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Acoustic Factor in the Formation of Architectural Space

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Abstract. The article is based on the scientifically grounded fact that living matter is not inert to sound vibrations. The research of acoustic influence results allows us to predict the possibility of designing spatial-environmental specificity in architecture and represents the level of a descriptively-generalizing method of systematizing the theoretical researches on this subject. Acoustics affects the formation of information and emotional background of an architectural object and its artistic image by reflecting many mental and physiological phenomena. The possibility of modeling the architectural space, which has a psychophysiological positive impact on the consumer of architecture, is based on the analysis of architectural artifacts, the purpose of which - the creation of acoustic architectural space. This research of information and emotional relations between a person and the environment is an integral part in the practical reconstruction of the geospatial environment studied by the architectural geonics.

1. Introduction

Currently, the environmental subject in architecture continues its cultivation with a new direction – architectural geonics [1-2]. Which main subject of study is the formation of creation the principles of geo-synthesizing space capable having such an impact. The primary systematization of the concept of the describing a specific architectural space in the categories of system-structural approach is given in the paper "Implementation of topical problems of development geo-tendency in architectural geonics" [3]. The hypothesis put forward in it consists in confirming the influence of geo-factors on the formation of an architectural specific space. Geo-factors are understood as a number of the natural phenomena influencing perception of the person, including, natural sounds – external acoustics. An important role in the descriptive reality of the psycho-emotional impact of geo-specific space is played by the psychology conceptions of perception spatial- environmental forms at the level of sensual sensations. An important role in a descriptive reality of psycho-emotional influence of geo-specificity of space is played by concepts of psychology of perception of spatial and environmental forms at the level of sensual feelings.

2. The scientific significance of the issue with a brief review of literature

In environmental psychology, the main areas of research have been formed, specifically scientific concepts of which can be used for the predicted perception of the environment [4], the formation of systematicity study of acoustic geo-factor influence on the creation of a specific space and, as a consequence, on man. This is the research of information and emotional relations between a person and the environment, including spatial knowledge, perception, interpretation and evaluation of both separate components and integral parts of the environment.

Defining the nature of the effects of certain acoustic ranges on behavior and the human psyche, including the influence of non-optimal frequencies is considered in the works of N. A. Kuralesina [5], A. Kuzmicheva and V. M. Ukhabova [6].

The bio-resonance influences capable to increase the stability of the regulatory mechanisms of physiological functions in the process of interaction of sensory stimuli of the vibrational wave nature



with the endogenous rhythms of the organism at certain ratios of phase-frequency characteristics are considered in the work of Narici L., Pizzella V., Romani G.L. [7].

The general assessment of the factors optimizing the impact of sounds is given in the works of I.L. Pershina "About a trans-disciplinary tandem of medicine and architectural geonics" [8, p.68-70] and "Medical aspect of architectural geonics - the effect of sounds on human" [9, p.58-63].

Combining natural science and humanitarian approaches assumes the use of specific properties of the acoustic environment and instrumentally fixed reactions to them by users of the environment.

3. Problem statement

As an acoustic material it is supposed to use the sounds received as a result of passing of air streams through strings (fig. 1) or pipes (fig.2) established as elements of the architectural structure.



Figure 1. Aeolian harp, South Carolina, USA. By Rodney Carroll.



Figure 2. Singing ringing tree in Burnley, Lancashire. Architects Mike Tonkin and Anna Liu.

Detection of the " necessary " frequencies will affect the volumetric and spatial formation of the structure: geometrical characteristics of the pipes, such as the tube length, the diameter of the inner cavity, existence of a cut off the ends of a tube; dependence on the pipe material, affecting the sound-reflecting ability; the influence of the tube wall thickness; the use of methods for creating wind musical instruments for extracting sound harmonic oscillations- and all this in the conditions of spontaneity of the wind force and direction. As a result, pipes or strings as the main translators of sound, will be able to synthesize only that audio frequency range which makes only the positive impact. At the same time sounds will have some philharmonic complexity.

On the basis of this, it is possible to assert the legitimacy of creating an alternative to natural spontaneity, through the calculations and selection of the above- mentioned characteristics, when the sound background can be controlled and directed.

4. Interdisciplinary analysis of acoustic space

4.1. Examples of architectural artifacts

In architectural practice, there are precedents of creating acoustic space. This refers to the deposit of spaces created by means of "singing" small forms. For example, wave organ is in San Francisco (authors Peter Richards, George Gonzales) [9]. The wave organ consists of 25 pipes made of the PVC and concrete, located at different heights on the dam. The combination of inflows and waves pushes the air in the pipes, creating the gurgling sounds.

The sound garden in Seattle [10] designed in the 1980 by the sculptor Douglas Hollis. The sound garden consists of 12 steel towers. On the towers there are organ pipes of different diameters, which make low sounds under the influence of the wind. Weather vanes, located on the tops of the towers, catch the wind and turn the pipe.

Windorgel, town Vlissingen, Netherlands [10]. On the seashore several vertical bamboo tubes with holes on all length are set. They make different sounds when the wind blows.

The singing ringing tree in Burnley in Lancashire [10] (fig. 2), – consists of numerous pipes of different sizes and comes to life when wind blows. The three-meter high zinc galvanized steel construction was designed by architects Mike Tonkin and Anna Liu and built on a hill in 2006. The wind passes through the tube branches of the mythical tree, at the ends of which special holes are made. Because the direction of wind changes and passes through different layers of tubes, installation makes new sounds all the time – sometimes mystical whistle, sometimes a dissonant and shrill sound, sometimes the silent harmonic choral singing covering several octaves, and sometimes a soft and iridescent ringing.

British Luke Jerram designed the interactive pavilion Aeolian [11]. Jerram called the pavilion Aeolian harp of the wind. The object includes 310 pipes. Pipes of the same diameter are designed in such a way that they sound even when the wind does not seem. A small architectural form produces low-frequency sounds. Aeolian harp has been known in architecture since ancient times. The harp consists of a resonator - a narrow wooden box with a hole, inside of which strings are stretched. The number of strings (usually from 4 to 12, sometimes 24 or 48) is arbitrary. Strings of the same length, but different thickness and level of tension are usually adjusted in unison, for example, "salt" (a small octave); in case of oscillations they produce not only the basic tone, but also overtones, so that the general range of the Aeolian harp is quite significant. The stronger the wind, the higher overtones are heard. With a weak breeze, the sound of Aeolian harp is light and gentle, in case of bursts - sharp and loud. The instruments were installed in such a way as to provide the maximum possible access to the wind. Aeolian harps are usually placed on roofs and gables of buildings (e.g. window openings), in the park gazebo (rotunda), grottoes, etc., so that the wind blew from the side, parallel to the deck. Some Aeolian harps were equipped with a special device to give the air flow the desired (most advantageous for the excitation of the string) direction [12].

According to the Jewish legend David's psaltery sounded from the wind: "A psaltery hung over David's bed, against holes window. When midnight came, the northern wind was blowing, moving the strings of the psaltery and they began to sound themselves", — that is, apparently, by the principle of Aeolian harp [13]. Strings of a harp move due to the "the vortex track of the Pocket" [14], chains of vortices hiding in the flow of liquid or gas around a cylindrical object.

4.2. Psycho-physiological aspect of influence of acoustic space

It is known that the influence of acoustics on the creation of psychological climate, generation of the positive emotions, creative mood, cogitative activities. Different frequencies can make different impact on a state of a human body. The study of this sphere is called psychoacoustics. In fact, psychoacoustics is the theoretical basis of sound therapy. The above examples of architectural artifacts that create a sound background in the conditions of spontaneous air flow are a psychoacoustic technique that forms the specificity of space. If to add to this experience, mathematical calculations, then the sound background will be controlled and therefore, directed. Calculations of "correction" the natural spontaneity will help to create the alternative imitating the tempo and rhythm of music.

In studies of the effects of harmonic sound vibrations [15-24], it is shown that the dynamics of the emotions during listening is always accompanied by certain hormonal and biochemical changes [15-20], indirectly affecting the intensity of metabolic processes [17], respiratory and cardiovascular systems [16, 18, 19, 23], central nervous system tone [21], blood circulation [19]. We believe that similar changes can take place when listening to the sounds of the nature reproduced by means of architectural artifacts. Data on a study of neurological influence of a sound show that the human brain reacts to pure sounds in a certain way. The natural biological activity of a brain alpha, a theta - amplifies and decreases a beta-activity [22, 24]. Positive tomography, which changes the level of glucose absorption at the cellular level, indicates that harmonic sounds stimulate an increase in cellular activity in the right "non-dominant" hemisphere [24]. The resistance of muscles increases, the speed of protein synthesis increases [20].

4.3. Digital data

The human ear perceives vibrations within 16-20000 Hz. The speech range is within 60-60000 Hz. From 5 kHz to 8 kHz takes "nutritious" range of singing birds. The sound of 14-16 Hz allows to treat the stomach. Vibration with a frequency of 100 Hz increases muscle resistance, increases the speed of protein synthesis. The frequencies of other spectral areas also produce biological effects, but through another level of organization: molecular and atomic [12].

For the upper limit of the infrasonic area take the frequency of 16-25 Hz. Fluctuations from tenths or even hundredths of Hz may be of practical interest, i.e. with periods of ten seconds. At the same time the person hears infrasound with the whole body. The general level of sound pressure for works of different level of intellectual and emotional tension should not exceed 95 dB [25]. The level of 120 dB at purity of 20 Hz can be accepted as the limit of absence of negative impact of low-frequency acoustic oscillations [5].

Infrasound causes nervous tension, malaise, dizziness, changes in the activities of the internal organs, especially the nervous and cardiovascular systems.

Sounds, intensity of 90-100 dB at frequencies of 1000-3000 Hz cause paranecrotic phenomena in isolated cells, i.e. significant damage, which can be judged by an increase in the color of vital dyes. The effect of the sound becomes noticeable from the frequency of 200 Hz. Below these frequencies the effect is absent. The maximum effect is observed at 2500 Hz; at 5-6 kHz, the effect is also absent [16].

In the case of action on a brain intermittent sound intensity of 120 dB was found a significant increase in coloration, which means cell damage [16].

5. Practical significance, proposals and results of implementation, the results of experimental studies

The design of architectural space, taking into account the biological significance of the spectral characteristics of an acoustic factor, will allow us to predict stable forms of spatial experiences. Predetermining for the architect the intentionality is as distinction of mental and physical phenomena of "installation". Defining frequency boundaries will simulate the sound pressure with the aim of identifying their possible effects on the consumer of a geo-specific environment. The results of acoustic data will allow us to continue the experimental work of the authors on architectural design of the small forms producing acoustic space. The intermediate results of this work have publications [26] and publication [27].

6. Main conclusions of research

So, based on the analysis of architectural prototypes, including historical facts of the use of architectural small forms, contributing to the emergence of sounds, it is possible to conclude about the conscious use of acoustics as a means of creating a psychological climate. The given scientifically based data of biological significance of sounds of different frequencies and intensities can be used as a tool for physiological effects in the design of the architectural environment.

To determine the methodology of manipulating the impression and physiological changes in the stimulating environment, as well as to determine the nature of the impact of individual environmental factors on the behavior and psyche of the human defined frequency limits from 14-16 Hz to 8 kHz. These data allow us to continue the development of the idea of cultivation of architectural and design possibilities of creating forms and surfaces of structures capable of synthesizing the acoustic capabilities of geo-medium in terms of the spontaneity of force and direction of wind flow. Application in research and innovation - creative work of the architect of these data will serve as the beginning of solving the problem of creating an architectural environment that has a therapeutic effect on the physical and psycho-emotional state of a persons.

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