Statyba

ISSN: 1392-1525 (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tcem19

THE EFFECT OF THE FORM OF THE SLITS IN THE RESONANT SUSPENDED CEILING ON THE ACOUSTIC INDICATORS OF A HALL

V. Stauskis

ISSN 1392-1525. STATYBA - CIVIL ENGINEERING - СТРОИТЕЛЬСТВО, 1997, Nr. 4(12)

THE EFFECT OF THE FORM OF THE SLITS IN THE RESONANT SUSPENDED CEILING ON THE ACOUSTIC INDICATORS OF A HALL

V. Stauskis

1. Introduction

The optimisation of the frequency characteristics of the reverberation time and the diffusive sound field is one of the main tasks of hall acoustics. Depending on the purpose of the hall, the reverberation values must be different at low, medium and high frequencies. To achieve this, materials of different acoustic characteristics or special structures must be used.

Suspended ceiling made of even planes with slits between them could serve as a sound-absorbing structure. If the slits are arranged in opposite directions, the ceiling with the cross-shaped slits is formed and if they are arranged in one direction, the ceiling with the rectangularly-shaped slits is obtained. Such structure will absorb part of the sound energy through the presence of the slits, while part of the energy will be reflected back to the listeners. The reflections may be directional in character, which is desirable for the formation of the hall reflection structure. When the ceiling planes consist of various structural elements, the latter may help form the diffusive sound field which is very important for hall acoustics.

The effect of both cross-shaped and rectangularly-shaped slits upon the hall acoustics has been examined theoretically and experimentally in [1,2,3,4]. The purpose of this paper is to experimentally determine the influence both of the slit form and the overall slit area on the acoustic indicators using a physical model of a hall.

2. Subject of investigations

The investigations were conducted in a hall model scaled 1:25. The layout of the resonant ceiling with the cross-shaped slits between the planes is presented in Fig 1 and of the one with the rectangularly-shaped slits in Fig 2.

The ceiling planes were made of veneer 25 mm thick with three layers of lacquer. Thus, the suspended ceiling reflects the sound energy well. No additional sound-absorbing materials were placed above the suspended ceiling.

All surfaces in the hall were made of sound-reflecting materials, with the exception of the orchestra platform 119 m^2, which was covered with the sound-absorbing material simulating the absorption of the sound produced by the orchestra players.

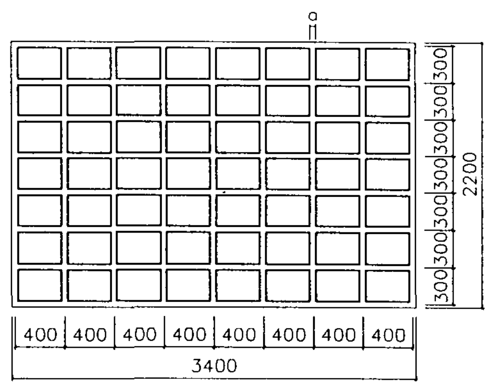

Fig 1. The layout of the suspended ceiling with the cross-shaped slits between the planes

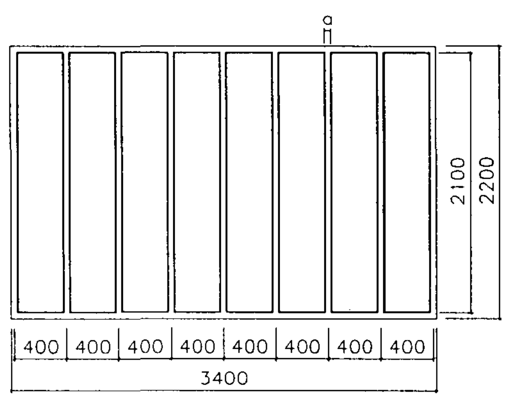

Fig 2. The layout of the suspended ceiling with the rectangularly-shaped slits between the planes

The width of the slits was accepted as 50 cm in all cases and the distance from the suspended ceiling to the rigid surface was accepted as 100 cm. Hence the overall area of the cross-shaped slits is 258 m^2, or 34.4% of the total ceiling area. The area of the rectangularly-shaped slits is 160 m^2, or 19.5% of the total ceiling area. Thus, the area of the cross-shaped slits exceeds the one of the rectangularly-shaped slits by the factor of 1.76.

3. Results of investigations

Fig 3 depicts the decrease of the sound energy under various forms of slits in the suspended ceiling and under different overall slit areas.

The diagram shows that the energy decrease is not affected by the overall slit area in the early period of field decrease, which occupies the time interval up to 300-400 ms. In time, the decrease of the sound field is slower when the overall area of the slits is the largest, ie when the ceiling has cross-shaped and not rectangularly-shaped slits. Consequently, the decrease of the sound field should be faster under the cross-shaped slits, but a reverse result is obtained.

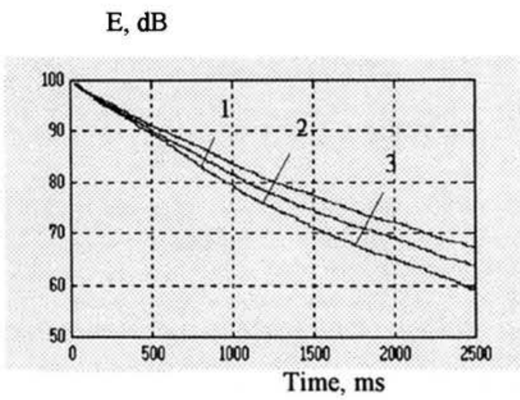

Fig 3. The decrease of the sound energy in the hall depending on the form of the slits and the overall slit area. 1 - hall without suspended ceiling; 2 - with cross-shaped slits; 3 - with rectangularly-shaped slits

Fig 4 shows changes in the standard hall reverberation time depending on the overall slit area and slit form.

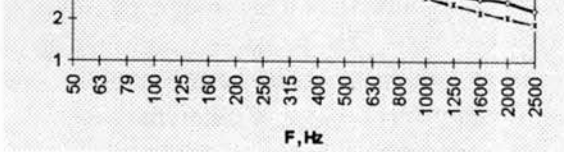

Fig 4. The change in the hall reverberation time depending on the form of the slits in the suspended ceiling and the overall slit area. 1 - hall without suspended ceiling; 2 - with cross-shaped slits

In an empty hall, just as one could expect, the reverberation time is the longest throughout the frequency range. The reduction by the suspended ceiling also occurs throughout the frequency range. The greatest cutting of the reverberation time is observed when the overall slit area is smaller, ie when the slits are rectangularly-shaped. This reduction is only marked in the frequency range up to 400 -500 Hz, ie mainly at the low and medium frequencies. The change of the reverberation time is best understood while analysing the relative results presented in Fig 5. In all cases the 0 line corresponds to the case without the suspended ceiling.

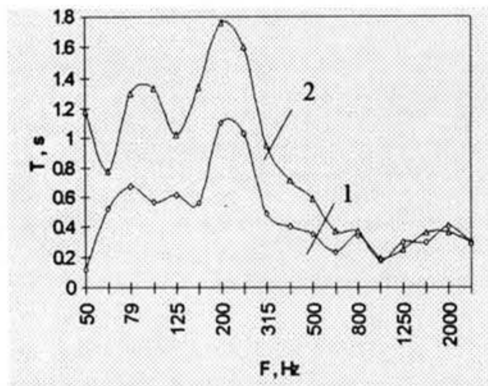

Fig 5. Reduction in the relative reverberation time of the hall depending on the form of the slits in the suspended ceiling and the overall slit area. 1 - cross-shaped slits; 2 - rectangularly-shaped slits

The greatest reduction (by 0.8 - 1.8 s) in the reverberation time is obtained when the slits are rectangularly shaped, ie when their overall area is smaller. As the overall slit area increases, the reverberation time is reduced to 0.2 - 1.0 in the frequency range up to 500 Hz. The greatest difference amounts to as much as 0.8 s. This reduction has a pronounced resonant character with the maximum at 200 Hz and 250 Hz. These results show that the increase in the overall slit area brings about a much smaller reduction of the reverberation time.

The standard reverberation time is related to the late period of decreasing of the sound field. The early reverberation time (EDT) related to the early sound reflections is very important for the evaluation of the hall acoustics, subjective evaluation in particular. The change in the early reverberation time is shown in Fig 6.

In this case the difference in the results is still more marked. The early reverberation time in the frequency range up to 200 Hz is much more decreased by the suspended ceiling with the rectangularly-shaped slits, ie the smaller overall slit area, than by the cross-shaped slits with the larger overall area. In both cases, the resonant character of the change in the early reverberation time in the frequency range up to 200 Hz is revealed. These results show that the decrease of the sound field is different in various intervals of time.

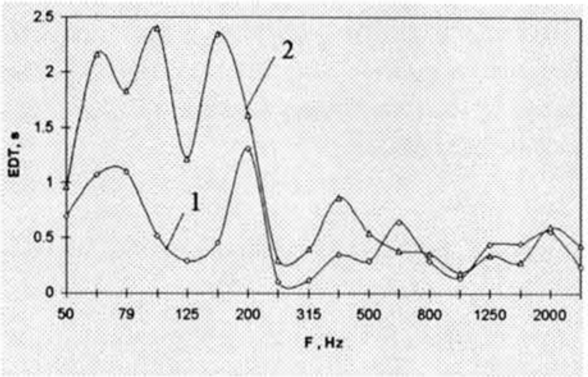

Fig 6. The reduction in the relative early reverberation time of the hall depending on the form of the slits in the suspended ceiling and the overall slit area. 1 - cross-shaped slits; 2 - rectangularly-shaped slits

Knowing reverberation time values, one may determine the change in the sound absorption coefficients and the overall sound absorption in the hall depending on the shape of the slits and the slit area. The change in the absorption coefficient is shown in Fig 7.

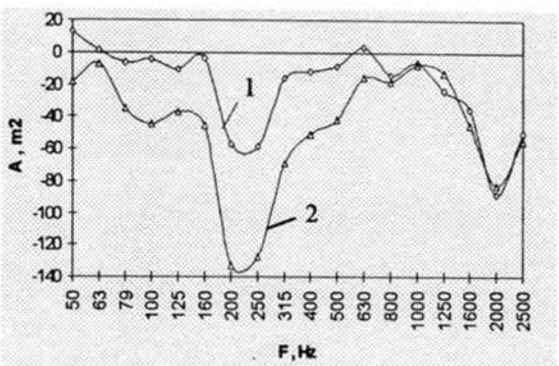

Fig 7. The increase in the relative sound absorption coefficients of the hall depending on the form of the slits in the suspended ceiling and the overall slit area. 1 - cross-shaped slits; 2 - rectangularly-shaped slits

Negative values correspond to the increase in the absorption coefficients. The absorption coefficients have been calculated taking into consideration the areas both of the suspended ceiling and all surfaces of the hall, therefore small absolute values of these coefficients were obtained. The diagram shows that the maximum values of the absorption coefficients are reached at 200 Hz and 250 Hz and they vary in inverse proportion to the slit area, ie the absorption coefficients are larger with the rectangularly-shaped slits. Such change in the absorption coefficient corresponds to the change in the reverberation time.

Fig 8 depicts the change in the hall absorption along with the change in the form of the slits and the slit area.

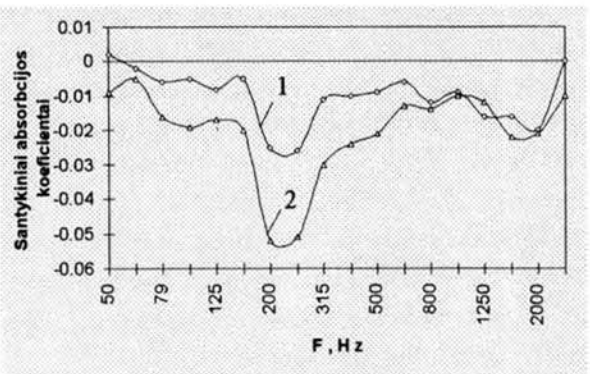

Fig 8. The increase in the relative sound absorption of the hall depending on the form of the slits in the suspended ceiling and the overall slit area. 0 line corresponds to the case without the suspended ceiling. 1 - cross-shaped slits; 2 - rectangularly-shaped slits

The situation is analogous to the one concerning the sound absorption coefficient. The relative sound absorption is larger when the overall slit area is smaller. At 200 Hz and 250 Hz, with the larger overall slit area (ie cross-shaped slits), the sound absorption increases to 60 m^2, while with the rectangularly-shaped slits it becomes as large as 140 m^2.

These results show that there is a difference in the intensity of interaction between the sound fields of the two air bodies separated by the suspended ceiling [5]. When the suspended ceiling has the cross-shaped slits and the overall slit area is larger as compared with the slits that are rectangularly shaped, the interchange between the sound energies is more intensive. As a result, smaller values of the reverberation time, the absorption coefficients and sound absorption are obtained when the suspended ceiling has cross-shaped slits. This would be confirmed by the experiment with the sound-absorbing material placed above the suspended ceiling of different shapes.

Such subjective criterion of evaluation of music sound as the sound clarity index is also affected by the shape of the suspended ceiling. The change in the music sound clarity index is shown in Fig 9.

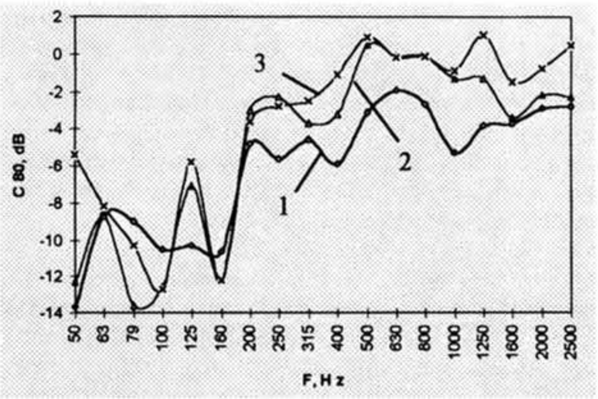

Fig 9. The dependence of the music sound clarity index on the shape of the suspended ceiling. 1 - without suspended ceiling; 2- cross-shaped slits; 3 - rectangularly-shaped slits

The music sound clarity index is started to be affected by the shape of the suspended ceiling from 200 Hz on. Then the values of the index are larger, with the both shapes of suspended ceiling, than in the case when the hall has no suspended ceiling.

Fig 10 shows the change in the acoustic centre of gravity depending on the shape of the suspended ceiling and the overall slit area.

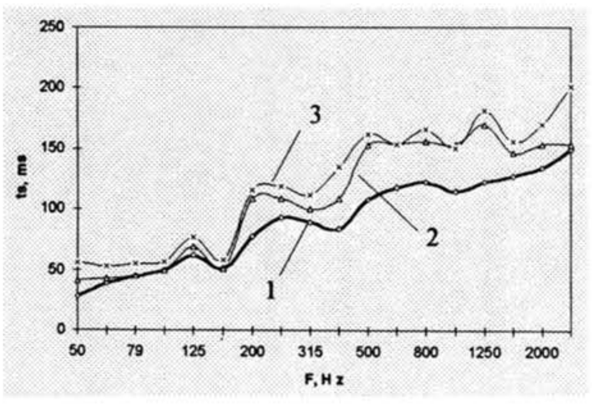

Fig 10. The dependence of the acoustic centre of gravity on the form of the slits in the suspended ceiling. 1 - without suspended ceiling; 2- cross-shaped slits; 3 - rectangularly-shaped slits

The acoustic centre of gravity is increased by the suspended ceiling beginning with the frequencies exceeding 200 Hz, whereas the influence of the change in the shape of the ceiling and the overall slit area is minor.

4. Conclusions

1. The reverberation time is reduced more by the rectangularly-shaped slits of the resonant suspended ceiling than by the cross-shaped slits, whose overall area exceeds the one of the rectangularly-shaped slits by the factor of 1.76.

2. When the suspended ceiling has slits of various shapes, an interaction between the sound fields of the upper and the lower air body takes place, and the larger the slit area, the more intensive the interaction.

3. The increase in the sound absorption coefficients and the overall sound absorption in the hall is inversely related to the overall slit area, ie the increase is larger with the rectangularly-shaped slits.

References

1. V. Stauskis. The sound absorption properties of a cross-shaped isolated acoustic resonator // Archives of Acoustics. Warszava. Polish scientific publishers. Vol. 22, No 2, p. 129-140 (1997).
2. V. Stauskis. The influence of a cross-shaped resonance ceiling on the hall acoustics. // Archives of Acoustics. Warszava. Polish scientific publishers.Vol. 22, No 2, p. 140-152 (1997).
3. V. Stauskis. Rezonansinių kabamųjų lubų įtaka salės akustiniams rodikliams. // Statyba, No 3(7). Vilnius: Technika, 1996, p. 64-69.
4. V. Stauskis. The influence of the resonant ceiling with the rectangular-chaped slits on the hall acoustics // Statyba, No 4 (8). Vilnius: Technika, 1996, p. 104 - 109.
5. V. Stauskis. The interaction of sound fields separated by the resonant suspended ceiling // Statyba, No 3 (11). Vilnius: Technika, 1997, p. 90-95.

Įteikta 1997 09 12

REZONANSINIŲ KABAMŲJŲ LUBŲ PLYŠIŲ FORMOS ĮTAKA SALĖS AKUSTINIAMS RODIKLIAMS

V. Stauskis

S a n t r a u k a

Straipsnyje nagrinėjama rezonansinių kabamųjų lubų su stačiakampio ir kryžiaus formos plyšiais įtaka objektyviems salės akustiniams rodikliams.

Lubų plokštumos pagamintos iš 25 mm storio faneros, kuri lakuota tris kartus. Taigi kabamosios lubos pagamintos iš garsą atspindinčių medžiagų. Virš kabamųjų lubų papildomų absorbuojančių medžiagų nėra. Visos salės plokštumos yra iš garsą atspindinčių medžiagų, ir tik 119 m^2 orkestro pakyla padengta absorbuojančia medžiaga. Plyšių plotis abiem atvejais - 50 cm, o kabamųjų lubų aukštis nuo standaus paviršiaus - 100 cm. Tokiu atveju suminis kryžiaus formos plyšių plotas yra 258 m^2, arba 34,4 % bendro lubų ploto. Stačiakampio formos plyšių plotas yra 160 m^2, arba 19,5 % bendro lubų ploto. Vadinasi, kryžiaus formos plyšių plotas yra 1,76 karto didesnis negu stačiakampio formos plyšių plotas.

Tyrimai rodo, kad nefiltruoto signalo energijos slopimui plyšių suminis plotas neturi įtakos ankstyvuoju lauko slopimo periodu, kuris užima laiko intervalą iki 300-

400 ms. Toliau einant laikui garso laukas lėčiau slopsta tada, kai plyšių suminis plotas yra didžiausias, t.y. esant kryžiaus, bet ne stačiakampio formos plyšiams. Vadinasi, garso laukas greičiau turėtų nuslopti esant kryžiaus formos plyšiams, o įvyksta atvirkščiai.

Reverberacijos laikas daugiausia, net 0,8 - 1,8 s, sumažėja tada, kai plyšiai yra stačiakampio formos, t.y. kai jų suminis plotas yra mažiausias. Didėjant suminiam plyšių plotui reverberacijos laikas mažėja mažiau ir siekia iki 0,2 - 0,8 s, kai dažnių diapazonas iki 500 Hz. Didžiausias skirtumas siekia net apie 0,8 s. Šis mažėjimas turi išreikštą rezonansinį pobūdį su maksimumu, kai yra prie 200 ir 250 Hz.

Absorbcijos koeficientai buvo apskaičiuoti pagal kabamųjų lubų ir visų salės paviršių plotus. Todėl jų absoliutinės reikšmės buvo mažos. Grafikas rodo, kad absorbcijos koeficientai maksimalias reikšmes turi esant 200 ir 250 Hz, ir jos yra didesnės tada, kai mažesnis plyšių plotas, t.y. stačiakampio formos plyšiams. Toks absorbcijos koeficiento kitimas atitinka ir reverberacijos laiko kitimą.

Santykinė garso absorbcija didesnė tada, kai suminis plyšių plotas yra mažiausias. Kai 200 ir 250 Hz, esant didesniam plyšių plotui, t.y. kryžiaus formos plyšiams, absorbcija padidėja iki 60 m^2, o esant mažesniam suminiam plyšių plotui ji padidėja jau iki 140 m^2.

Šie rezultatai rodo, kad tarp dviejų salės tūrių, kurie atskirti kabamosiomis lubomis, vyksta skirtinga garso laukų sąveika. Kai lubos yra su kryžiaus formos plyšiais ir kada jų suminis plotas yra didesnis negu esant stačiakampio formos plyšiams, tada vyksta didesnis garso energijų pasikeitimas tarp abiejų tūrių. Dėl to gauname mažesnes reverberacijos laiko, absorbcijos koeficiento ir absorbcijos reikšmes tada, kai lubos yra su kryžiaus formos plyšiais.

Vytautas STAUSKIS. Doctor, Associate Professor. Department of Building Structures. Vilnius Technical University, 11 Saulėtekio Ave, LT-2040 Vilnius, Lithuania. In 1974 a thesis in technical science. From 1974 on at VTU Department of Building Structures as assistant, Master of science. Scientific visits: Moscow Civil Engineering Institute, Sankt-Peterburg Politechnic Institute. Research interests: experimental testing of halls by primary hall models and on site, computer simulation of theoretic tasks, wave diffraction and reflections, direct sound and subjective acoustic indicators, large-dimension resonance structures, early attenuation of acoustic field and its relation to hall acoustics.