Challenges in entire building sound insulation calculation

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Abstract

Standard ISO 12354 series specify calculation models in building acoustics. The target is the estimation of the acoustic performance of buildings from the performance of its elements considering direct and indirect flanking transmission regarding two adjacent rooms. However, all practical projects involve more than two rooms, up to the ultimate extent, the entire building. These projects manage massive data: rooms and building geometry, junctions between rooms, construction materials, compliance, quality limits, and budget. In the era of digitalisation, the scientific and practitioner community requires tools featuring a broader and simpler scope than the original and restricted to two rooms calculation. Thus, an approach that might explore all data at once and provide building analytics concerning sound insulation in a more efficient way is very convenient. This paper discusses the beneficial strategies of the entire building approach with respect to the Standard, specially dealing with its limitations when modelling the geometric and constructive reality.

Keywords: building acoustics, iso 12354

1 Introduction

The estimation of sound insulation between rooms is a constant in most of the consultancy projects in Building Acoustics. The capability of predicting the acoustic performance of a building and its elements is crucial when designing dwellings.

To date, ISO 12354 standards are the preferred methods due to their balanced engineering frameworks. ISO 12354 covers the main issues for prediction in general Building Acoustics, notably: airborne sound insulation between rooms, ISO 12354-1:2017; impact sound insulation between rooms, ISO 12354-2:2017; airborne sound insulation against outdoor noise, ISO 12354-3:2017; transmission of indoor sound to the outside, ISO 12354-4:2017; and sound absorption in enclosed spaces, EN 12354-6:2009. The first four standards of the series were technically updated, and the new standards were launched in 2017 [1],[2],[3],[4]. Some relevant changes in the standards involved remarkably calculations concerning lightweight materials [5],[6]. It is now a good opportunity to make a review on how to be more efficient when applying these standards as they have just been updated.

The target of ISO 12354 remains clear: the estimation of *in situ* acoustic performance considering direct and flanking transmission between two adjacent rooms. However, all practical projects involve more than those two rooms. These projects manage massive data from the building features: every single room and building shape and volumes, different types of junctions between rooms, construction materials for all the walls, compliance with local regulations or ISO standards, quality limits to higher standards as acoustic classification scheme for buildings, and budget for the current project or needed enhancements. In the era of digitalisation, the scientific and practitioner community requires tools featuring a broader and simpler scope than the original and restricted to two rooms calculation. Society, partners and project stakeholders want more comprehensive data, which is available almost immediately in a shareable format.

Thus, an approach that might explore all data at once and provide building analytics concerning sound insulation in a more efficient way is very convenient, and it is almost a must these days. This paper discusses the beneficial strategies of the entire building approach with respect to the Standard two-rooms estimation, especially dealing with its limitations when modelling the geometric and constructive reality. Ten years ago, Sound of Numbers SL developed SONarchitect, the very first tool for calculating sound insulation according to ISO 12354 (formerly EN 12354) in entire buildings. This experience is being included in this publication.

2 The entire building digitalisation approach

2.1 Problems statement

ISO 12354 is based on SEA (Statistic Energy Analysis) method. In short: two systems (the rooms) are sharing some energy (sound) through a connection (separating wall and flanking elements). The very first challenge is fitting the reality in such a simple concept. In order to travel from the reality to the simplicity, there must be a lot of approximations. The reality is not two rectangular box-shaped rooms anymore.

Why trying to choose the worst cases in a building and calculating only those when it is possible to calculate the entire building with the same effort? In [7] a project of medium size building for a hospital with 1256 rooms leads to 5209 and 6035 calculations of two-rooms airborne sound insulation and impact sound insulation, respectively. To find just a few significant two-rooms cases of the entire building becomes overwhelming due to the vast range of variability of shapes, sizes, joints and materials. A very experienced consultancy team would be required to verify all the relevant features of each possible two-rooms combination. Once they were found, the expense on time would be unaffordable. Thus, the tools employed in the prediction of the acoustic performance of buildings should consider all their rooms in order to provide comprehensive and unbiased information. Furthermore, those tools should simplify and improve the used resources from a heuristic approach.

2.2 Unrestricted geometry in 3D

Practitioners and researchers who deal with large projects in Building Acoustics, face complex geometry frequently. Some other tools based on the same ISO standards approximate complex geometry with two rectangular box-shaped rooms, and only one separating element between the two adjacent rooms. The ISO Standard calculation could be followed by estimating equivalent areas, mainly. However, these assumptions result in errors in the *in situ* structural reverberation time ($T_{s,\ in\ situ}$), and the *in situ* equivalent absorption length; also, some deviations might rise about the flanking walls and the changes in the reduction indexes in junctions.

For example: Figure 1 presents a case where these approximations become a challenge: between those two rooms blue and green there is one common wall and five edges. Should we take on account the edge that is not connected to the separating wall? Further research in this kind of special cases must be conducted.

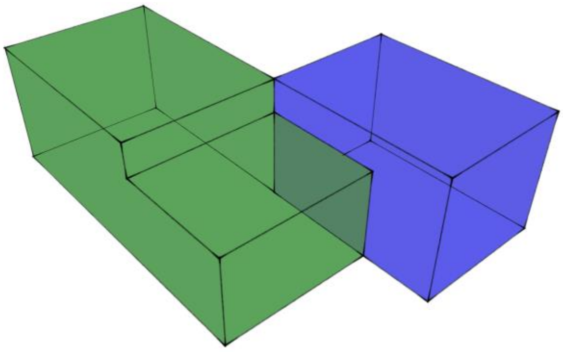

Figure 1 - Special case for transmission paths analysis

SONarchitect offers no restrictions for complex geometries since it computes the sound insulation through all the separating elements involved, considering all the flanking paths. Every transmission path can be inspected, and the dominant ones are underlined.

A 3D point of view helps verifying building drawings. This option improves the adequate insertion of general plans in a SONarchitect project with a realistic point of view for the designers. A convenient drawing toolbox is available to simplify this process. The result is an "acoustic" plan that satisfies the requirements of the calculation models and avoids useless and no significant data for sound insulation. Layers for lighting, decoration, symbols or outside building elements should be deleted.

This simplified geometry information can be inserted by simply drawing the building plan by plan, using a template (can be a DXF file or a soon-to-be deployed BIM model) or even importing a CAD model, but no matter what, there must be a simplification of the geometry in order to achieve reliable results. In the following points we will investigate why.

2.3 Automatic detection of rooms and junctions

Large projects consist of a considerable number of rooms that lead to a much higher number of junctions. The features of the junctions depend on the walls, floors and ceilings where they fit. SONarchitect automatically detects all the rooms and junctions in the building and characterize them with the proper shape and combination of materials. Hence, once the project has the geometry and the material of the surfaces involved, junctions are specified without any further action by the user. Only the addition of resilient layers requires that the user provides that information junction by junction. Thus, the huge workload on defining every junction disappears using SONarchitect, as it is automatically done and reported in the results accordingly.

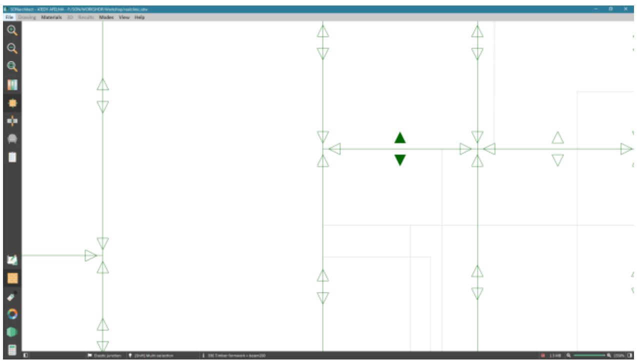

Figure 2 - Drawing representing regular junctions, white arrows; and resilient junctions, solid arrows

This automatic workflow also prevents from the wrong estimation of $T_{s,\,in\,situ}$, as described in Annex C of ISO 12354-1 [1]. Additional corrections are needed when the area considered is part of a larger structural element, and the junctions are formed by lightweight material elements. As shown in Figure 3, in SONarchitect v3.1, these considerations can be customized. As a future line, SONarchitect will also allow the user to enter new junction formulae and models.

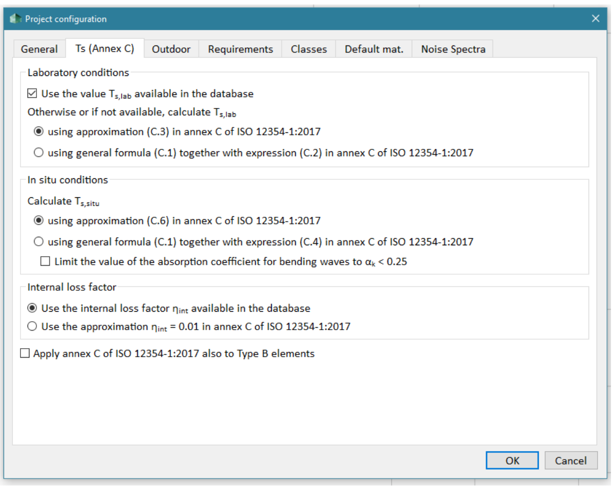

Figure 3 - Annex C approximation

2.4 Geometry dysfunction search

SONarchitect can calculate the sound transmission through thousands of encounters in seconds. However, projects made of too small walls, curved areas, or tilted roofs may cause problems in the computation of insulation ratings.

Firstly, for applying ISO 12354 standard, it is needed to simplify curves and arcs and turn them into equivalent surfaces. SONarchitect drawing toolbox suggests the user to draw walls larger than 20 cm. Wall, floor and ceiling encounters are also forced to coincide; otherwise, the ISO 12354 model could not be applied.

$$R_{i,j} = \frac{R_{i,situ}}{2} + \frac{R_{j,situ}}{2} + \overline{D_{v,ij,situ}} + 10log\left(\frac{S_s}{\sqrt{S_i S_j}}\right)\ [dB] \qquad (1)$$

The calculation of *R'* depends on the wall surface [1]. Hence, the calculation avoids the error due to too small enclosures. This kind of walls causes an increase in the computation time and remarkable deviations in sound insulation estimation that does not match reality. Generally, *R'* is overestimated, as it can be inferred from equation (1), which defines the calculation of each flanking transmission path. Nevertheless, in case the user includes a small wall accidentally, the software would warn in the results reports. Furthermore, the user needs to, somehow, simplify the geometry in order to avoid these geometry restrictions. For example, in Figure 4 it is shown how a small wall in the façade can be approximated into a larger wall, thus, the user gets rid of a potential small wall that might overestimate the calculations.

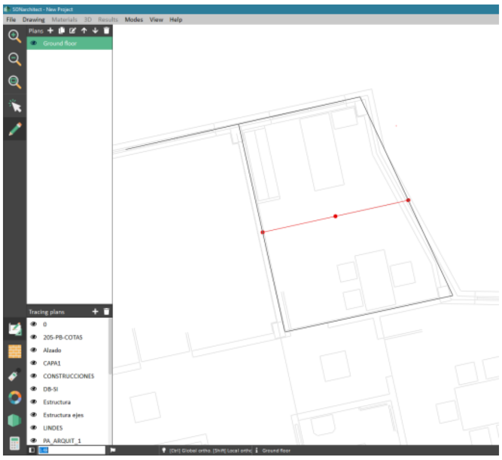

Figure 4 - Geometry approximation

2.5 Data analytics on sound insulation

Currently, data is becoming a valuable resource in all disciplines. Sound insulation is not an exception, and comprehensive information data is more useful than having just some disadvantageous cases. SONarchitect can compute all rooms in building despite the number. Each separating element is assessed along with all the flanking paths. The contribution of the different transmission is available and ranked on a colour scale, which helps inspect paths quickly.
Facing a project with thousands of rooms can be overwhelming when trying to analyse it. Hence, this colour tool is also employed to find rooms which do not comply with requirements easily. SONarchitect is customizable for any specific local building regulation or an *ad hoc* specification. This feature, combined with the compelling 3D view, presents a convenient tool to focus quickly on the problems that may appear in the project. Figure 5 illustrates how helpful this would be when dealing with up to 115 transmission paths.

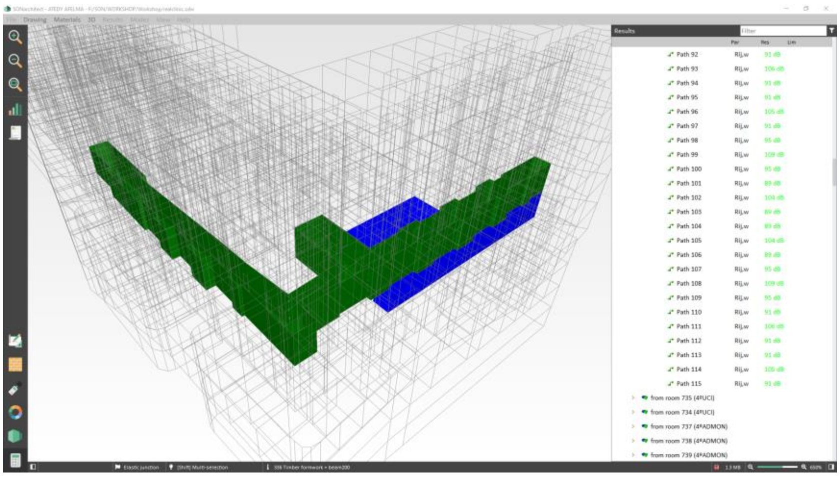

Figure 5 - 3D view of a compliant pair of rooms and the list of transmission paths (115)

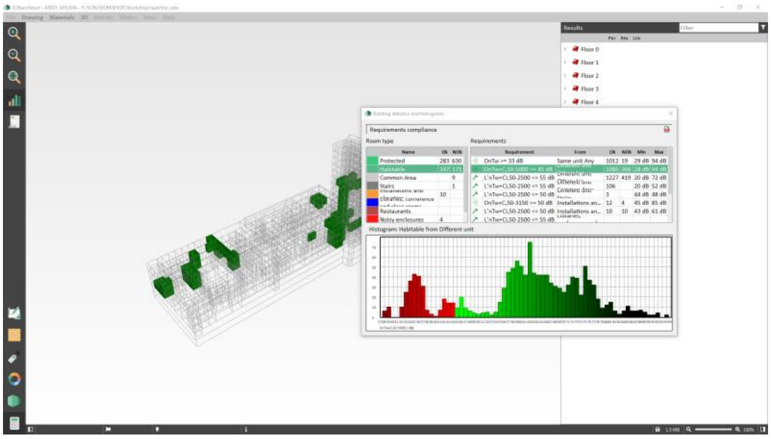

Figure 6 - Statistics computing

Nevertheless, a solution based on verifying the colours of all the rooms would remain repetitive. A smarter way of analysing aggregated results from the calculation is the use of Statistics. Hence, SONarchitect embeds a tool that presents histograms containing all calculations. Some of the conclusions of the project might be directly drawn from this software feature. Some examples are compliance of the rooms for airborne sound insulation or the number of protected room non-compliant with impact sound insulation. Once the Statistics menu is set and computed, the 3D view locates the rooms that fulfil the requirements. Thus, consultants may focus on the rooms that need some design reviews. Figure 6 shows a statistics output example, where the compliant rooms for a particular use are marked in green in the 3D model and the histograms present the behaviour of all the rooms regarding the requirement.
Finally, massive data can be reported using customizable templates. This tool help communicate the conclusions of the projects smartly and even account for new or updated budgets.

2.6 Computational and graphical efficiency

The technology used by SONarchitect features a graphical algorithm that computes ISO 12354 models fast. The software is not only capable of detect rooms and junction, and even micro-walls but also calculates in a short time. The example of the hospital previously presented would take just some seconds to be presented both graphically in the 3D views, as all the ratings for rooms and flanking paths, including their corresponding alerts on compliance.

2.7 Integration with other tools

In a global world, tools are expected to work efficiently with other tools. Their combination would result in expert suites that can face projects with broader scopes. SONarchitect is a powerful software that manages the calculation needed for modelling buildings according to ISO 12354 standards. However, a Building Acoustics project may include other points of view.
Hence, practitioners usually need sound insulation solution that might not exist in their materials database, despite that literature and SONarchitect databases provide a wide range of alternatives. The quick pace of technology, the *in-situ* constraints, or the experiments of new types of materials and their combinations seem to be the reason to update databases continuously. In the meantime, general laboratory models for sound insulation as Insul [8] could help.
Furthermore, Sound of Numbers is evolving SONarchitect in the path of integration with engineering and architecture tools like Revit, Archicad and Simplebim among others.

3 Conclusion

In Building Acoustics, the estimation of the acoustic performance plays a central role. The ISO 12354 Standards provide a predictive method that helps practitioners analyse about sound insulation before designs are implemented. Hence, the projects can be evaluated and improved, when necessary. A heuristic approach seeks for the more significant two-rooms cases in the building, for instances the worst rooms concerning the compliance on a specific Building Code.
However, practical projects deal with buildings which consist of many rooms, and the previous approach could not be efficient from an analytical point of view. Additionally, the traditional approach that simplifies the shape of rooms to rectangular box-shaped ones is not suitable in real cases and could lead to some calculation errors due to surfaces approximations.
SONarchitect is a consultancy tool that fulfils the requirements of sound insulation projects in the era of digitalisation. This software deals with the massive data included in an entire building, ranging from geometry to performance ratings. An efficient computation engine calculates in short delays and provides graphical and intuitive means for an adequate and comprehensive analysis of the projects. All the rooms are considered, and the heuristic approaches are enhanced. Thus, safer and almost error-free results can be presented to customers, and more time is available for other tasks in a daily routine.
SONarchitect is trying to seamlessly integrate the sound insulation assessment into the practitioner workflow with connections to DXF and BIM models, however, it is proved that a human being is needed in order to simplify the reality and create an acoustic model of the building.

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