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PERIODICALLY REPEATING SOUND AS A DISRUPTIVE AGENT IN BUILDINGS

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ABSTRACT

This work focuses on subjective perception of disruptive sounds with different harmonic frequencies and parts. It verifies the core of subjective disturbance on basis of a listening test. The effort is to clarify if there is more problematic the issue of clearly audible beats – which is more informative contents issue – or predominantly low frequencies of sound. Clearly audible impulses in sound records are meant by the definition beats in this article – for example drums in the recording. The point of interest is mainly low efficiency of sound insulation against low frequency sound as music with significant beats. The research is restricted only on respondents without hearing difficulties. Based on answers from more than 20 respondents there is conclusion from this paper that the research focus is far from clearance and simplicity. Answers are often very inconsistent and complaints about impossible task were noticed multiple times. In general, however, there is very clear that the problem in disturbance is hidden in low frequencies and with audible beats. The low frequencies are the key disturbance agent in this particular matter.

KEYWORDS

Acoustics, Subjective evaluation, Listening test, Low frequency sound

INTRODUCTION

Insufficient sound insulation and its connection with low-frequency sound sources in building acoustics brings a new problem. In reference to this, there is increasing number of user complaints on the clearly audible beats within a noise from neighborhood. Periodically recurring "beats" in music are mostly a low frequency component. The problem is how to effectively decrease transition of these noise components in lightweight multi-layered structures. These lightweight structures are very different from heavyweight in terms of acoustic behavior.

For a multilayer construction we can consider as an illustrative example a wall made of gypsum board on metal frame where the spaces between which are filled with mineral insulation - see Figure 1.

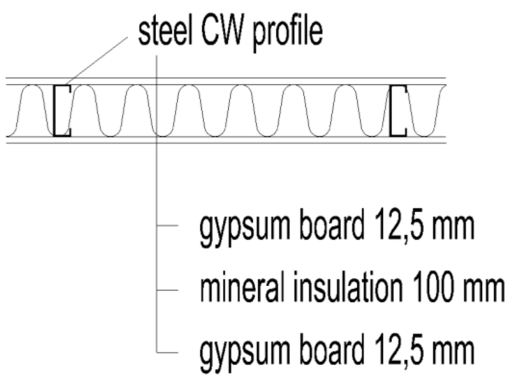

Fig. 1 - Example of lightweight multi-layered structure

The specificity of this type of structure is the mass-pliability-mass resonance and the standing waves in the air gap between the boards. Due to this behavior, this structure generally has higher sound insulation values than a monolayer structure with an adequate basis weight, but there is a problem with certain frequencies, especially in the low frequency range.

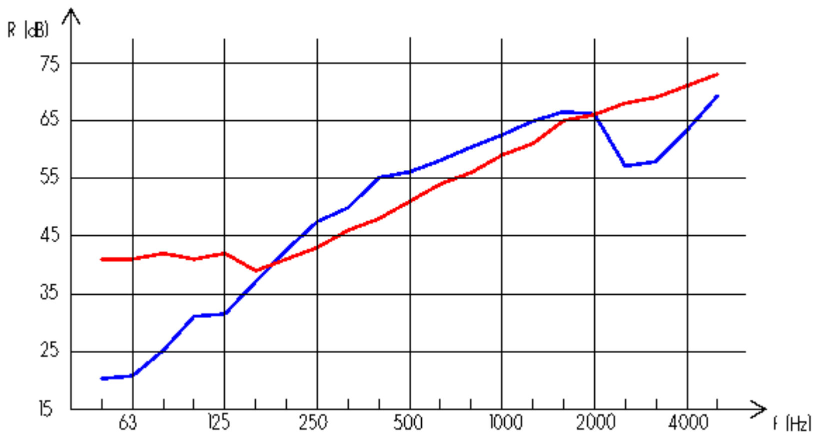

Fig. 2 - Example of difference in sound reduction index – red line represents concrete wall with thickness of 150 mm; blue line represents plasterboard on wooden frame. Both structures have the same Rw - weighted sound reduction index.

In most day-to-day activities, this area of low frequencies, where the sound attenuation is small, does not have much relevance to human perception of comfort. However, there is one very important exception to this rule, which has become more and more frequent in recent years due to the development of available electronics. The exception is quality music listening, which contains a large component of low-frequency sound. The increasing number of home cinemas, high-quality speakers with subwoofers and low-frequency speakers, combined with multi-layered designs, have led to a growing number of complaints from residents.

The basic research question of this work is whether the dominant component of sound disturbance is rather low frequency or clearly audible repeating beats. The listening test used to answer this question is narrowed to a healthy audience without any hearing impairment. The finding should help to design structures more efficiently in terms of sound insulating parameters.

METHODS

Respondents

Since the work is aimed at healthy individuals without auditory pathologies, the respondents were subjected to an indicative audiology examination prior to testing. This examination was conducted under the supervision of the test administrator and is freely available on the website [1]. The original verification of this online audiogram was done by the author of the article which compared the results of this online test and audiogram with the physician - audiologist. Both audiograms differed only in small sessions and therefore it can be concluded that for the purposes of this work the accuracy of freely available audiology investigation of respondents is sufficient. However, it must be emphasized that it is definitely not a full-fledged substitute for an audiogram from a medical professional.

Recordings

The audio recordings used in the listening tests are digitally synthesized from the sound of the undercover music (played on electric keys that was deliberately chosen neutral and not known to the respondents) and drum strokes at 180 BMP (beats per minute). The underlying music remains the same in all the samples, the effect of the percussion instruments, beats. These are equalized to achieve their main frequencies at 50 Hz 500 Hz and 5000 Hz. The other frequencies were subdued from the original, the frequency then slightly increased. These sounds were then paired and submitted to the respondents.

The underlying sound has been muted by 5 dB in comparison to the original, so that the beats cannot stand out and be audible. This background sound was deliberately chosen to be unknown, and thus did not incite other unsupervised unconscious responses of respondents. It was also advisable that this sound itself did not contain clearly audible and recognizable beats. The length of the sound recordings is 7 seconds, long enough to show and record beats, but so short that the whole sound does not shrink (because it is not very interesting, informally or musically).

Sound pressure levels (SPL) for third-octave bands - For beats at 50 Hz, 500 Hz and 5000 Hz - Left always flat, right with filter A:

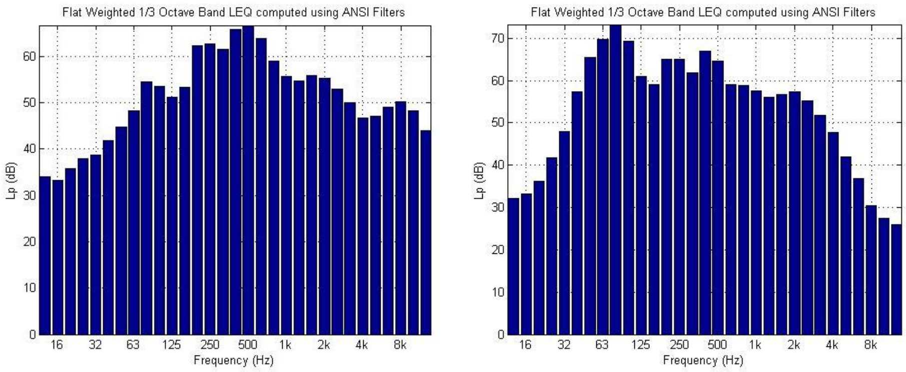

Fig. 1 - SPL - recording 50 Hz

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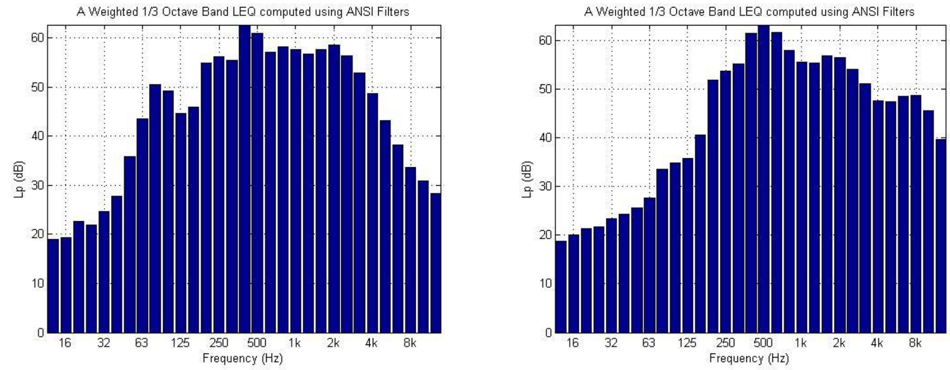

Fig. 4 - SPL - recording 500 Hz

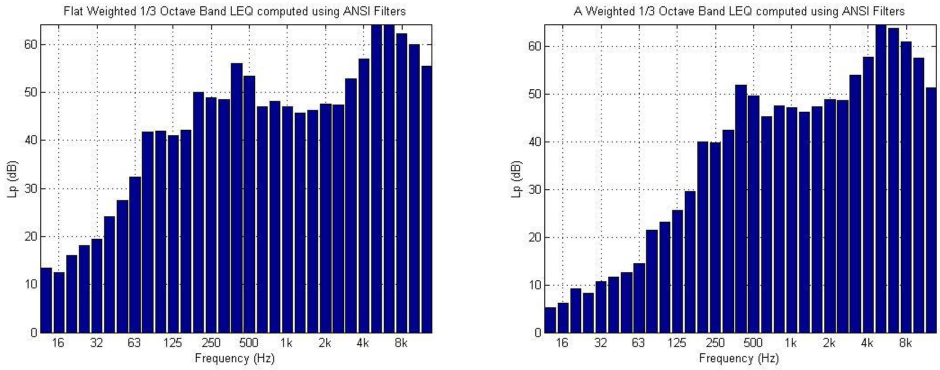

Fig. 2 - SPL - recording 5000 Hz

Listening tests

Respondents who passed an audiology test were presented with listening tests. On the first page there is an introduction to the test and a short questionnaire on the respondent's national - age, gender, whether he or she has previously participated in a listening test and the last question whether he or she is aware of any hearing impairment. There are 9 screens in which respondents have the task of assigning an appropriate level of volume to the sound judged to match the default sound - see Figure 6. They have the ability to click on the buttons to amplify and attenuate the sound being played and, of course, to play the default sound. After comparing the volume to the best of consciousness, the respondent moves the "OK" button to another form. The entire test is created in C # programming language in Visual Studio 2015 [3].The whole questionnaire is conceived as anonymous. The sound can be played repeatedly by clicking on the button, but it does not play in the loop - again to better keep the attention of the respondents. The final test form is dedicated to giving feedback and encouraging you to leave a comment.

Fig. 3 - Screen of listening test [4]

The schema in which the evaluation form was ordered is outlined in Figure 7. In addition to retrospective assessment (e.g., the relationship between 500 Hz and 5000 Hz with 500 Hz), the evaluation of the sound with itself is taken into question. The judged sound has a different volume set from the beginning, so the 50 Hz and 50 Hz comparison results should not be 0 to be correct. The arrow always goes from the default sound (which has a fixed volume to sounds that can be mitigated / amplified by the respondent.) The arrow number then represents the order of the form in the listening test.

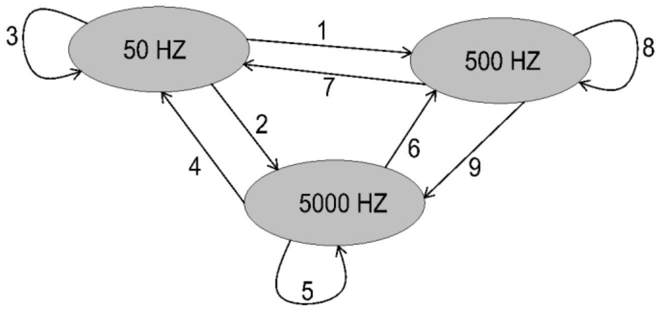

Fig. 4 - Schema of testing

Equipment used for all of the listening tests:

Headset SEP 629 with specification:

Diameter of loudspeaker: Ø 40 mm

Impedance: 32 Ω +/- 10 %

Frequency span: 20 Hz - 20 kHz

Sensitivity: 106 dB +/- 3 dB /1 mW (SPL na 1 kHz)

Tests took place at different places, depending on the respondents' preference. In any case, however, the test was performed within a acoustically insulated room, without other distractions and without significant psychological subtexts.

RESULTS

According the answers from respondent of listening tests there is possible to conclude several things.

In following table there are shown all the raw valid answers. There were also 4 respondents who do not satisfy the preliminary audiology test so their answers are not processed.

Tab. 1 - Sheet with answers from respondents

comparison of sounds. First (default) sound is louder by 5 point than the second one.														
inquiry						frequency comparison								
datum	number	age	gender	previous participation	hearing problem	50-500 Hz	50-5000 Hz	50-50 Hz	5000-50 Hz	5000-5000 Hz	5000-500 Hz	500-50 Hz	500-500 Hz	500-5000 Hz
03.12.2017	1	24-30	male	yes	no	-3	14	-5	-19	-4	-16	-8	-5	12
03.12.2017	2	50-65	male	yes	no	-1	9	-3	-6	-1	-12	-7	-4	5
03.12.2017	3	50-65	female	yes	no	-2	11	-4	-14	-10	-13	-8	-7	5
03.12.2017	4	24-30	female	yes	no	-5	-7	-6	-7	-4	-6	-9	-5	-11
06.12.2017	5	24-30	male	yes	no	-4	-2	-7	-10	-6	-10	-8	-7	1
24.12.2017	6	30-40	male	no	no	-4	9	-4	-14	-2	-12	-8	-1	8
24.12.2017	7	24-30	male	no	no	-1	16	-4	-17	-4	-16	-10	-5	14
24.12.2017	8	24-30	female	no	no	-6	-5	-8	-9	-7	-9	-10	-4	-5
24.12.2017	9	30-40	male	yes	no	-4	2	-5	-12	-6	-10	-12	-7	1
24.12.2017	10	50-65	female	no	no	0	13	-4	-19	-4	-14	-9	-4	8
24.12.2017	11	>65	male	yes	no	0	15	-5	-13	-3	-14	-10	-5	9
28.12.2017	12	30-40	male	no	no	-3	9	-7	-17	-4	-10	-9	-5	8
28.12.2017	13	50-65	female	yes	no	-1	-7	-4	-12	-4	-12	-7	-7	1
28.12.2017	14	24-30	male	yes	no	-6	2	-4	-13	-7	-12	-8	-5	1
28.12.2017	15	30-40	male	no	no	-3	13	-8	-7	-10	-16	-10	-4	5
28.12.2017	16	24-30	female	no	no	-4	16	-3	-10	-1	-6	-8	-7	8
29.12.2017	17	50-65	male	yes	no	-3	11	-4	-13	-5	-14	-8	-5	7
29.12.2017	18	50-65	female	no	no	-2	-8	-4	-14	-4	-11	-8	-6	4
29.12.2017	19	30-40	female	no	no	-3	5	-5	-12	-5	-11	-9	-5	4
29.12.2017	20	24-30	male	yes	no	-4	6	-4	-10	-6	-12	-10	-4	5

From the table is clearly visible that the range of answers is quite broad. The conclusion is that it is highly difficult for people to compare different sounds – despite their similarity. Answers depend on each respondent and his preference or maybe better spoken - immunity to particular component of disturbing sound. Therefore, it is not possible to strictly announce that something is true covering all of population.

In the next table there are results already processed by some means. Answers are averaged and adjusted to the same level (nullification of that +5 sound level point in default sound). Also there is added the analyzed sound from sound analyzer, which is very appreciated for objective comparison.

Tab. 2 - Sheet with processed results

	50-500 Hz	50-5000 Hz	50-50 Hz	5000-50 Hz	5000-5000 Hz	5000-500 Hz	500-50 Hz	500-500 Hz	500-5000 Hz
average of respondents	2,05	10,68	0,11	-7,05	0,11	-6,58	-3,84	-0,11	9,11
standard deviation	1,76	8,18	1,52	3,75	2,43	2,86	1,24	1,48	5,63
from sound analysator: default (dB)	70,1	69,9	70,2	74	73	75	68,6	69,7	68,6
from sound analysator: default - average(dB)		70,1			74,0			69,0	
right answer according sound analysator	-1	-8	0	7	-1	10	-2	1	-5
difference between sound analysator and respondents	3,05	18,68	0,11	-14,05	1,11	-16,58	-1,84	-1,11	14,11

The blue columns show the same sound – at this point there is agreement within the answers in respondents themselves and analyzer as well. One decibel is close to the Just Noticeable Difference (JND) for sound level [2]. On the other hand there are significant differences in others columns. In general, however there is clearly visible inclination to evaluate sounds with dominant frequencies of 5000 Hz as the most silent ones and 50 Hz as the loudest one – Comparison 50 Hz and 5000 Hz differs about 18,68 points (respectively 14,05 in case of 5000 Hz and 50 Hz) from real A weighted scale based on analyzer. 1 point in answer sheet responds approximately to 1 dB in sound pressure level based on sound analyzer measurement. The difference between 50 Hz and 500 Hz is insignificant. In exact numbers is in average less than 2,5 points.

CONCLUSION

At the first there must be noticed that the population of respondents is very limited and therefore the statistical significance is not so great. There should be more research and study to confirm and specify these results.

The respondents were relatively accurate in evaluation the same sounds – comparison 50 Hz and 50 Hz for example. However there was big difference in comparison of other sounds. Also there were multiple complaints of almost impossible task to compare such different sounds – although only difference was in frequency of the beats.

Answers had anyway shown that in general there is strong inclination to evaluate beats played in higher frequencies as not so loud as beats played on low frequencies. In other words the hypothesis of low frequencies as the dominant disruptive element is confirmed in this paper. If this conclusion is proven right in further studies and research, it should be comprehend into methodic of design of buildings. Based on these results there is crucial way to increase sound reduction especially on low frequencies in order to achieve better insulation capabilities.

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