Prediction models for building performance - European need and world wide use

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The development of the unified European market made it necessary to create CE-marking to indicate a certain performance of products. For building products the performance had to enable the fulfillment of essential requirements by buildings, constructed with those products. This made it essential for acoustic requirements to standardize predictions models: the link between acoustic product performance and building performance. In the mean time all six parts of that standard (EN 12354) have been published and are used. Some parts have also been published as ISO standard (ISO 15712) indicating the wider interest in the subject.
To be of use in Europe and elsewhere it is important that all types of building structures are covered and indeed work is going on to extend the models to lighter building elements, even more common outside Europe than within. Furthermore, a very important aspect of prediction models is the input data, hence an increased need of standards to determine product performance in an appropriate way. This is even more an item of world wide interest. The existing standards, the current developments for improvement and the identified need for product standards are addressed in this paper.

1 Introduction

Since the sixties standards have been developed within ISO in the field of Building Acoustics. The first standard, recommendation R 140 [1], treated field and laboratory measurements of airborne and impact sound of buildings and buildings elements, soon followed by a standard to express these measurement results in a single number [2] and a standard on sound absorption of elements and objects [3]. It seemed logical to apply the same type of measurements in the laboratory as in the field, though with some additional laboratory conditions. In Germany those conditions were chosen to simulate actual (German) field conditions in order to keep the link with building practice. But in other countries the focus was more and more on reliable determination of the product performance; comparing products became more important than to link the performance to field situations. The link between field performance and the element performance as determined by laboratory measurements only got real international attention at the end of the last century within the European standardization organization CEN. This not only meant the development of that link but at the same time made clear what type of product performance is really needed to estimate field performance of buildings. It also shifted a bit the purpose of laboratory measurements on elements from mainly comparing product performance in a fair way towards gathering input data in a relevant way for estimations of field performance of buildings.

2 Acoustic building performance

The required acoustic performance of buildings concerns varies aspects: airborne and impact sound insulation between rooms, airborne sound insulation against outdoor noise, sound radiation from inside to outside, sound levels due to service equipment and reverberant sound in enclosed spaces. Though not all these aspects are regulated in every country, by legal requirements, standards or general guidelines, most countries have at least requirements on some of these aspects. The policy within the European Union to create an open market required that the performance of products is established in a harmonized way as basis for CE-marking. For buildings elements this meant that the products must be fit to erect buildings that will fulfill some essential requirements, among which also protection against noise. So standards were needed to measure the performance of buildings, the performance of building elements and to establish the acoustic link between building and buildings elements. Though several ISO standards in this area were already available and in use, it was clear that varies standards were also missing. So activities were started within ISO or CEN to fill the gaps.

To establish the field performance of buildings several parts of the continuously renewed ISO 140 [4] are available; for airborne and impact sound insulation and façade sound insulation these were also adopted as European standards (EN-ISO 140). Missing was a method to measure the sound levels due to service equipment in buildings and activities were started leading finally to ISO 16032 [5]. Besides methods with an engineering precision there was a need for simplified survey methods. So also ISO 10052 was created with quick scan methods covering all aspects of ISO 140 and ISO 16032 [6].

The link between building performance and product performance for all relevant aspects could be based on research in the past, though for instance for equipment noise still a lot of open questions are to be solved. But prediction models are only practical on an engineering level if the appropriate input data are also available. So such prediction models specify the need for laboratory measurement methods to determine the acoustic performance of building elements and product. And often not only the type of data but also the condition for their determination. Thus the development of the EN 12354 series [7] has a clear influence on the existing product standards and on the desired products standards, while the field measurement methods serve as a fixed reference (predictions are a simulation of field measurement). In the next chapter this will be discussed in more detail.

Though the main interest and need for these prediction models had to do with European regulations, hence EN standards, the item of estimation performance is of world wide interest. In the mean time the first four parts of the series have been adopted as ISO standard also (ISO 15712).

The requirements on the performance of buildings are usually expressed in single numbers deduced from frequency band data. Although an ISO standard existed already a long time for this purpose [3], the practice was and is that various countries apply there own method to deduce single number ratings from the building performance that is measured or calculated in essentially the same way everywhere. Though the latest version of ISO 717 is an effort to reduce the variation in single number rating systems, as promoted by the European

Union, there still is a large variety. As long as predictions are performed in frequency bands, and octave bands will certainly be sufficient for this purpose, this is no problem since all variations in single number rating can be deduced from that result. But simplifying even further by performing calculations in single number ratings is at least frustrated by this large variation in single number ratings.

3 Need for product standards

3.1 Airborne and impact sound insulation

EN 12354-1 & 2 deal with the prediction of airborne and impact sound insulation between rooms. This could be based largely on earlier research, at least for more or less homogeneous structures [8]. The model uses the sound reduction index R of all involved building elements and the normalized impact sound pressure level L_n of floors as measured through ISO 140-3 and -6. The prediction model takes into account the structural reverberation time in the field, so it also restarted the discussion on taking this into account for heavier building elements in the laboratory, to facilitate predictions and to reduce the influence of the laboratory properties. But this discussion has not been finalized yet. While for floor coverings and floating floors a method to measure the improvements is available (ΔL, ISO 140-8), this was clearly missing for linings and suspended ceilings (.ΔR). Hence this work item was added resulting in a draft for ISO 140 part 17.

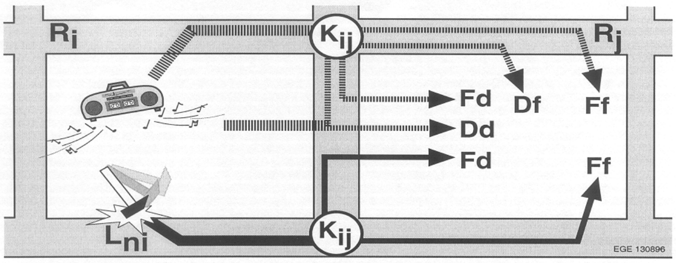

Fig.1 Illustration of airborne and impact sound transmission path with relevant quantities.

However, the main missing aspect was the performance of junctions between building elements. A new quantity was defined, vibration reduction index K_{ij}, and a measurement standard established ISO 10848 [9]. This standard than also covered the measurement of the total flanking transmission by element combinations, including suspended ceilings and raised floors, formally treated in some of the ISO 140 parts.

3.2 Façade insulation and radiation

In EN 12354-3 & 4: the sound transmission through facades is treated, either to protect against outdoor noise (mainly traffic noise) or to protect the outside against radiated noise (workplaces, disco's etc.). These parts are based mainly on well-known theories, the main discussions were on what to consider as element: for instance the window as a whole or the composing parts like the glass, the frame and the sealing. Finally both approaches were covered by the standard. For many building elements as applied in facades measurement methods are available for the element performance R, (ISO 140-3) and D_{ne} (ISO 140-10). Problems might arise with large elements for which no representative version can be tested in the laboratory test opening; there dedicated field measurements in selected situations can be helpful. Missing are standards to characterize sealing of slits, though such measurements can be based on the existing methods. Probably a test code could be developed for such products in line with the proposals for the restructured version of the laboratory parts of ISO 140 [10].

Another important element for façade insulation can be the influence of the façade shape, the presence of balconies and such (ΔL_{fs}). However, it is not likely that a general measurement method can be established for this aspect. The data in the standard can best be extended by results of research or be replaced by a future engineering prediction method for these effects. One of the input data then needed will be the absorption of elements and surface treatments for which a standard is available [3].

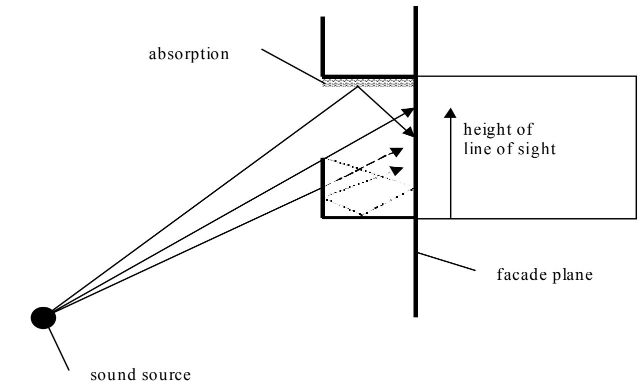

Fig.2 Illustration of the effects (screening, reflections) of balconies on the sound transmission through a facade.

Part 4 actually deals only with the façade itself and thus gives no direct answers to outdoor sound levels. Both the estimation of the inside sound levels as caused by the sound sources as the sound propagation outdoors are outside the scope of the standard and should be dealt with by other prediction models. Just to be helpful an informative annex gives a complete prediction model for the sound level outside for very simple situations.

3.3 Service equipment

The most complicated part of the series is EN 12354-5 for sound levels due to service equipment in buildings. This is partly caused by the large variety of equipment concerned and the various mechanisms of sound generation and propagation. The standard has to deal with sound propagation through ducts and pipes, airborne sound as radiated from sources and structure-borne sound form sources, where it must be realized the each equipment or installation can be composed of many sources. While already a lot is known and studied concerning the first item [11, 12, 13] and the second item can largely be based on available knowledeg, there is a huge lack of practical research results concerning the last parts [14].

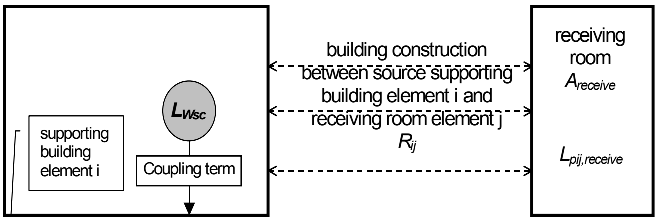

Fig.3 Illustration of parameters for the structure-borne sound transmission from a source to a receiver room.

Though some measurement methods for elements existed [15, 16], an overall scheme was missing in which the various elements and quantities used could find a logical place. This was therefore the first objective for part 5 of EN 12345: to create a general framework. For structure-borne sound the transmission through the building starts with the injected sound power by the source, applying the transmission as describe din parts 1 and 2. The injected power follows from characteristics sound power $L_{\mathrm{Ws,c}}$ for the source and a coupling term D_{C} including the appropriate source and building properties. For the time being various methods can be used to deduce those source properties, as indicated in the standard. Hopefully in due time the measurement methods for sources will show a more direct link to these quantities. Indeed, the development of EN 12354 has triggered already a lot of research activities, also leading to new measurement standards for equipment noise, as relevant for heavy building structures [17, 18]. But a lot of questions are still to be solved.

3.4 Reverberant sound

As is normal practice, EN 12354-6 used Sabine's relation to link reverberation times to absorption data for building elements and objects as determined by ISO 354 [2]. Especially for the use in larger or occupied spaces, attention is given to the actual empty volume to be used and the effect of air absorption. However, the main problem is that for various enclosed spaces the Sabine-relation is not really adequate since the sound field is far from diffuse or the absorption is rather localized, for instance only the ceiling. To indicate at least possible deviations from the Sabine results an informative annex is included with a more detailed prediction model [19]. This certainly will not be the last answer, but at least as important for reliable predictions is the fact that the uncertainty in the input data as deduced from ISO 354 is still rather large. Variations between laboratories are not negligible and due to some differences in requirements the results from ISO and ASTM measurements seems to show a systematic difference.

4 Current activities for EN 12354

4.1 Light weight building structures

The prediction models of part 1 and 2 of EN 12354 have been used quite extensively over the last years and have shown to be very useful, at least for buildings with mainly homogeneous structures. A point of concern has been to best way to apply the methods for light weight building structures. How to interpret the equations? How to adjust or extent them? How to collect the relevant input data?

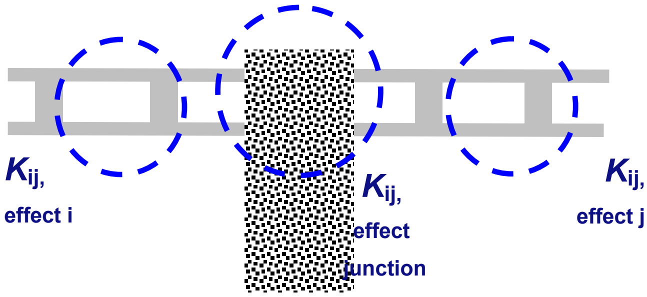

Fig.4 Junction with light weight building elements indicating various components of the vibration reduction.

With light weight elements the damping is less depending on the surrounding of the elements and more an inherent properties of the elements concerned, hence the vibration reduction index could get a different meaning, being composed of a junction effect and an element effect (see Fig.4) [20]. But also the role of the radiation efficiency, being different for forced and resonant transmission, has to be reconsidered [21]. Fortunately a lot of research is going on in this area which should make it possible to extend and adjust EN 12354-1&2 as well as ISO 10848 in the near future in order to cover also light weight structures [22], [23, 24].

4.2 Service equipment

For the prediction of sound levels due to service equipment in buildings only the first draft of the standard EN 12354-5 is available. It is clear that this standard needs to be extended, adjusted and improved while gaining more practical knowledge on the subject in the future. To that extent research is going on [25, 26] as is also reflected in several papers on the subject during this congress. These are also necessary contributions improve measurement methods to characterize sources and other equipment parts. The most challenging aspect is the combination of equipment and light weight building structures [27]. The drafted EN 12354-5 for sound levels due to service equipment noise already proves to be a fruitful framework for the development of measurement standards for sources and system elements.

5 Conclusion

Developing prediction models for the acoustic performance of buildings was triggered by the creation of the free market within Europe, but the need for such models was also felt in Europe and elsewhere to be able to erect buildings with new methods and materials and improved performance which can no longer be achieved with the 'trial-and-error' approach, so common for the construction industry.

However, to be able to predict the building performance it is necessary to have data on the performance of all building elements involved. Drafting the prediction models made clear that indeed measurement standards were available for some elements, but needed adjustment for others or were just simply missing. Hence activities were started to develop or improve all standards that could produce the necessary input data for predictions.

Especially the drafted EN 12354-5 for service equipment noise proves a fruitful framework for the development of measurement standards for sources and system elements, defining the type of quantities and data needed and showing how that data can be used.

Acknowledgments

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