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Structural and Physical Aspects of Construction Engineering

Construction Machines as a Source of Construction noise

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Abstract

The contribution deals with issues concerning the modelling of the production area of a construction site from the aspect of the placement of construction machines, which are a source of noise for the protected area outside the site according to Government Regulation No. 272/2011 Coll. It covers the determination of a construction site noise prognosis for planned investments. It suggests reference procedures for the noise certification of construction sites with regard to surrounding terrain and developed areas, both reflective and non-reflective surrounding terrain and natural noise barriers. It defines inputs necessary for the verification of construction noise intensity during the construction preparation stage. It describes the options for modelling the noise burden at building sites, and the options for the placement of machinery within the manufacturing area based on knowledge regarding the noise level produced by machines and technological procedures. It justifies the necessity of assessing noise from construction machines during the optimization of construction site operations.

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1. The legislative environment relevant to the issue

The technical activities that people engage in are accompanied by undesired sounds that we refer to as noise. Today, noise is a pollutant which impacts the human working and living environment. People act to protect themselves against high noise levels both materially and through legislation. Where measures leading to a decrease in noise are not employed successfully, and when exposure to noise lasts for a longer period of time, human health can be damaged. This can express itself through restlessness, headaches, inadequate sleep, and diseases of the nervous and vascular system. The occurrence of such diseases lowers the ability of individuals to perform well and, as a final result, also

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hampers the creation of gross domestic product. These losses have even been calculated, and they are estimated to amount to 1.7 – 2.0% of GDP. [3].

With regard to the increasing intensity of the sounds emitted all around us, as well as the results of medical research, this issue has started to be monitored and limits defined for these undesired sounds (noise) in relation to "interior protected areas" (i.e. areas inside buildings), outdoor protected areas, and the workplace. Efforts are being made to eliminate the unfavourable effects of noise on the human organism. [1,2,11].

Transport engineering is a field which dedicates a lot of effort to noise and its limitation. The influence of traffic noise is modelled intensively and noise pollution is defined according to technical conditions (TC). In this connection one can often encounter the term "old noise pollution", which is noise caused by traffic on roads and railways constructed before 1.1.2001. [5,6,7].

Less attention is given to the problem of noise arising during construction, i.e. construction site noise or noise produced by building activities. Even though today's legislation sets limits for construction site noise, it is quite common for them to be exceeded when more demanding construction techniques are being carried out. This often results in a visit by the municipal or state police to the construction site, the imposing of fines and, in extreme cases, the ceasing of construction work. In addition, civil lawsuits have started to appear fairly frequently concerning lost profit in cases where business subjects in the vicinity of construction sites have been disadvantaged.

According to the law, the operator of the source of noise and vibration has the duty to ensure that the facility they operate conforms to all limits as far as both the technical and organizational aspects are concerned. [12,14].

By treating noise pollution limits as one of the requirements a construction project must fulfill, noise has become one of the factors of the production process, just like the workforce, means and objects involved, and it can also be worked with in this way in the area of design optimization. If we view the preparations for the realization of construction work from this angle, we can choose procedures which will decrease noise during construction. The main supplier and sub-suppliers are the producers of noise in the case of construction deliveries. With regard to the valid legislation, they should try to optimize (i.e. lower) their production of construction site noise.

The protection of human health against noise and vibration is covered in Act No. 258/2000 Coll. on the protection of public health, specifically in §§ 30-34 of this act [1]. Another such law is Act No. 309/2006 Coll. which outlines other requirements for health protection and safety at work in labour-law relations, and the ensuring of health protection and safety during activities or the provision of services outside labour-law relations (the Act on the provision of other conditions for safety and health protection at work) [13].

In accordance with these acts, Government Regulation No. 272/2011 on the protection of health against the unfavourable effects of noise and vibration was issued on 24th August 2011 [2]. This regulation incorporates and enacts relevant European Union regulations and sets hygiene limits for noise and vibration in the workplace, along with methods for their determination and evaluation, and also establishes the minimum scope of employee health protection measures.

From the aspect of the target area of construction site noise, Government Regulation No. 9/2002 Coll. is also important. It determines the technical requirements for products with regard to noise emissions (compaction machines, compressors, pneumatic drills, dozers, dampers, excavators, loaders, grass mowers, cranes, welder generators, etc.). These requirements concern the measurement of the acoustic output level for the catalogue sheet and brand of each given product, i.e. they define the data which are necessary for the modeling of noise. [15]

In the period before 2011, Government Regulation No. 148/2006 Coll. on the protection of health against the unfavourable effects of noise and vibration was valid. It was then superseded by the issue of the new Government Regulation, 272/2011 [2]. Nevertheless, it is mentioned in many specialized texts and links.

2. Protected outdoor areas

Land parcels which haven´t been built on and which are used for relaxation, sport, health treatments or tuition are considered to be protected outdoor areas. This classification does not include land parcels intended for agricultural use, forests and outdoor workplaces. The following kinds of protected outdoor areas are also defined in the valid legislation mentioned above: [2,11]

- Protected outdoor area of an inpatient medical facility or spa.
- Other protected outdoor areas.

As far as the measurement and evaluation of noise are concerned, this regulation refers to procedures described in methods and terminology concerning the areas of electroacoustics, acoustics and vibration which are contained in the relevant Czech technical standards. [8,9]. When the procedures are complied with, the result is considered to be valid. They are used for the evaluation and calculation of measurement corrections and uncertainties.

Protected outdoor areas are understood to be land parcels which have not been built on and which are used for relaxation, sport, health treatments and tuition, with the exception of forests, agricultural land and outdoor workplaces. The outdoor protected area of a building is an area lying within two metres of an apartment building, family home, or building used for school and pre-school education or for health and social purposes, as well as any other building with a similar function. In such outdoor areas, measurement microphones are usually placed within 2 metres of a building's façade in front of the window to a room or in another exposed place, depending on the source of noise.

For the evaluation of noise in a protected outdoor area around a building, the evaluation criterion is the level of acoustic pressure imposed by the noise reaching the façade of the evaluated building [8,9].

The acoustic pressure levels of the incident sound are determined for the purpose of evaluation from measurements gained from a microphone placed at a distance of 0.5 to 2 m from a reflective surface with the use of correction in order to obtain the incident sound field. The recommended distance to be used is 2 m.

Uncertainties in the calculation of noise are considered for all evaluations, and such computational uncertainties are checked with the aid of terrain measurements before using the evaluated data with modelling software. The determination of computational uncertainties and the quality of the computational model are not the only factors enabling the successful modelling of noise: the most fundamental requirement is that the entry data for the calculation is entered correctly and exactly [16].

Noise from construction activities is not considered to originate from inside the building if it penetrates the building in a way other than through the air, e.g. through the structure or the base.

For the hygiene limits concerning noise from construction activities that is affecting the protected outdoor areas of other buildings, the maximum acoustic pressure levels for the individual time periods shown in Table 1 are valid according to the aforementioned government regulation:

Table 1: Hygiene limits for noise from construction activities [2,11].

Type of protected area	Type of noise	Evaluated period			
		Hygiene limit of the equivalent level of acoustic pressure A $L_{Aeq,\,S}$ (dB)			
		6am - 7am	7am - 9pm	21pm - 22pm	22pm - 6am
Protected outdoor area of other buildings	Noise from construction activity	60	65	60	45

L_{Aeq} is what is known as the equivalent level of noise. It expresses the level of irregularly changing noise, for example traffic noise. It expresses the energy content of variable noise which was in effect at a given time using a value for the level of steady noise which would contain the same quantity of acoustic energy for the same period as the measured noise. The equivalent level of noise is always related to a certain time interval, marked L_{AeqT}

An eight-hour L_{Aeq} is generally stated for a working environment, while in a non-working environment (LD) is used for day time, (LN) for night time and (LDN, L24h) for the whole day.

The value $L_{Aeq\ hodnotící}$ is used by public health authorities for the evaluation of the acceptability/non-acceptability of the acoustic situation in the protected outdoor areas of buildings. The hygiene limit of the equivalent level of acoustic pressure A is determined as the sum of the basic level of acoustic pressure A $L_{Aeq,T}$ = 50 dB and a correction which takes the type of protected area and time of day (day or night time) into account. [1,2,11]

3. Sources of noise

The main sources of noise at a construction site include construction machines (mainly machines which produce impacts, e.g. devices for breaking concrete), earth-moving machines, pile drivers, pneumatically driven devices and combustion engines. For the purposes of noise studies, these mechanisms must be considered to be point or linear noise sources depending on the level of movement at the construction site.

Some types of construction projects are not endangered by increased noise pollution at all, while others are, but only when particular conditions coincide. In the case of certain construction sites, increased impact can already be expected from the very nature and location of the project.

The latter situation mainly occurs when construction takes place in the vicinity of existing buildings or in a reflective environment. Another area which needs to be dealt with as far as noise is concerned is that of large complexes of apartment houses and family homes when the investment project is executed via a gradual construction process. In other words, construction takes place in stages which are each subject to individual approval proceedings, meaning that some buildings are already inhabited while new buildings are being created in their neighbourhood.

In order that we might work with specific values, we have to know the acoustic output value or the level of acoustic pressure at a certain distance for the evaluated source, which is information that needs to be obtained from the product sheets provided by construction machine manufacturers. Two values are often stated on a machine's technical data sheets – internal and external noise. The internal noise is the noise in the driver's cab, so it is the outside noise value that is considered for the purpose of evaluating construction site noise.

4. Support software

Sophisticated programmes are used for the modelling of noise maps. They work with the entered physical values in such a way that the calculated noise can be modelled using isophon curves, otherwise known as equal-loudness-level contours. There are several software systems which enable the identification and immediate analysis of various types of noise and the determination of their mutual share in the total noise at the evaluated location.

They are classified according to the environment for which they are intended as aids in the evaluation of noise:

- CadnaA - a programme for the calculation and evaluation of noise from road and railway traffic, air transport, industrial devices and industrial plants and sites, from industrial sources, and from sports and leisure facilities
- CadnaR – software for the calculation and evaluation of noise in rooms and in the workplace
- BASTIAN – a programme for the calculation of the transfer of sound between rooms in buildings and from outdoor to indoor areas.
- Neprůzvučnost – a programme for the theoretical evaluation of the airborne and footstep sound attenuation of building structures
- HLUK+ – a programme for the calculation of noise from traffic and industrial sources [16]

HLUK+ software is suitable for the modelling of construction noise. In this software, a group of construction machines can be classified as an "industrial source".

This is then a point source of noise: if the construction site is under continuous load, its definition as a line source of noise can also be considered.

5. Measures applied to the path of noise propagation

If no machine with a low noise level exists for the performance of a given task, or if it is not available to the supplier for the given construction, passive measures in the form of obstacles must be selected. During the propagation of noise, it can pass through the obstacle, be reflected, be absorbed, or go around the obstacle. Calculations or modelling therefore need to be performed for the whole situation within the context of the source of noise as well as the surrounding terrain so that an efficient obstacle can be selected. An acoustically effective obstacle can take the form

of a cutting through terrain, an earth wall, a retaining wall, a strip of greenery, or an artificial anti-noise barrier or cover.

In the proceedings of the ENVI BUILD conference, an example was given in the article “Construction noise and its influence on the protected area of existing buildings” of a combination of machines at a construction site and their acoustic output values for a specific technical process. A calculation, correction and comparison with hygiene limits were performed for these machines. With regard to the distance of this combination of machines from the protected built-up area, their period of operation was limited to 16% of total working hours. [4]

The shortening of a machine’s operating period is a standard solution in cases when noise values exceed hygiene limits.

However, this results in the extension of the period needed for the execution of individual technical processes, as well as the total duration of construction work. One solution is the use of a noise barrier, such as that shown in the documentation in Fig.1.

Fig. 1. Layout of construction site equipment with a suitably placed noise barrier (CARLA Centre for the Support of the Humanities, Faculty of Arts, MU).

Construction site storage areas for material or parts can also serve as a noise barrier. Similarly, it is possible to plan the shaping of volumes of excavated rock to form acoustic earth mounds and even out the balance between embankments and trenches during construction. Noise can be partially dealt with by adapting the course of operations at the construction site, and the placement of piles of loose material and items of site equipment to form a natural noise barrier.

Theoretically, such obstacles can decrease noise by 15 or more decibels, both models show the picture number 2 and 3. Modeling in HLUK+ [16]

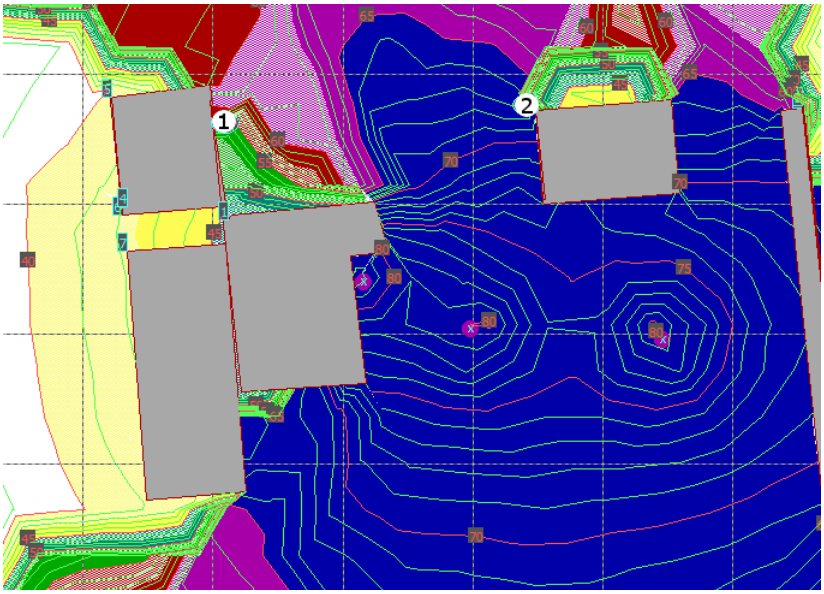

Fig.2. Course contours without placing noise barriers at construction site (CARLA Centre for the Support of the Humanities, Faculty of Arts, MU), Between points 1 and 2 must reduce noise by 5 decibels.

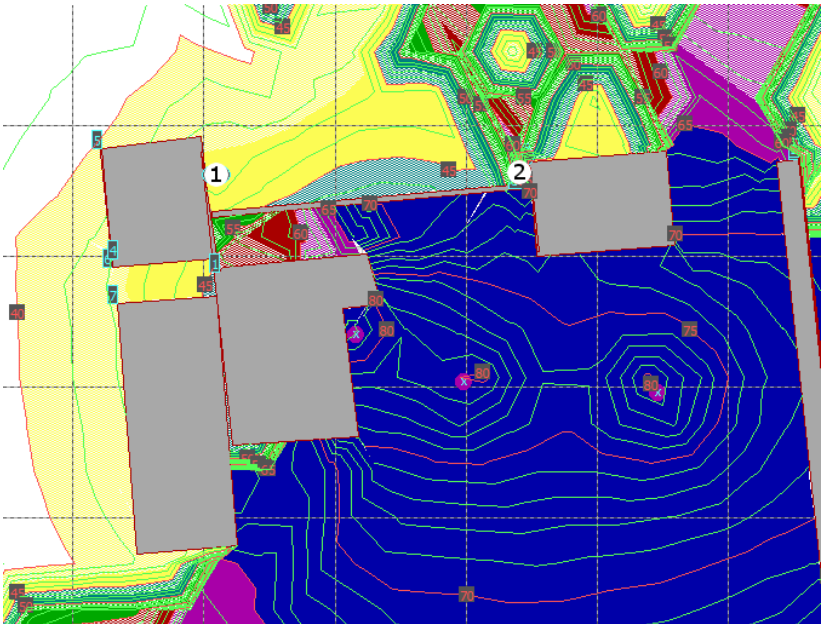

Fig.3. Depiction of the influence of a noise barrier on isophon curves (CARLA Centre for the Support of the Humanities, Faculty of Arts, MU), Placed sound wall height of 3 meters.

Fig. 4. Mobile noise barrier with openings [10,17].

Suitably selected construction site fencing can also be used as a noise barrier. It is also possible to insert just part of a sound barrier between a noise source and a location exposed to limit-exceeding noise. Sound barriers constructed in the way shown in Fig 4. unfortunately suffer from a deficiency in the form of a gap between the concrete wall foundations and the bottom edge of the wall. This allows noise to partially “leak” through the wall into the screened-off area.

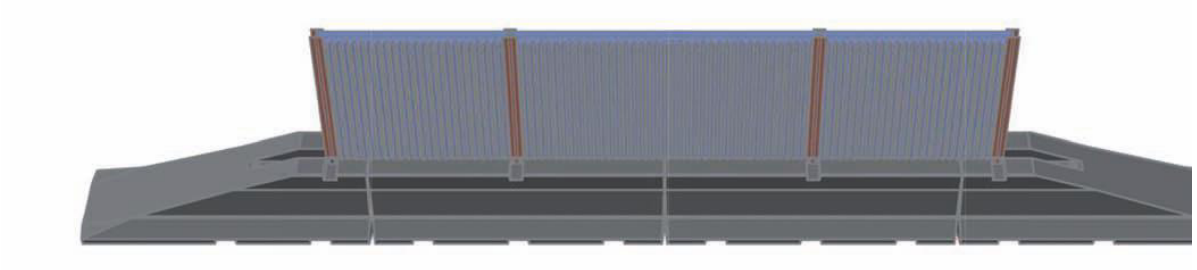

Fig. 5. Mobile noise barrier without openings [10,17].

A more suitable mobile noise barrier variant is shown in Fig. 5.

The cost of installing noise barriers will of course raise construction costs, and so the use of passive barriers is more advantageous.

6. Noise abatement preparedness of construction sites

It can be said in conclusion that informedness regarding valid legislation, the technical data available for construction machines and possible noise prevention measures will certainly contribute to a successful construction process and, in particular, allow handover deadlines to be met.

I recommend using the following procedure to achieve a qualified decrease in noise pollution:

- Determine the type of outdoor protected area
- Acquire machine product lists with stated noise values
- Define risky point sources of noise – the locations of machines or combinations of machines
- Define risky linear sources of noise – the trajectories of machines or combinations of machines
- Define exposed locations in outdoor protected areas (points exposed to the incidence of noise)
- Determine the absorbability or reflectivity of the terrain, banks, cuttings, greenery, surrounding buildings, roads
- Calculate the prospective acoustic situation (determine the level of sound transfer from the source to the point of incidence by the measured façade of the protected building)
- Perform an evaluation with regard to hygiene limits
- Propose measures, calculate the prospective acoustic situation, conduct a new evaluation with regard to hygiene limits

References

[1] Act No.258/2000 Coll. on public health protection, as amended
[2] Government Regulation 272/2011 Coll., on the protection of health against the unfavourable effects of noise and vibration
[3] Václav Cílek, Tsunami je stále s námi, ISBN 80-86851-22-2
[4] R. Kantová, V. Motyčka, Construction Site Noise and its Influence on Protected Area of the Existing Buildings, contribution to the conference proceedings Elektronický sborník konference enviBuild 2014, ISSN 1022-6680, ISBN 978-80-214-5003-5, Trans Tech Publications Ltd, Switzerland, 2014
[5] Technical conditions (TC) of the Ministry of Transport of the Czech Republic 189 2nd edition: "Determination of the intensity of transport on roads"
[6] TP 219: "Traffic engineering data for the quantification of the influence of road transport on the environment"
[7] TP 225 2nd edition: "Prognosis of the intensity of road transport"
[8] ČSN ISO 1996 (01 1621): Acoustics – Description, measurement and evaluation of noise from the environment – Part 2: Determination of the levels of noise from the environment. ČNI, August 2009
[9] ČSN ISO 1996-2, which, among other things, specifies the procedure for the determination of the level of acoustic pressure created by a field of acoustic waves hitting the façade of a building
[10] ČSN ISO 10847: determination of the in situ insertion loss of all types of outdoor noise barriers
[11] HH ČR č.j. 62545/2010-OVZ-32.3-1.11.2010 METHODOLOGICAL INSTRUCTION for the unification of the procedure employed by public health authorities and health institutions when executing state health supervision during the evaluation of noise in the protected outdoor areas of buildings, Ministry of Health - chief hygienist of the Czech Republic
[12] Government Regulation No. 178/2001 Coll., determining the conditions for the protection of the health of employees at work
[13] Act No. 309/2006 Coll., which defines other health and safety at work requirements in labour-law relationships, and governs health protection and safety during activities or the provision of services outside labour-law relations (the Act on the provision of other conditions and health protection at work)
[14] Act No. 100/2001Coll., on the evaluation of environment impacts, and on changes to certain related acts, as amended
[15] Government Regulation No. 9/2002 Coll., which determines the technical requirements for products from the perspective of noise emissions
[16] www.hlukplus.cz
[17] www.renanova.cz/ostatni-vyrobky/mobilni-protihlukova-stena