complies with the status of the building, excellently uncovers its architecture and decorative elements of the facade.
1A, Sovetskaya st.			THE OBJECT Buildings with AHL Arch. Dominants: Level 3	The building of the Tula Arms Plant is not a dominant. The architectural lighting fully complies with the status of the building, excellently uncovers its architecture and decorative elements of the facade.
2, Sovetskaya st.			THE OBJECT Buildings with AHL Arch. Dominants: Level 2 Level 3	The building of the City Concert Hall is not an architectural dominant. The architectural lighting of the building uniformly lights the facade facing the Sovetskaya st. In the context of the surrounding lighting environment and town-planning value, the luminance of the main facade of the building is too high.
78, Sovetskaya st.			THE OBJECT Buildings with AHL	The building at 78 Sovetskaya st. is not an architectural dominant. The architectural lighting of the building expresses the architectural distinctions, but due to different chromaticity of sources and high luminance, the building is visually torn out of the evening urban environment. The Lenin square where the closest major dominants are concentrated is located nearby. In the context of the surrounding lighting environment and town-planning value, the luminance of the main facade of the building is too high.
13, Turgenevskaya st.			THE OBJECT Buildings with AHL	The luminance of the lighting of the building at 13, Turgenevskaya st. is too high, which is inappropriate due to the fact that the building is not a dominant. The used methods of architectural lighting express all architectural distinctions of the building, but due to high luminance, the building is visually torn out of the evening urban environment. The Lenin square where the closest major dominants are concentrated is located nearby.

Fig.3. Example of the objects database with the existing lighting

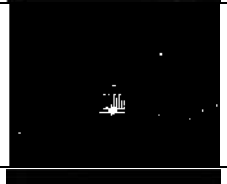
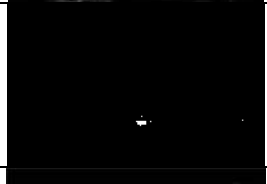
56A, Sovetskaya st.			66 cd/m^2, the most luminous part of the light spot is 140 cd/m^2, luminance of the advertising line is 220 cd/m^2	15 cd/m^2, 200 cd/m^2 (for advertising)	Luminance standard is exceeded by 4.4 times. Average luminance of the most intensive light spot is 9.3 times higher than the standard value, the luminance of the advertising lighting is 1.1 times higher. The relation between the maximum and the minimum value of illuminance within the illuminated surface exceeds 30:1, which causes high contrast, the building volume cannot be perceived.
4 Puteyskaya st.			46 cd/m^2, the most luminous part of the light spot is 98 cd/m^2	30 cd/m^2	Luminance of the facade complies with the standard. The building of the Moscow train station is the architectural dominant of the 3rd level, therefore exceeding of the luminance standard by 50% (up to 45 cd/m^2) is acceptable.
48k1, Krasnoarmeyskiy prospect.			73 cd/m^2, the most luminous part of the light spot is 167 cd/m^2	15 cd/m^2	Luminance standard is exceeded by 4.8 times. Average luminance of the most intensive light spot is 11 times higher than the standard value. The relation between the maximum and the minimum value of illuminance within the illuminated surface exceeds 30:1, which causes high contrast, the building volume cannot be perceived.
Tula tea-party. Sculpture			7 cd/m^2	10 cd/m^2	Luminance of the monument is slightly lower than the standard. The solution is acceptable since the surface of the monument is dark.
78, Oktyabrskaya st.			37 cd/m^2, the most luminous part of the light spot is 65 cd/m^2, luminance of the advertisment is 91 cd/m^2	30 cd/m^2	Luminance of the facade complies with the standard. The building of the Church of St. Sergius of Radonezh at the Moscow Pike is the architectural dominant of the 2nd level, therefore exceeding of the luminance standard by 50% (up to 45 cd/m^2) is acceptable. Advertising illumination of the pizza restaurant is 2.5 times more luminous that the illumination of the church facade, which interferes into visual perception of the dominating object.

Fig.4. General Database of the measurement objects

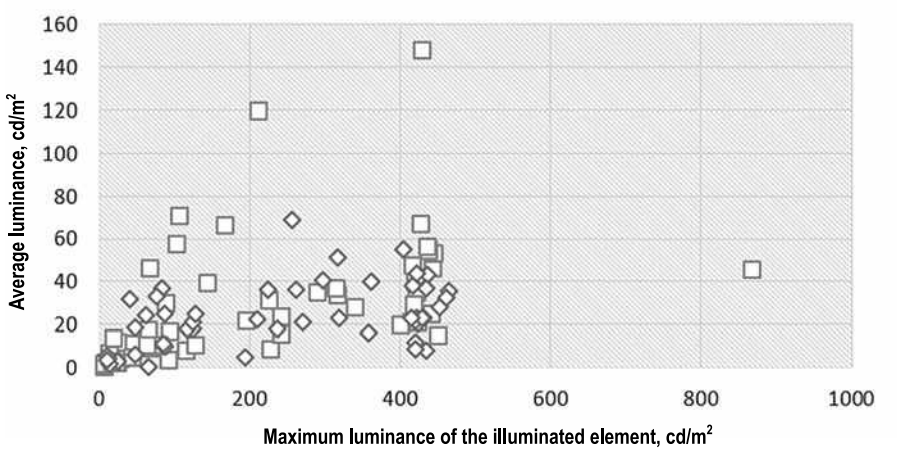


Fig.5. Average and maximum values of luminance of the analysed objects

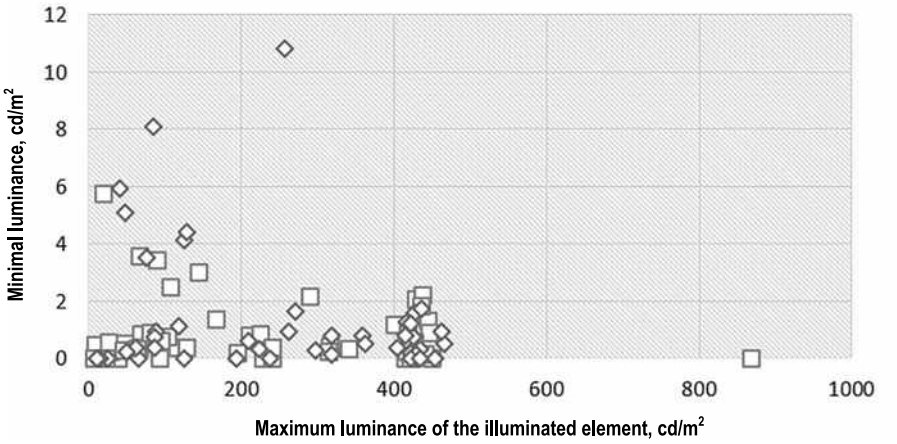


Fig.6. Minimum and maximum values of luminance of the analysed objects

inary preparation of lighting installations was not conducted [8, 9].

2. METHODOLOGY OF THE STUDY

The methodology of the study comprised town-planning analysis and subsequent photometric analysis of the existing lighting environment. The town-planning analysis comprised studying of the most important characteristics of the city, the structural analysis of the city, analysis of pedestrian routes, squares and important social centres, setting of areas of probable location of spectators and mapping of all the listed.

The objects with architectural lighting located in 11 central streets of Tula were considered during the study: Sovetskaya st., Metallistov st., Oktyabrskaya st., Lozhevaya st., Proletarskaya st., Pervomayskaya st., Friedrich Engels st., Krestovozdvizhenskaya st., Krasnoarmeysky prospect and Lenin prospect. 235 measurement files were processed, the hierarchy of the objects within the urban structure was formulated, luminance relations between the objects were analysed.

The town-planning analysis was conducted using GIS systems, the data regarding the illuminated objects was mapped layer by layer for subsequent analysis. The buildings with architectural lighting in the considered 11 streets are presented in Fig. 1.

The luminance distribution estimation was performed using the direct method by means of LMK Mobile Advanced luminance meter based on CCD matrix, matrix type: CMOS Canon APS-C, corrected for relative spectral responsivity of a standard observer, the instrument was calibrated for measurement of luminance at values of focal number ranging between F4 and F11, focus distance is 18 to 50 mm, ISO light sensitivity of 100 to 1600, resolution 5566×3706 (2748×1834 effective pixels), field angle: for focus distance of 17 mm: 65°×45°, for focus distance of 50 mm: 28°×19°, exposure

Fig.7. Evening photograph and luminance distribution over the facade, Staronikitskaya st. 1

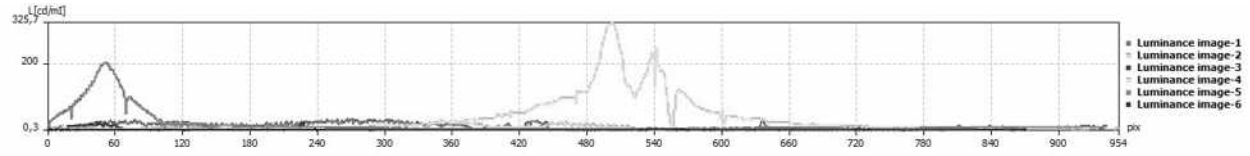


Fig.8. Relation between the values of luminance over the image, Staronikitskaya st. 1

Fig.9. Evening photograph and luminance distribution over the facade, Mendeleevskaya st.1

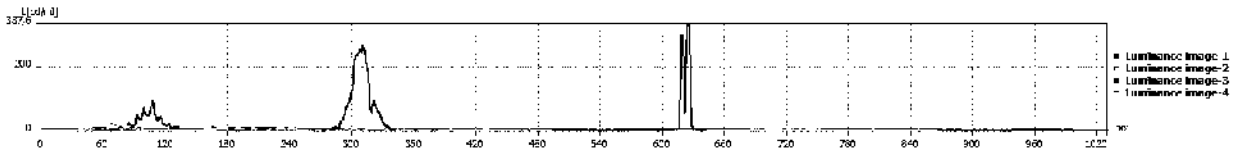


Fig.10. Relation between the values of luminance over the image, Mendeleevskaya st. 1

time 30–1/1000 s, thresholds of acceptable relative measurement error of luminance are ±5 %.

Conditions of measurements:

– The luminance meter lens is protected from entry of stray light;

– The shadow of the luminance meter or the person conducting the measurements does not fall on the measured surface;

– The luminance meter is located on the line coming from the centre of the survey area in direction of the object;

– The luminance meter is installed at height of 1.5 m from the surface of the road.

Before the measurements, preliminary preparation of the lighting installation (replacement of burned-out bulbs and cleaning of luminaires) was not performed.

Spectral responsivity of the measurement instrument is shown in Fig. 2.

The quantitative criterion of the phorometric evaluation was average luminance of the lighted element in accordance with SR 52.13330.2016 as well as the minimal and the maximum values of luminance and relation between them. In the course of the study, 56 objects were considered within the town-planning context with the existing architectural lighting, the stylistics of approaches

was analysed, the data was registered in the general data base of objects [10].

3. RESULTS

The conducted study allowed us to define the most qualitatively implemented objects within the area of the city fragment limited by the 11 central streets, general trends of the existing lighting of Tula were found, put, and analysed for compliance with the major goals of lighting standardisation. The luminance characteristics of 12 out from 56 objects comply with the regulatory requirements; the average luminance level of a number of objects is more than 10 times higher than the standard one.

The data of photometric evaluation of luminance characteristics of the considered 56 objects were registered in the general data base of the objects the example of which is given in Fig. 3.

The data of measurement results was also registered in the general database of the objects and the example is given in Fig. 4.

The average values of luminance of the elements illuminated by light for 6 objects significantly exceed the values specified in regulatory requirements. For a number of objects, the average luminance value is close to the standard on, at the same time, the relation between the minimum and the maximum values significantly exceeds the values specified by SP 52.13330.2016 [10]. The values of average, minimum and maximum luminance of the illuminated elements of buildings with architectural lighting are shown in Figs. 5 and 6.

In accordance with the results of the measurements, in 82 % of cases, average luminance of the illuminated element for buildings with local lighting exceeds 10 cd/m^2. The value of 30 cd/m^2 which is the maximum acceptable value in accordance with SP 52.13330.2016 is exceeded for 54 % of objects, which leads to compositional destruction of urban fragments, irrational using of energy resources, negative affect on visual perception.

Minimal values of luminance of illuminated elements do not exceed 1 cd/m^2 in 85 % of cases. In accordance with SR 52.13330.2016, the relation between the minimum and maximum values of illuminance should not exceed 1:30. Due to the fact that the surfaces of facades may be considered diffusely-reflecting surfaces, it is possible to consider relations between minimal and maximum values of luminance instead of relations between values of illuminance. The data acquired in the course of experiments allow to make a conclusion that the acceptable level of the said relation is exceeded in 87 % of cases. This leads to compositional destruction of the facade and wrong vision of the architectural exterior of the city during night-time.

The examples of illumination methods negatively affecting visual perception of facades are given in Figs. 7–10.

4. CONCLUSION

The new generation of measurement instruments allow us to conduct comprehensive analysis of the lighting environment; therefore, increase of the quality of the conducted photometric studies is of great interest and is important for lighting quality development.

Significant non-compliance of actual values of facade luminance with the standard ones is largely owing to the fact that regulation and quality assessment of the introduced solutions are not always conducted at the moment of putting an object with architectural lighting into operation. Architectural lighting of objects is not always on the books of companies operating exterior lighting installations, and architectural lighting is not always regulated.

The results of the study confirm the importance of considering clarifications for the existing standard requirements, e.g. setting of maximum acceptable values of luminance of illuminated elements in order to maintain integrity of urban environment during evening time and rationalisation of energy resources consumption.

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