Unconventional method of the evaluation of acoustic comfort of pedestrians in urban space

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Introduction

A number of indicators are used in room acoustics to define the reception quality of an acoustic signal and, consequently, to assess the acoustic quality of enclosed space from the point of view of the audience.

It may be accepted that acoustic indicators applied in room acoustics, such as Reverberation Time (RT) or Early Decay Time (EDT) and others, could also be employed in the acoustic assessment of urban interiors, including open spaces. It would contribute to an improved evaluation of acoustic comfort of the occupants of such spaces, as, for instance, city streets or squares through which pedestrians travel.

A direct analysis of the acoustic climate of urbanised spaces, based on *in situ* measurements, both requires a great deal of effort and is highly expensive. The measurement procedure may, however, be eliminated in many cases, and the interpretative process, useful in preliminary analyses, simplified. A simple analogy between enclosed space, limited by strict geometric dimensions, and open space whose boundaries are arbitrary, was the underlying assumption in this analysis.

Computer simulations of such spaces were examined. The simulations relied on numerical calculations performed in keeping with the European standards based on the Odeon software.

The analysis of the results shows that the adopted methodological approach should be developed and future studies on the issue are called for.

Parameters of the assessment of the acoustic climate of an enclosed room and open space

A number of parameters are traditionally used to assess the acoustic quality of enclosed space from the point of view of its function (auditorium, performance venue, with or without a microphone, etc.). These parameters are related not only to the distribution of acoustic energy in a room but also its decay in time at individual points in the space designated for the audience (the zone of receiver points of acoustic signals).
A sound level decay curve in a room is used to determine parameters connected with the decay of acoustic energy in time, NF EN ISO 3382 (2000). The RT values are the most important ones. It is recommended that EDT should be determined together with RT because of the subjective significance of the former. EDT reflects the impression of reverberation, while RT serves only a referential quantifier of a hall (for instance, the reverberation time, RT, in the Carnegie Hall in New York is 1.7 s).
Because of the high mean correlation indicator for all octave bands between RT or EDT and t_s (centre time), r=0.983 [1], this parameter should also be examined. As the studies by Fasold W. et al. [2] show, its recommended value is between 60 and 80 ms for speech, and between 70 and 180 ms for music, depending on its type.

Open space versus enclosed space

Each external space, including urban space, may be compared to an enclosed room represented in a corresponding scale.
Urban space is actually a room with infinite three dimensions from which some enclosed space can be separated with virtual baffles [3],[4]. The material from which the baffles (external walls and the ceiling) are constructed must absorb acoustic energy completely. The sound absorption coefficient then equals 1 in the entire considered frequency range Picaut M.J. [5]. The quality of such space can then be assessed with parameters used in room acoustics. The studies carried out so far as well as the results of the measurements of the reverberation time, conducted *in situ* in rue Orleans in Nantes and repeated using the street model in the scale 1 :500, are highly convergent Picaut M.J. [5]. They seem to provide sufficient premises for further studies on the development of the concept of urban space as an enclosed room.

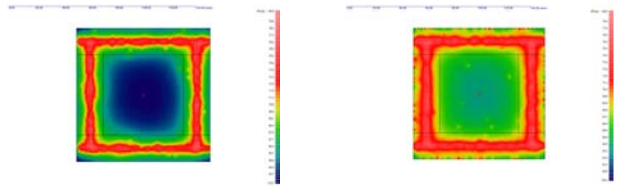
Description of the space analysed and the calculation method

The space analysed is contained within 100 m x 100 m x 12 m (Fig. 1). Intersecting streets, simulated by four linear sources whose acoustic power remains constant in their entire length, are sources of noise. The sound absorption coefficient of the walls and the ceiling equals 1 (completely absorptive). The floor is strongly reflective (reflection coefficient equals almost 1). The sound absorption coefficient was constant for all the elements such as urban structures (buildings), including all their surfaces. Atmospheric conditions were homogenous.
Numerical calculations were conducted for two cases: a fragment of space completely empty, without buildings (case "a") and space surrounded with buildings 12m high (case "b") (Fig. 1). Apart from distribution maps of individual parameters (SPL(A), EDT, C_{80} and t_s), calculations were also carried out in points situated along the diagonal of a square, 60x60m that is the outline of a virtual public square. Calculations were conducted at the height of 1.50m, i.e. the average height of the human ear. The accepted location of points simulates a pedestrian travelling across the virtual public square located between four virtual streets.

Figure 1: A three-dimensional view of the space analysed: case “b”

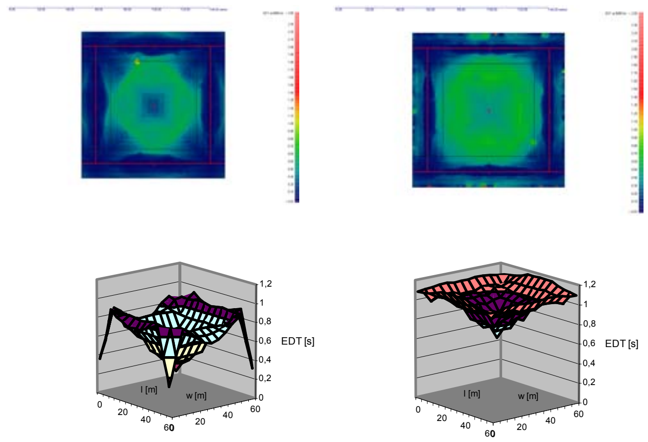
Results of computer simulations

The noise map at the height of 1.5 m, created on the basis of the results for cases a and b, are given in Fig. 2. The results of the calculations of the parameters connected with the decay curve conducted, i.e. EDT, are presented in Fig.3



Case “a” Case “b”

Figure 2: Results of calculations of SPL (A)



Case “a” Case “b”

Figure 3: Results of the calculations of the EDT

SPL(A), EDT and t_s values, determined along the route of the simulated passage of a pedestrian along the diagonal, are presented in Fig. 4, while differences between values of individual parameters are compared in Table 1.

Conclusions

- Urbanised space is usually characterised by greater noise, and its user, as in any other space, would like to receive relevant sounds without being excessively distracted (for instance having a conversation in the street) in the way that not only does not require unnecessary concentration or effort but is also nice.
- A pedestrian travelling along the streets or in public squares of modern cities is susceptible to changes in acoustic conditions that are not only connected with the noise level but also influence a broadly defined comfort of the reception of acoustic signals.
- To establish both relationships between acoustic comfort indicators and their optimum values it is necessary to conduct a number of examinations in the conditions of increased noise level.
- In the conditions of the actual acoustic field, it is mandatory to normalise studies on the reception of acoustic signals reaching the observer's ear from different directions.

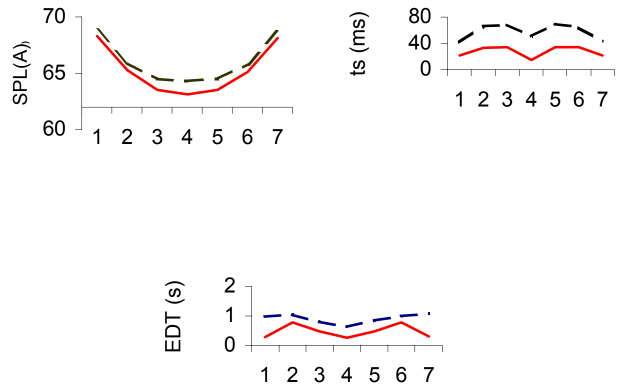


Figure 4: SPL(A), EDT and ts in points 1÷7, equally distant from one another, along the square's diagonal, Case a – continuous line, Case b - - broken line

		minimum	maximum	average	difference between extreme values
SPL (A)	a	63,1	68,3	65.3	5,2
	b	64,3	68.8	66,1	4,5
EDT	a	0,26	0,78	0,48	0,52
	b	0,64	1.08	0,91	0,44
ts	a	15	34	27	13
	b	42	69	58	27

Table 1: Comparison of calculation results along the diagonal of the square

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