DISCUSSED REVIEW ON ISO 12354-1 AND ISO 10848-1 STANDARDS

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ABSTRACT

Standard ISO 12354 series specify calculation models in building acoustics. The target is the estimation of acoustic performance of buildings from the performance of its elements considering direct and indirect flanking transmission. Measured data are preferred as input variable in calculation models. ISO 10848 series provide measurement methods to comply with ISO 12354 requirements. Both standards were technically revised and some new standards were launched on 2017. This article reviews the more relevant differences regarding former standards and discuss their application in real engineering environments concerning airborne sound insulation between rooms.

RESUMEN

El conjunto de normas ISO 12354 especifica modelos de cálculo en acústica de la edificación. el objetivo es la estimación de las características acústicas de los edificios a partir de las de sus elementos teniendo en cuenta la trasmisión directa y la indirecta por flancos. Los datos obtenidos de mediciones son preferibles como datos de entrada en los modelos. El conjunto de normas ISO 10848 ofrece métodos de medida para satisfacer los requerimientos de la ISO 12354. Ambas normas fueron revisadas técnicamente y nuevas versiones de las mismas aparecieron en 2017. Esta comunicación analiza los cambios más relevantes respecto a las normas antiguas y discute su aplicación en entornos reales de ingeniería en lo que respecta al aislamiento a ruido aéreo entre dos recintos adyacentes.

INTRODUCTION

The prediction of acoustic performance of buildings and/or its elements is an important acoustic engineering task. There are some different approaches to perform those acoustic predictions as SEA, FEM or BEM models. Nevertheless, along the years, ISO 12354 series approach remains as a balanced engineering method trading-off accuracy, simplicity and resources effectiveness. The current standards work properly with homogeneous and heavy building materials and indicates limitations on lightweight materials.

Sustainable building trends are employing more and more those lightweight materials which involves changes in prediction and flanking measurement frameworks. Research performed during the last years [1,2,3,4] led to next generation of standards considering remarkable facts as: larger damping and no even velocity distribution in most lightweight elements and to distinguish between resonant and non-resonant transmission.

Calculation models in building acoustics are specified by ISO 12354 series. Different parts of the series cover the most general approaches to: airborne sound insulation between rooms, part 1; impact sound insulation between rooms, part 2; airborne sound insulation against outdoor noise, part 3; transmission of indoor sound to the outside, part 4; sound level due to the service equipment, part 5; and sound absorption in enclosed spaces, part 6. The first four parts were technically revised, and some new standards were launched in 2017. The most relevant differences are included in ISO 12354-1 [5,6] regarding the previous year 2000 version [7].

ISO 10848 series specify measurement methods to characterize the flanking transmission in buildings [8,9]. All parts focus on measurement of flanking transmission of airborne and impact sound between adjoining rooms but considering different building junction environments. These standards are linked to model calculation model ones since they provide measurement methods to collect input data for ISO 12354. The ISO 10848 series were also extended and revised in 2017.

The goal of this paper is to provide a discussed review on the practical application of most relevant changes in both ISO series, regarding predictive models. This work is focused on airborne sound insulation between rooms since it is the area where more remarkable differences are found from old standards.

ISO 12354-1

New ISO 12354-1s:2017 bring some changes from the 2000 standard. Most of literal, layout or location of contents difference between documents have been compared recently [6]. In this section the more relevant changes involved in calculation facts are reviewed and discussed from an engineering development point of view.

Type A and Type B elements

The definition of these two different building elements is likely to be the main difference between the analysed standard versions. Some of the more important changes are founded in the type of element:

- *Type A* element: whose structural reverberation time is determined by the connected elements and the decrease in vibration level across the element is less than 6dB (up to at least 1kHz). Examples: concrete, solid wood, glass, bricks or metal.
- *Type B* element: any one not suitable as *Type A* element. Examples: plasterboard, timber or metal frames.

Thus, *Type A* elements match those mainly consider in the previous standard. Moreover, currently an element can be defined as pure *Type A* or B element, or a mixture of both depending on the frequency range.

Normalized direction-averaged vibration level difference, $\overline{D_{v,ij,n}}$ is a new defined quantity linked to lightweight elements, in general *Type B*. Normalization is set on junction length and measurement areas on both side elements since these elements, often highly-damped at junction, present non-uniform vibration fields. Therefore, K_{ij} use is not suitable and $\overline{D_{v,ij,n}}$ is the new estimator employed to characterize lightweight elements, as it can be checked in vibration transmission over junction next section. This alternative junction characterization is spread over the 2017 standard. For instance, when transferring input data to in situ values, *Type A* and *Type B* approaches are also different. *Type A* elements are treated as in the former standard. *Type B* (or *Type A* + *Type B* mixed elements) elements follow the same old correction for lightweight elements and $R = R_{situ}$. However, $\overline{D_{v,ij,n}}$ now needs to be transformed to in situ values in a similar way to other estimators in standards.

Vibration transmission over junction

Annex E in the new standard is very similar to the previous one, but now only heavy structures such as masonry concrete walls and floor are considered. A new theoretical formula based on coupling loss factor between direct and flanking elements is available. Wall junction with flexible interlayer is different form old standard and K_{ij} definition; only K_{23} and K_{24} remain the same. To solve the rest K_{ij} more data is required: dynamic stiffness and load on the resilient layer, Young´s modules and the thickness of the interlayer. These new possibilities provide a more specific model when it comes to the flexible interlayer and it is not limited by only one example interlayer as in the old standard. Thus, predictions may consider different interlayers layouts and lead to better acoustic designs. On the other hand, more qualified input data is required to perform calculations: from manufacturers specifications (stiffness, thickness and Young´s modulus) and from detailed building process (load).

Moreover, very interesting K_{ij} data from simulation is presented. K_{ij} is assumed as frequency-independent in a general approach to simplify calculation procedure. However, in practice there are changes mainly in mid- and high-frequency ranges. Wave theory and FEM models were employed to suggest an alternative and more accurate formula when calculating theoretical K_{ij}. To include these new formulae in a calculation model will complicate them but will also provide more information in high uncertainty environments.

Annex F is a complete new piece on information concerning vibration transmission over junction in the case of lightweight buildings. The lightweight material which are considered are: massive cross-laminated timber (CLT) element and steel or wood frame lightweight building. A crucial fact in this section is to consider either the whole element or only the inner layer that faces the source and receiving room when dealing with double-leaf elements.

Empirical data for junction characterized by K_{ij} are provided for cross-laminated timber (CLT) building elements: T-Junction and Cross-junction. Empirical data for junction characterized by $\overline{D_{v,ij,n}}$ are provided for steel or timber frame lightweight building elements:

- Inner leaf transmission: T-junction between floor and façade, Cross-junction between a floor and a double frame separating wall and T-junction with continuous floor.
- Double elements as a whole: junction of lightweight coupled double leaf walls, which was included in Annex E in the former standard but characterized by K_{ij}.

Sound Reduction Index and resonant transmission

A new *Annex B* is performed in 2017. Even though it is an informative part of the standard, a relevant issue regarding the detailed model for structure-borne transmission is explained in detail.

Beforehand, preferred input data for the model were laboratory measurement of the elements, but now for each flanking transmission path, only resonant transmission index are preferred. Laboratory measurement are right above the coincidence/critical frequency, but a correction needs to be applied over the rest of the interest frequency range.

The procedure consists of deducing resonant transmission from laboratory measurements [1,4]. There is not standardized method to determine the required airborne and structural-borne radiation efficiency factors, but some correction based on building element type. Thus, double elements with cavity keep almost the same laboratory *R*. For single, homogenous or layered, wood or steel frame elements a correction of 8dB is applied below the critical frequency. This way, a more accurate and not underestimated *R* values are employed in models, remarkably concerning lightweight elements, whose coincidence frequency set around 2kHz-3kHz and the correction should apply then most of the interest frequency range. Practitioners must have this correction into account when collecting data from other theory models which only predict forced/non-resonant transmission in order to follow new standard recommendations.

Limitations

Differences in the new standard are included is the new *Annex J* which extends the old section of interpretation of composed and complicated elements. A collection of interpretation of complicated junction is also new in this section. Thus, the new standard proposes an interpretation in the case of some Cross-junction and T-junctions with more than 2 elements types, junction with small offset and junction with double wall. However, this task will have to be considered by design Engineers when performing predictive models and it has less to do with model calculation itself.

Uncertainty

New *Annex K* provides more information regarding accuracy of model. Both simplified and detailed model can benefit from the suggested uncertainty method once input data is available. This model is far from being a very robust one and it is declared to lack some proper knowledge in some parts. However, uncertainty is a useful tool to have an indication of accuracy and the application of safety margin to results. As it is stated in ISO 12354 standards, all types and variations of building constructions cannot be covered for the time being and the users of the calculation model are responsible to address inaccuracy on results and limit them regarding the quality of input data available. So, as it is usual in measurements, prediction model should provide an additional uncertainty framework along with model calculations and so, much more information.

Sound reduction index improvement of additional layers

Prediction of performance for interior linings below 200Hz one-third octave is changed and now a common formula describes those low frequency bands; results are around 2dB higher.

A new section for prediction of performance for exterior lining provides formulae for systems glued to a heavy basic wall, mineral wools and different foams with or without anchors or different glued areas.

Regarding single number rating predictions, the measured or estimated laboratory single number rating needs to be transferred into a field single number rating considering the performance of the basic element.

Sound insulation in the low frequency range

This new *Annex I* deals with the recent changes in airborne sound insulation carried out in accordance with ISO 16283-1. These measurements are linked to the calculation model through the input data. Since some input data comes for those engineering grade procedures, low frequency range issues must be considered on prediction uncertainty. Waterhouse correction is suggested to control results.

Structural reverberation time
The reverberation time of a structural element is evaluated only for *Type A* elements. An "in situ" total loss factor estimation formula is added and is preferred since it is based on theory with empirical adjustment from mounted building elements.

ISO 10848-1
This standard series specifies methods to characterize the flanking transmission of one or several building components. Part 1 is the framework and general document that serves as an example to show main changes in the revised version; other parts specify the application for different types of junctions. Procedures and quantities to be measured included can be used to compare performance of product, but it is remarkable their use as characterizing quantities for input data in predictive models. Nevertheless, the 2017 version includes an extension to building service equipment and the introduction of new concept of transmission function measurement with a calibrated structure-borne sound source; but this issue is out of the scope of this article. Then, discussion on main differences in new 2017standard [8] from the former version [9], regarding ISO 12354-1:2017 follows.

Extension to field measurements
This is one of the most appealing changes from the former standard from practitioner's point of view. Building environment is very complex and is impossible to characterize all types and variations of junctions. Laboratory requirements were described in the previous standard, but very often building mock-ups are not suitable in general engineering requirements because of time and budget restrictions. However, the standard only considers using laboratory procedures and requirements as a guide for field measurements; although the standard admits it will be possible not to comply with them very often. For instance, regarding practical consideration of influences from other parts of the building construction in a field environment, it is stated that transmission through junction other than the one under test should not have any effect on K_{ij}. Only laboratory recommendations appear, and they are not suitable for field situations: using heavier construction, inserting vibration breaks, install the flanking element without connection to other elements; shielding seems to be a non-suitable option either.

As a specific requirement for sound pressure level measurements, room volumes must be over 25m^3. Test facility and elements requirements are the same as in the former standard but referenced to updated laboratory measurements of sound insulation of building elements. These references can differ slightly from field measurements, as ISO 16283 which are supposed to be more suitable in field.

For heavy elements coupled to heavy ones, the evaluation of decays when determining structural reverberation time is allowed with a 5 dB to 10 dB range for field measurements; instead of the general 20 dB to 30 dB range.

Beforehand, K_{ij} could be measured with airborne or structural-borne excitation and explanation were presented regarding consequences about resonant and non-resonant transmission. Since only resonant transmission seems to be useful according to ISO 12354-1 in flanking paths, only structure-borne transmission is allowed in the revised version of the standard. In field application, structure-borne excitation increases testing inconvenience. Furthermore, when it is also required 10 dB difference between signal and vibration background noise and correction value should not exceed 1.3 dB in each one-third octave band.

Type A and Type B elements
As in ISO 12354-1, classification of building elements is one of the main differences between versions. Previously, there were comments on general lightweight elements (*Type B*), but now every relevant section is different for different type materials. Thus, issues with terms "heavy" and "light" want to be avoided.

Type A and *Type B* definitions are the same already included in this article. Sections where *Type A* and *Type B* elements differ in the standard are the following ones. Quantities to characterize flanking transmission, measurement methods applied, procedure for vibration measurements, measurement of the structural reverberation time, criterion to asses flanking transmission for junction, verification for flanking element that is structurally independent of a separating element and expression of results. In general, *Type A* contains the same as the former standard since it was focus on heavy elements, while *Type B* contains comments aside from the previous standard and a certain extension based on the new estimator $\overline{D_{v,ij,n}}$.

The target of 10848 series ever is to characterize vibration over junctions. The different type of element determines which estimator characterize junctions: K_{ij} (*Type A* elements and combinations of *Type A* and *Type B* elements junctions); $\overline{D_{v,ij,n}}$ (*Type B* elements junctions).

Measurement methods
There are many changes in the selection table of the measurement method according to the types of junction elements from the previous one based on: different types of elements, introduction of a new estimator and update of specific standards of the 10848 series to apply.

Another important difference is, that currently an assessment method for the decrease in vibration level with distance is available. Beforehand, just a short warning and a not very detailed section was found. *Annex A* (normative) provides a detailed procedure that helps practitioners to check whether vibration field are reverberant or not and so, the validity of measurements as input data in a SEA model.

Much more information is also found regarding accelerometers in the new standards. Concerns are: sensor fixing technique, reasonable for laboratory measurement but to improve for field application sometimes [10]; and minimization of effects of sensor mass loading¸ *Table 1* shows maximum sensor mass. Adding the latter to background vibration signals [11], accelerometer selection becomes not that trivial depending on the building element to be tested.

Expression of results
Annex A in the former standard provided the way to present results after all procedures were applied. Nowadays, a section extends the content to $\overline{D_{v,ij,n}}$. Furthermore, a proposal on splitting frequency range is provided for cases when estimators vary considerably and for employing as input data in detailed ISO 12354 models.

CONCLUSIONS
This article shows how ISO 12354-1 has become a more detailed and complete standard in the new 2017 version. Although it did not become a general application framework, research efforts led to extended knowledge that could be transferred to practitioners and help them work out in circumstances which were not included (or slightly commented) in the previous standard version. Remarkable changes in model calculations must be considered when predicting airborne sound insulation between rooms. Lightweight building elements and its junctions show most of important differences and new approaches. Including an uncertainty framework is useful in controlling

design safety margin. Therefore, all calculation models referenced to former standard must be updated and upgraded to comply with new standard ISO 12354-1:2017 requirements.

Regarding ISO 10848-1, the article show synchronisation with crucial new issues in ISO 12354-1:2017 as: different type of building elements and the focus on resonant transmission. In fact, one of the remarkable targets of ISO 10848 is to provide valuable data to predictive models. The new version is a more detailed one in procedures. However, it misses an affordable approach for field measurements that hopefully can be developed in next revisions.

f(Hz)	Steel	Plasterboard	Concrete	Glass	Timber	Brick
100	0.22	0.35	177.17	2.29	0.44	514.77
125	0.18	0.28	141.74	1.83	0.35	411.81
160	0.14	0.22	110.73	1.43	0.28	321.73
200	0.11	0.17	88.59	1.14	0.22	257.38
250	0.09	0.14	70.87	0.92	0.18	205.91
315	0.07	0.11	56.24	0.73	0.14	163.42
400	0.06	0.09	44.29	0.57	0.11	128.69
500	0.04	0.07	35.43	0.46	0.09	102.95
630	0.04	0.06	28.12	0.36	0.07	81.71
800	0.03	0.04	22.15	0.29	0.06	64.35
1000	0.02	0.03	17.72	0.23	0.04	51.48
1250	0.02	0.03	14.17	0.18	0.04	41.18
1600	0.01	0.02	11.07	0.14	0.03	32.17
2000	0.01	0.02	8.86	0.11	0.02	25.74
2500	0.01	0.01	7.09	0.09	0.02	20.59
3150	0.01	0.01	5.62	0.07	0.01	16.34
4000	0.01	0.01	4.43	0.06	0.01	12.87
5000	0.00	0.01	3.54	0.05	0.01	10.30

Table 1. Maximum accelerometer mass in Kg according to material [12] and ISO 10848-1 [8] standard, in one-third octave bands.

REFERENCES

[1] COST Action FP0702 Net-Acoustics for timber based lightweight building and elements, 2012
[2] Schoenwald, S. Comparison of proposed methods to include lightweight framed structures in EN12354 prediction model, Euronoise 2012, Prage (Czech Republic).
[3] Gerretsen, E. Extending EN 12354 sound insulation modelling to composed, lightweight building systems, Internoise 2015, San Francisco (USA).
[4] Villot, M, & Guigou-Carter, C. Measurement methods adapted to wood frame lightweight constructions. Building Acoustics. 2006, 13 pp. 189-198.

[5] ISO 12354-1:2017 Building acoustics, Estimation of acoustic performance of buildings from the performance of elements, Part 1: Airborne sound insulation between rooms, 2017.

[6] Rosao, V., Silva, J, Comparison of EN 12354-1 to -4 of 2000 with EN 12354-1 to -4 of 2017, Euronoise 2018, Crete, 1161-1164.

[7] EN 12354-1:2000 Building Acoustics, Estimation of acoustic performance of buildings from the performance of elements, Part 1: Airborne sound insulation between rooms, 2000.

[8] ISO 10848-1:2017 Acoustics--Laboratory and field measurements of flanking transmission for airborne and impact sound between adjoining rooms--Part 1: Frame document.

[9] ISO 10848-1:2006 Acoustics--Laboratory measurements of flanking transmission for airborne, impact and building service equipment sound between adjoining rooms--Part 1: Frame document.

[10] San Millán-Castillo, Roberto; Domingo Bets, Salvador; Pavón García, Ignacio. "Evolución de una sonda de vibraciones para simplificar la evaluación de transmisión sonora por flancos entre recintos". 46º Spanish Congress on Acoustics, Tecniacústica Valencia; 2015.

[11] San Millán-Castillo, Roberto; Morgado Reyes, Eduardo; Goya Esteban, Rebeca; Figuera Pozuelo, Carlos. "Instrumentation inherent noise considerations in building acoustics vibration velocity" European Symposium on sustainable building acoustics, La Coruña (Spain); 2017.

[12] Hopkins, C. Sound insulation. Elsevier/Butterworth-Heinemann; 2007.