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Research Of The Acoustic Parameters Of Halls And Practical Methods Of Eliminating Acoustic Defects

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ABSTRACT

In this research paper, on the basis of the graphical method, the determination of the acoustic parameters of the room, the focusing points of the reflected sound waves is considered, an assessment is made of the compliance of the hall under the Senate of the Republic of Uzbekistan with the design standards and requirements of architectural acoustics, and recommendations are given for eliminating unfavorable acoustic defects.

KEYWORDS

Acoustics, dome, echo, enclosing structure, radius of curvature, focus.

INTRODUCTION

In acoustics and wave mechanics, the problem of oblique incidence of sound on the boundary of media is solved by means of Snell's (Snell's) laws and Fresnel formulas obtained for light rays and well confirmed by optical experiments. In acoustics, the Fresnel formulas for the transmission and reflection coefficients of sound are obtained theoretically by jointly solving the equations of continuity of the vibrational velocity and sound pressure at the boundary of the media and consist of the ratios of the acoustic impedances of the media. The rays of the incident, reflected and transmitted waves are represented by vectors in the form of line segments devoid of transverse dimensions, and the continuity conditions are considered at the intersection point of the vectors. That is, in the physical model of sound transmission, the beam cross-section factor is excluded from consideration. One of the conditions for the comfort of the environment is to ensure a favorable acoustic regime in the premises, which is largely achieved through the correct choice of the enclosing structures at the design stage.

The problem of the formation of a strong fluttering echo and focusing of reflected sound waves in the hall of high-level meetings at the Senate building of the Republic of Uzbekistan has been studied. The shape of the main room is a quadrangle in plan with sides 17.21x17.21 m, with a biconvex dome-shaped ceiling with a radius of 7.81 m and a rise height of 1.25 m. The structure of the dome is a solid stained glass glazing (Fig. 1).

Fig. 1. Cross section of the building

One of the common disadvantages for halls, including for the room in question, which can be classified as acoustic defects, is the concentration of sound energy in certain areas of the room, depending on the location of the source and the possibility of various types of echoes. Often the reason for the manifestation of these effects in halls is a high domed ceiling; vaulted surfaces contribute to the concentration of sound energy, i.e. focus the sound, forming focus F. In addition, there is a very unpleasant phenomenon, especially noticeable and pronounced in empty or half-empty rooms of large cubic capacity, called "fluttering echo". If you clap your hands in a large room with a high ceiling and hard surfaces, you can hear a fading reverberation-flutter or "fluttering echo". It will be the more noticeable, the larger the linear dimensions of the room and the more rigid the floors, walls and ceilings in it. By analogy with clap in the palm, any sharp and abrupt sound (falling of an object, exclamation) acquires a short, but noticeable "trembling" tail with a touch of metal.

The flutter echo effect is a collection of densely packed waves with a falling amplitude and a single frequency, depending on the distance between parallel surfaces of opposite walls, or floor and ceiling. The larger the room, the lower the frequency of the fluttering echo. The fluttering echo flutters between hard parallel surfaces and is considered a parasitic "acoustic phantom" interfering with the main signal. For this effect to occur, the room must have at least a pair of parallel walls with a decent distance between them. Given the shape of the vaulted ceiling, this adverse effect has an even more detrimental effect due to the focusing of the reflected rays.

The elimination of this gross acoustic disadvantage in the design of halls is ensured by the choice of the proper radius of curvature r, at which the focus is not formed in the area of the location of the receivers (listeners). The location of the focus is determined by the construction of reflected sound beams.

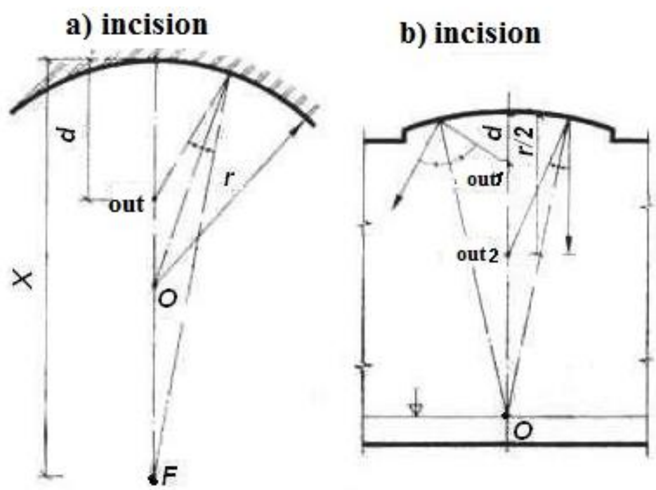

Fig. 2. Determination of the location of the foci with reflections with different radii of curvature when the sound source is located: a - near the reflecting surface; b - at a distance less than half the radius

If the sound source is located along the axis of the concave surface, the focus distance (X) from the concave surface can be determined by the formula:

$$X = \frac{d*r}{2d-r} \text{ m, where:}$$

d - distance from a sound source to a concave surface;
r - surface curvature radius.

When $d = \frac{r}{2}$; $X = \frac{d*r}{0} \to \infty$ those no focus.

When X <0 focus is on the other side of the bulge.

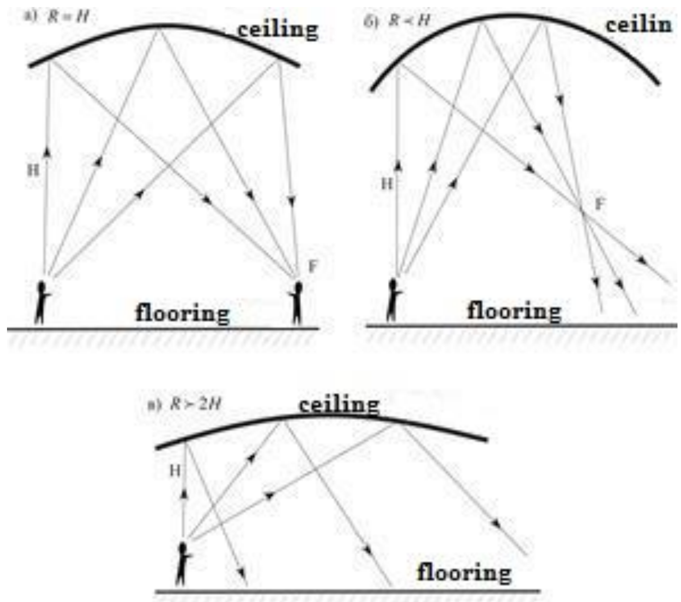

Fig 3. For a spherical (dome) ceiling, when the sound source is located at floor level, these structures of sound reflections (a, b, c) are possible

From the above schemes, we can conclude that with the same reflection area, the highest concentration of sound occurs when h = r and the reflecting surface is close to the floor surface (Fig. 3a). Therefore, the radius of curvature should be either less (Fig. 3b) or more (Fig. 3c) the height of the room.

To establish the cause of the formation of an echo in a given room, it is first of all necessary to graphically construct the structure of sound reflections for a cross section of this room. In addition to the relative position of the sound source and receiver, the structure of reflections is closely related to the dimensions of the hall, as well as to the outlines and finishing of its internal surfaces. A possible structure of sound reflections when the source is in the center of the room at a height of about 1.6 m (the height of the mouth of an average person) is shown in Fig. 3. The listener located in the hall first receives direct sound from the source. The path of this sound to the receiving point is the shortest. Then there are single and multiple reflections from individual interior surfaces of the hall. The levels of reflections (in terms of sound intensity) depend on the length of the traveled path and on the sound-reflecting properties of the interior surfaces of the hall.

The longer the distance traveled and the greater the sound absorption coefficient of the reflecting surface, the weaker the level of the incoming reflection. In fig. 4. The focusing of the reflected rays from the vaulted structure of the covering (red) is clearly visible, while the reflections from the supporting half-arches favorably scatter the incident sound waves (green).

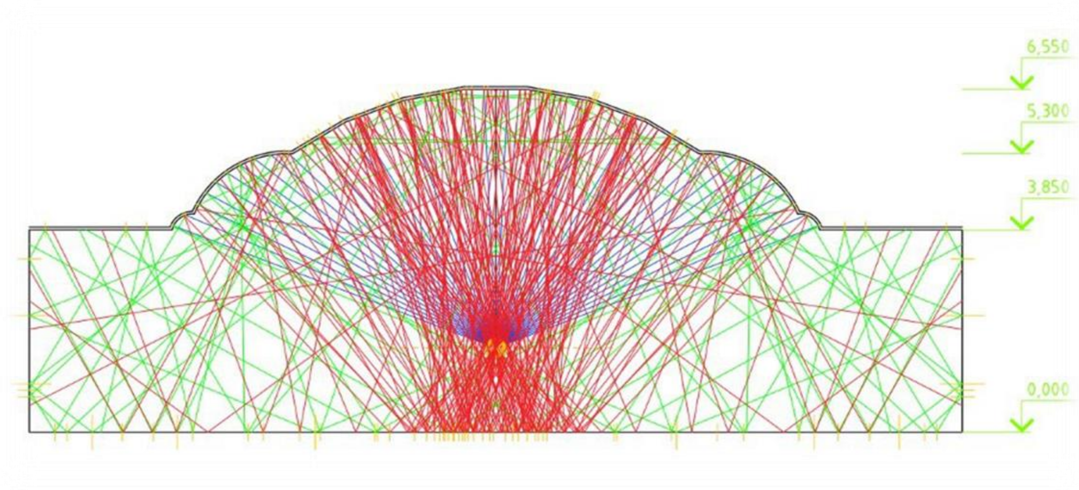

Fig. 4. The structure of sound reflections for a given transverse profile of the room

As an experiment, several design solutions were considered that contribute to the elimination of an unfavorable acoustic defect, namely, a pyramidal structure, a solution with a flat ceiling and, accordingly, an option with an increase in the initial radius of curvature of the arch to r = 2h.

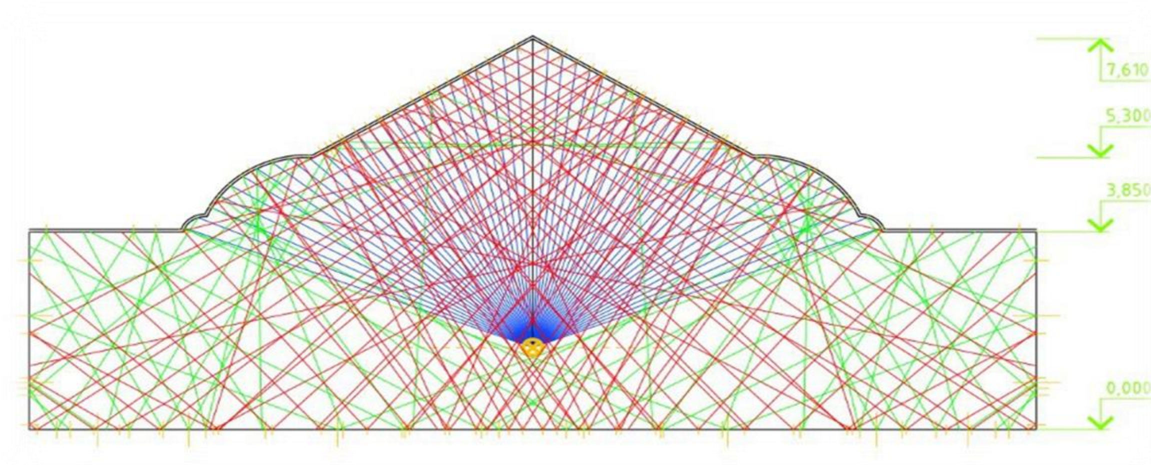

Fig. 5. The structure of sound reflections in the pyramidal structure of the stained glass coating

As you can see, such a solution significantly eliminates the original acoustic imperfections and contributes to a fairly uniform dispersion of sound waves in the room, however, this change option will entail significant material costs for the complete re-equipment of stained-glass panels and, possibly, lead to a deterioration in the appearance of the interior, high costs for heating in winter due to increased volume. The most rational solution from this point of view is the flat ceiling of the hall, as shown in Fig. 6.

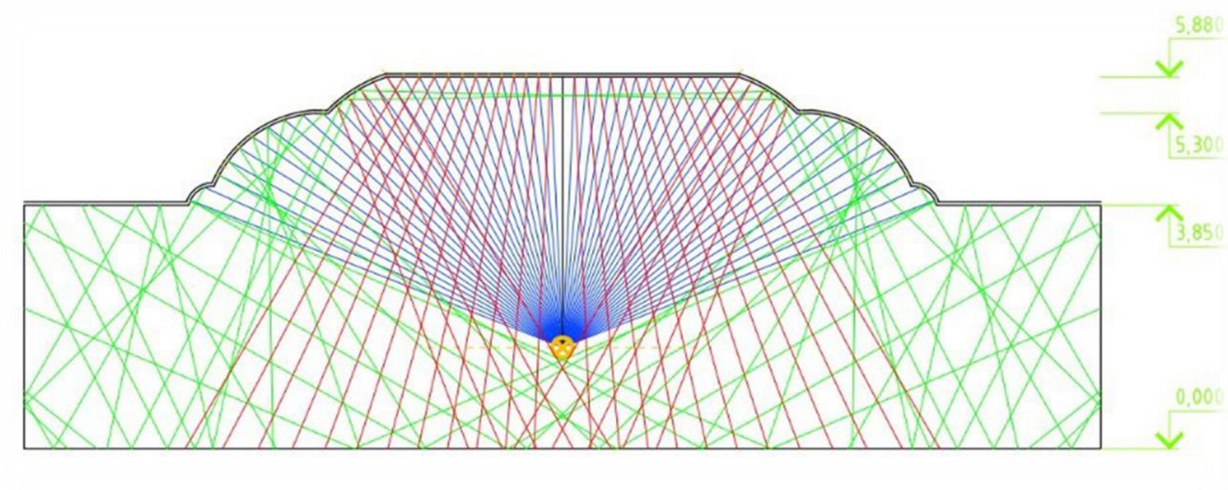

Fig. 6. The structure of sound reflections for a flat room ceiling

Based on the structure of the reflections, such a solution scatters sound waves in the most harmonious way, and the upper half-arches create the necessary background amplification of waves in the place where people talk. However, this solution also requires material costs in its execution and will violate the interior design of the room, therefore, the most expedient is to increase the curvature radius of the stained-glass window covering to the value of the doubled height of the arch lifting boom, and check by the graphical method how much this will improve the acoustic characteristics of the hall (Fig. 7.).

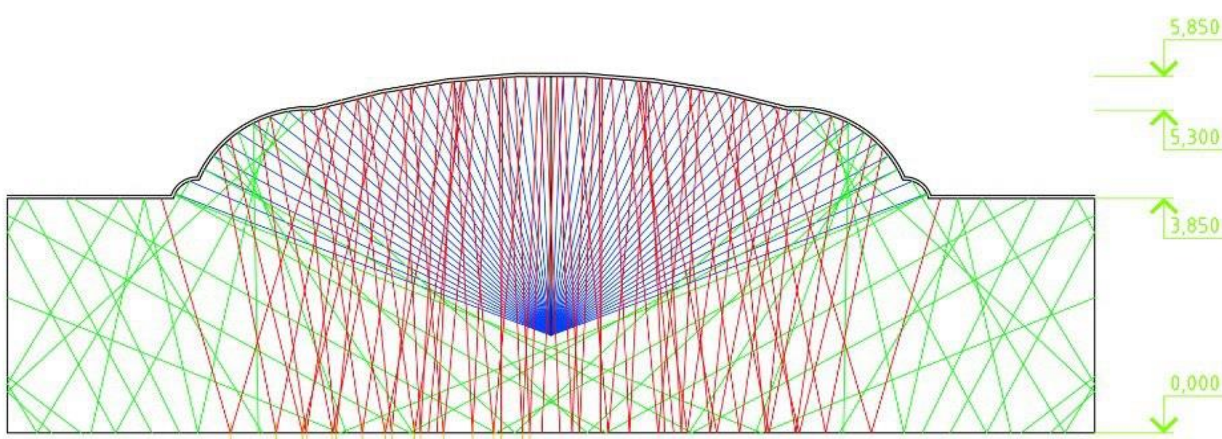

Fig. 7. The structure of sound reflections at a radius of curvature of the coating r = 2h

Fig. 7.It can be seen that the problem of focusing the reflected sound waves has been solved, the issue of the occurrence of an echo remains open, since dense rigid materials are used in the decoration of the room, poorly absorbing the incident sound waves, however, this can be eliminated when used in the interior facing with sound-absorbing materials

According to KMK 2.01.08-19 "Protection against noise", sound-absorbing cladding should be placed on the ceiling and walls of the premises at the points where the highest intensity or focusing of sound waves is observed, the required area of the cladding is determined by calculation.

CONCLUSION

It should be noted that it is extremely important to preliminary check the buildings under construction and the premises designed in them for compliance with the design and sound insulation standards adopted in the Republic of Uzbekistan, as well as the requirements of architectural acoustics, in order to avoid similar problems in the future.

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