Customization of software for sound insulation prediction in buildings to national legislations – Case study: Slovenia

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Abstract – **Estimation of sound insulation in buildings according to EN 12354 norms is or will soon be mandatory in European countries. In addition, each country accompanies to it its local requirements: minimum allowed descriptor values, safety margins, project report form etc. Specialized software is needed for the proposed calculations and local requirements open the possibility for it to be "nationally customized". This paper describes such software designed for Slovenia.**

Keywords – **sound insulation, sound insulation index, sound insulation prediction software.**

I. Introduction

Design of sound insulation in buildings is a task drawing much of attention recently. European COST Action TU0901: "Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions" in progress is dedicated to this subject [1]. The main reason for this is the fact that the quality of sound insulation determines acoustic comfort of residents in buildings [2].

The models of sound propagation in buildings and algorithms for the prediction of airborne and structure born sound insulation are popular topics in acoustic literature. However, it is only the calculation of sound reduction inside monolithic heavyweight elements which is relatively precisely and unambiguously described. On the other hand, there are still no generally accepted algorithms for sound reduction inside elements with more complex internal structure, such as drywall constructions with plasterboards. Hence, results of standard laboratory measurements of such element insulation performances are basic data used in the design phase.

In the last few decades a new approach to the calculation of sound insulation in buildings has been introduced, which produced far-reaching consequences to the national standardizations and design practice. In 2000, set of European norms under the label EN 12354 is published. It consists of several parts, the first three of which [3]-[5] are important for sound insulation in buildings. These three parts define procedures for calculation of airborne and structure born sound insulation between rooms and airborne sound insulation (of façade walls) against outdoor sound, respectively.

The new standards were soon being adopted by national standardizations as well. While EU countries adopted them almost immediately after their introduction, the acceptance in the rest of European countries was slower. In Serbia these three standards were approved in 2008. Even more important is the fact that their application is often mandatory when designing new buildings. For example, this became part of Slovenian legislative on 1 January 2013. It is reasonable to expect that the rest of the countries in the region will also accept this obligation in recent future.

Before the norms were published, the analyses of sound insulation between two adjacent rooms included only modelling the sound insulation properties of the separating element. The contribution of other (flanking) paths of sound transmission was taken into account approximately, through the correction of calculated single-number sound insulation value in decibels. The calculations were based on the results of field measurements and adjusted to match them.

The change of approach presented in the new norms is of great importance, since it requires that sound insulation between adjacent rooms is assessed through the influence of complex system of sound transmission paths between the rooms, including all their relevant physical properties. This makes the calculation of sound insulation rather complex, especially if it should be repeated in 1/3 octave frequency bands. It also made the algorithms described in EN 12354 too difficult to handle without the aid of some specialized software. For that reason, several such specialized software packages appeared on the market in the last decade [6], [7].

Local requirements in some of the countries in the region brought a necessity for nationally customized software for the calculation of sound insulation, according to the procedures given in EN 12354. Such software is realized in Laboratory of acoustics at the School of Electrical Engineering in Belgrade, to comply with legal requirements in Slovenia. The most important issues which appeared during the software development, as a result of its adaptation to the local requirements, its specificities and adopted solutions are described in this paper.

II. Realization of Software Based on EN 12354

The calculation procedures described in EN 12354 take into account all relevant sound transmission paths between two adjacent rooms. These paths are presented in Fig. 1 for

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airborne sound insulation. Capital letter D is used for the paths starting at the source side of the separating element, while small letter d is used for the paths ending with sound radiating from the receiving side. F marks the paths starting in the flanking elements of the source room and f marks the paths ending with sound radiating from the flanking elements in the receiving room.

From Fig. 1 [3] it follows that the model proposed by the standards incorporates the contribution of separating element between the rooms (direct transmission) as well as all flanking elements adjacent to it (flanking transmission). All elements which are adjacent to the separating element and have a common junction are regarded as flanking elements. Fig. 1 omits all airborne transmission paths, such as various openings, air inlets, flanking ventilation systems etc. These are all included in the standards, by quantifying sound power transmitted through them.

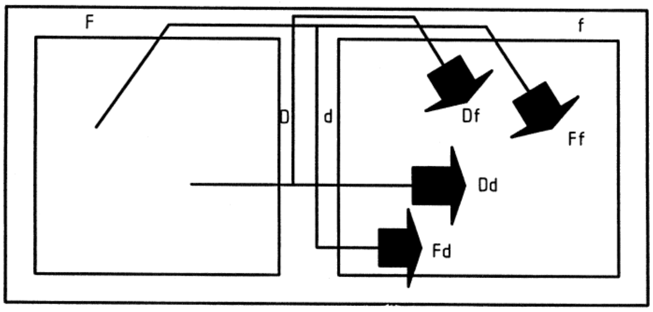

Fig. 1. Sound transmission paths between two rooms according to EN 12354-1:2000 [3]

Numerical parameters included in the calculations, which quantify physical properties of the transmission paths in Fig. 1, can be divided in three categories:

1) sound reduction index R of all elements involved in the transmission measured in laboratory,

2) structural reverberation time T_s, which quantifies sound energy losses in the materials of the elements,

3) vibration reduction index K_{ij}, representing sound energy losses in the junctions between each two elements (marked with *i* and *j*).

Heavyweight elements also show significantly different acoustic properties in laboratory and real situations in buildings. This is due to the sound energy losses at their junctions with adjacent elements, which influence the sound field in them. To take this into account, sound reduction index and structural reverberation time of these elements are transformed into real (*in situ*) values R_{situ} and $T_{s,situ}$, prior to the calculation. R_{situ} value of heavyweight monolithic elements depends on both laboratory sound reduction index and ratio between $T_{s,situ}$ and laboratory structural reverberation time $T_{s,lab}$.

Considering all the parameters needed, it follows that the calculation of sound insulation between two adjacent rooms generally requires data about R and T_s of nine elements (one separating and eight flanking) and K_{ij} of four junctions between the separating and flanking elements. Due to this complexity, the calculations are very hard to handle without the aid of specialized software.

Realization of software for calculation of sound insulation according to EN 12354 requires several practical issues to be considered.

1) As a starting point for the calculations, laboratory sound reduction index values of the elements are needed. This means that software must include a database of insulation properties of common building elements. Collecting these data from various attests is major concern and can be carried out only in cooperation with building companies, which finance attest of their products and own the obtained measurement results.

2) Value ranges of many physical quantities involved in the calculations should be considered (structural reverberation time, vibration reduction index).

3) The values of all physical parameters included in the calculations are not always available for all building materials and constructions. Therefore, estimations and approximations of their values cannot be avoided in such cases. Following that, knowledge on the quantitative contribution of each of these parameters is necessary in order to minimize the resulting error.

All these issues require additional preliminary work to be done before (or at least during) the software development phase. Two activities are especially needed:

- searching the relevant literature, mostly congress papers, for at least some data about the values of certain parameters and relations between them, and
- contacting manufacturers of building materials and collecting attests of various elements, to be imported in the database of the software.

III. Adaptation of Software to National Legislation

Each country presents its own specific requirements regarding the sound insulation in buildings. They can be a consequence of historical heritage, local conditions and habits, legislation system etc. International standards (ISO) and European norms (EN) only define sound insulation descriptors, measurement procedures and certain general interpretations. All other details, significant for sound insulation and noise protection in buildings, are to be defined by national regulations.

There are four important “national” domains in noise protection regulative which influence national customization of software for calculation of sound insulation.

1. The first domain is the choice of sound insulation descriptors to be used for defining legal requirements. It has been shown that there is still no consensus in Europe regarding the sound insulation descriptors [8]. Standards propose several ways to quantify sound insulation with a single number. For example, for airborne sound insulation quantities R'_w, $R'_w + C$, $R'_w + C_{50\text{-}3150}$, $D_{nT,w}$, $D_{nT,w} + C$, $D_{nT,w} + C_{100\text{-}5000}$, $D_{nT,w} + C_{tr}$, $D_{n,w}$ can be used. Similar case is with impact sound insulation. Different countries use different of these parameters to define their noise protection criteria in buildings.

2. Another domain is a set of locations inside the buildings for which minimum requirements for sound insulation are defined. Each country's legislation comprises a document which explicitly sets up classification of buildings according to the noise protection achieved and a list of locations inside them, for which minimum values of sound insulation are proposed. Some European countries also propose categorization of buildings according to acoustic comfort, with several different values of sound insulation descriptors defined, depending on the building category.

3. Calculation of airborne sound insulation against outdoor sound is often based on assessed value of sound level outside the building and maximum allowed value inside. The differences between countries in that directly determine the calculation of sound insulation of façades. Estimated values of outdoor noise level are often determined by acoustic zones, although in many countries acoustical zoning has not been carried out yet. Certain differences also exist between maximum allowed values of noise level in residential rooms.

4. Various building constructions are not equally presented in all European regions and countries. Wooden constructions dominate the market in some countries, while in other, mostly due to seismic protection, reinforced concrete is mandatory. This brings locally dominating building constructions into focus during the collection of data for the software database and the assessment of unavailable physical quantities values.

However, calculations of sound insulation according to EN 12354 are not mandatory in all European countries. The transition is still going on, at different pace between the countries. Most of the countries have incorporated the standards in their legislative, but have not made their implementation mandatory.

The differences described here leave the possibility to design software for calculation of sound insulation in buildings according to local conditions in countries. Although the calculation algorithms are based on the norms EN 12354, the choice of single-number parameters for expressing the calculation results and allowed values of sound insulation and noise levels is in accordance with local requirements. If the software is also provided with the functionality to generate the final project report, in locally prescribed form, it represents comprehensive nationally customized calculation tool.

IV. Customization of Software for Slovenia

One example of nationally customized software for calculation of sound insulation in buildings according to EN 12354 is developed in Laboratory of Acoustics at the School of Electrical Engineering in Belgrade, for Slovenian market. It includes specific local Slovenian requirements from each of the four domains listed in the previous section.

All specific details regarding the sound insulation requirements in Slovenia are given in the document published under the name "Tehnična smernica TSG-1-005:2012" [9]. This document proposes the following:

- mandatory implementation of EN 12354 norms,
- criteria for minimum acoustic conditions in various building types,
- mandatory field measurements of sound insulation after the building has been built,
- mandatory final project report as the official document with compared values of required, calculated and measured values of sound insulation.

Based on that, the software is made, to be distributed to the building designers in Slovenia with the following functionalities incorporated.

After inserting general information about the building – name and location of the building, acoustic zone, investor, project designer etc., the window in Fig. 2 is opened. In this window the user can select all building and room types, that is, calculation categories according to [9], to be included in the project.

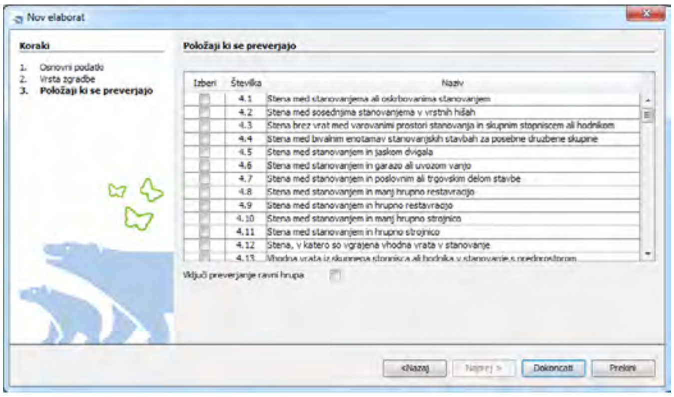

Fig. 2. Selection of the calculation categories

After initializing the project, each calculation is represented in the window shown in Fig. 3. All calculations are listed in the tree formation on the left-hand side of the window. Middle part of the window contains the geometry of the specific scenario of two adjacent rooms. The right-hand side part of the window provides a user with options for modifying the geometry, selecting basic materials of the elements, additional layers, small elements and other elements from the database, defining junction types and other details needed for the calculations according to EN 12354.

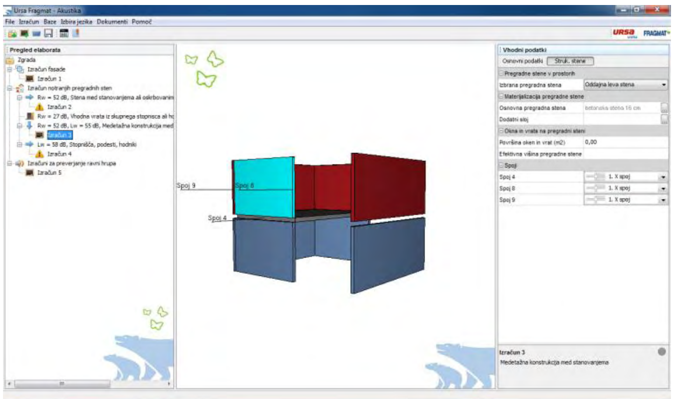

Fig. 3. Basic calculation window

The final results in terms of the values of single-number descriptors are listed in the window presented in Fig. 4. It also makes a comparison between the calculated values and the values required by "Tehnična smernica TSG-1-005:2012" [9] and notifies the user.

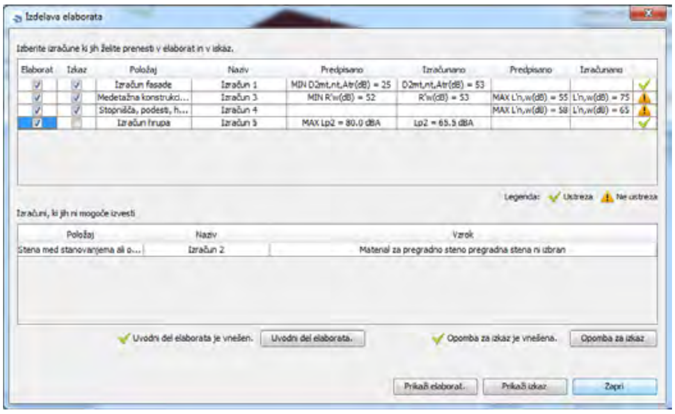

Fig. 4. Selection of calculation results to be included in the final project report

The selected calculation results are then put in two forms of project reports. Firstly, all calculation results in 1/3 octave frequency bands are given separately. Example of the report page with the results is shown in Fig. 5. In addition, all results are summarized in the form of a single table containing the values of single-number descriptors. Example of such table is shown in Fig. 6. It can be used afterwards for comparison between calculated and real values from field measurements.

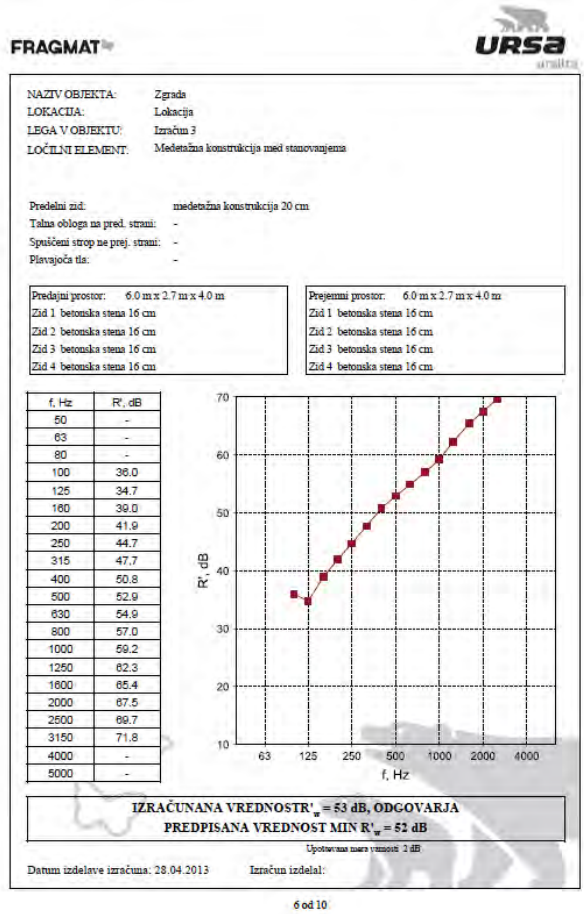

Fig. 5. Example of a project report page with the results of a single calculation

Zaščita pred hrupom v stavbi
Zvočna izolacija notranjih ločilnih elementov

				Načrtovani ukrepi	Izvedeni ukrepi	
Ločilni element ali prostor		Projektne vrednosti		Izračunane vrednosti	Izmerjene vrednosti	
Oznaka/ pozicija		Oznaka veličine (enota)				Ustreza (da/ne)
NOTRANJI POKONČNI LOČILNI ELEMENTI (stene, stene z vrati ipd.)						
1	Stopnišča, podesti, hodniki	L'_w(dB)	max 58	65		
2	Vhodna vrata iz skupnega stopnisca ali hodnika v stanovanje s predprostorom	R'_w(dB)	min 27	-		
NOTRANJI VODORAVNI LOČILNI ELEMENTI (medetažne konstrukcije, podesti, stopnice)						
1	Medetažna konstrukcija med stanovanjema	R'_w(dB)	min 52	53		
		$L'_{n,w}$(dB)	max 55	75		

Fig. 6. Example of a table with calculated values of single-number descriptors, as a part of a project report

V. Conclusion

This paper presented a software package for calculation of sound insulation in buildings. It is based on the algorithms described in European norms EN 12354. Another requirement was to make the software adapted to the national legislation in Slovenia. This is achieved through additional functionalities embedded in the software.

Creating such nationally customized software revealed another practical aspect of this approach. Incorporated elements of national legislative made the software a universal tool for creating a project of sound insulation in building. This opened a possibility for designers lacking knowledge in the field of building acoustics to deal with sound insulation issues more easily, at least in the case of simple buildings.

Acknowledgement

The work presented in this paper is a part of the activities on project TR 36026 of Serbian Ministry of Education, Science and Technological Development. The authors also wish to thank URSA Slovenija d.o.o. and Fragmat d.o.o. for generous support during the work on the software.

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