

Reliable building element sound insulation data for EN 12354 calculations facilitates analysis of Swedish dwelling houses

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Abstract [48] This paper describes a practical procedure to build a structured database of sound insulation data, that describes the constructions typical for older dwelling houses. The data are mainly based on calculations, but efforts have been made to compare calculated results to measured, and to verify that the calculated data *in situ* according to EN 12354 are reasonably representative for the actual types of building. Feed back from the users of the database may support future analyses and updates of the database or the calculation model.

1 INTRODUCTION

In Sweden, modernization of old dwelling houses is an important and growing building activity, e.g. infill development, expansion of attic storeys and conversion of other types of building into dwellings. Initially, severe problems with annoyance among the inhabitants were caused by poor sound insulation in these new dwellings. As a consequence thereof, sound insulation is now assigned high priority during the planning process. New building codes, within the third edition of the Swedish standard on sound classification [1], explicitly advise that a building acoustic documentation should be presented at an early stage of a project, based on calculations or measurements. Measurements in the building are often required, but they can only confirm the actual conditions. To predict the acoustic performance of a renovated building, with major changes of construction undertaken, calls for theoretical calculations. These may be difficult to perform however, since there is a lack of reliable data on airborne and impact sound insulation of older building types. There is some empirical knowledge of typical acoustical problems within houses from the 1950-, -60 and -70 decades, but it is often not structured such that it can be readily applied to future projects. With pensioning of experienced acoustic engineers close at hand, there was an urgent need to document empirical and theoretical knowledge of building acoustic properties of construction typical of old houses. A survey has been undertaken among the experts, and some literature data were gathered as well. A database of sound insulation of typical constructions suitable for the calculation of sound insulation *in situ* according to the European standard EN 12354 [2] has been established, including data for suitable renovation measures. The constructions are structured in the database according to an architectural survey, where building types established during 1880-2000 have been described [3]. A structured approach to find consistent data for these constructions was established, as described below.

2 PROCEDURE

Several aspects were considered before the survey was started, on various techniques to establish data for the constructions.

Among acoustic engineers, measurements are often considered more reliable than theoretical calculations, in spite of the difficulties with interpretation due to the large scatter found in laboratory measurements as well as results from the field. There is an expressive saying that concludes the problem: “everybody trust results from measurements except those doing them, but no one believes in results from calculations except those performing them”. As is shown in the table below, all known methods to determine sound insulation data have benefits and disadvantages that had to be accounted for in this project.

Type of analysis	Advantages	Disadvantages
Laboratory measurements	High repeatability (within the same lab.) Describes the actual construction, as-is	Moderate reproducibility between labs Many constructions are not tested (high costs, no owner of the data) Idealized mounting conditions
Field measurements	Estimate performance of assembled constructions in the field as actually built Influence of room modes and structural loss factors included	Data valid for the test rooms only Mix of direct and flanking transmission Difficult to predict influence of changes Moderate repeatability of test results Many types of house not tested
Theoretical calculations	Virtually all types of construction may be analyzed Consistent estimate of performance with respect to mass, change of construction etc	Unknown precision (systematic errors) Does not describe real constructions (acoustic behaviour is idealized)

The choice of source for construction data is not obvious. The strategy chosen in this project was to try a combination of all methods. A calculation model was compared to measurements in several laboratories and a statistical correction was established for several categories of construction. Then, the input data of the actual constructions in the database were calculated theoretically and corrected according to the comparison with laboratory measurements. As a final step, comparisons of calculated sound insulation in buildings with field measurements were made. This procedure combines, to some extent, the consistency of calculated data with the legitimacy of measured data. The procedure is described in detail below.

2.1 Describing typical constructions of old houses

It is necessary to describe the constructions typical for old houses in a schematic and structured way. Otherwise, the amount of variations in construction and sound insulation data may be prohibitive for the purpose of establishing a database that is practical to use. Fortunately, an architectural survey had been undertaken in Sweden some years ago, and the constructions typical for each decade have been described and illustrated [3]. An example is given in Figure 1. The task of the project was then to assign acoustical properties to the constructions listed in this survey.

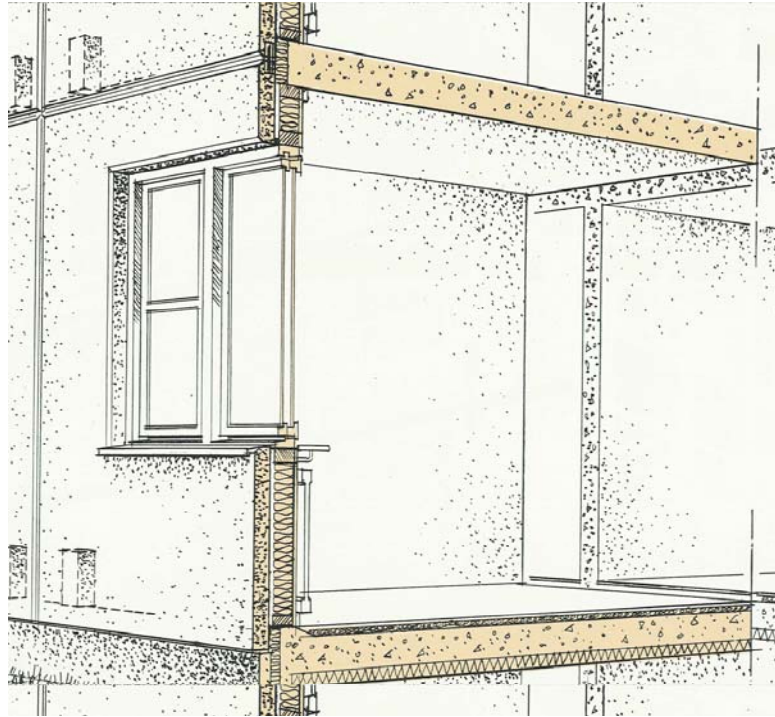


Figure 1. A sample illustration of house construction typical for the 3-5 storey houses built in the 1950:s, cited from ref. 3. The parquet floor rests on 30 mm sand, which is replaced during renovation.

2.2 Survey for measured data of old houses

The initial aim of the project was to document empirical experience of experts on building acoustics, who were asked to describe typical features of older houses from their own experience. Some field measurements were collected, that were thought to represent typical types of old building. However, only a few measurements from the same type of building were found. For many constructions, there were no data found at all. In most cases, the measurement reports were not completed with documentation on constructions of the measurement rooms. Therefore, it was uncertain which constructions they referred to. Another specific problem was the measurement uncertainty of 20-50 year old measurements and the limited frequency range (100-3150 Hz). In the Swedish building codes, a documentation is required in the range 50-3150 Hz.

The field measurement data were not used to describe single constructions, but will instead be applied at a later stage to verify results from calculations according to clause 2.5.

2.3 Comparison between measured data and calculated data

Measurement data from various laboratories were collected and compared to theoretical calculations, using the Insul software [4]. For each type of construction, the average difference between the calculated and the measured insulation was calculated as well as the standard deviation. An empirical correction to calculated results was then established for several types of construction, e.g. light weight inner walls and external walls, light weight concrete walls, windows and floorings.

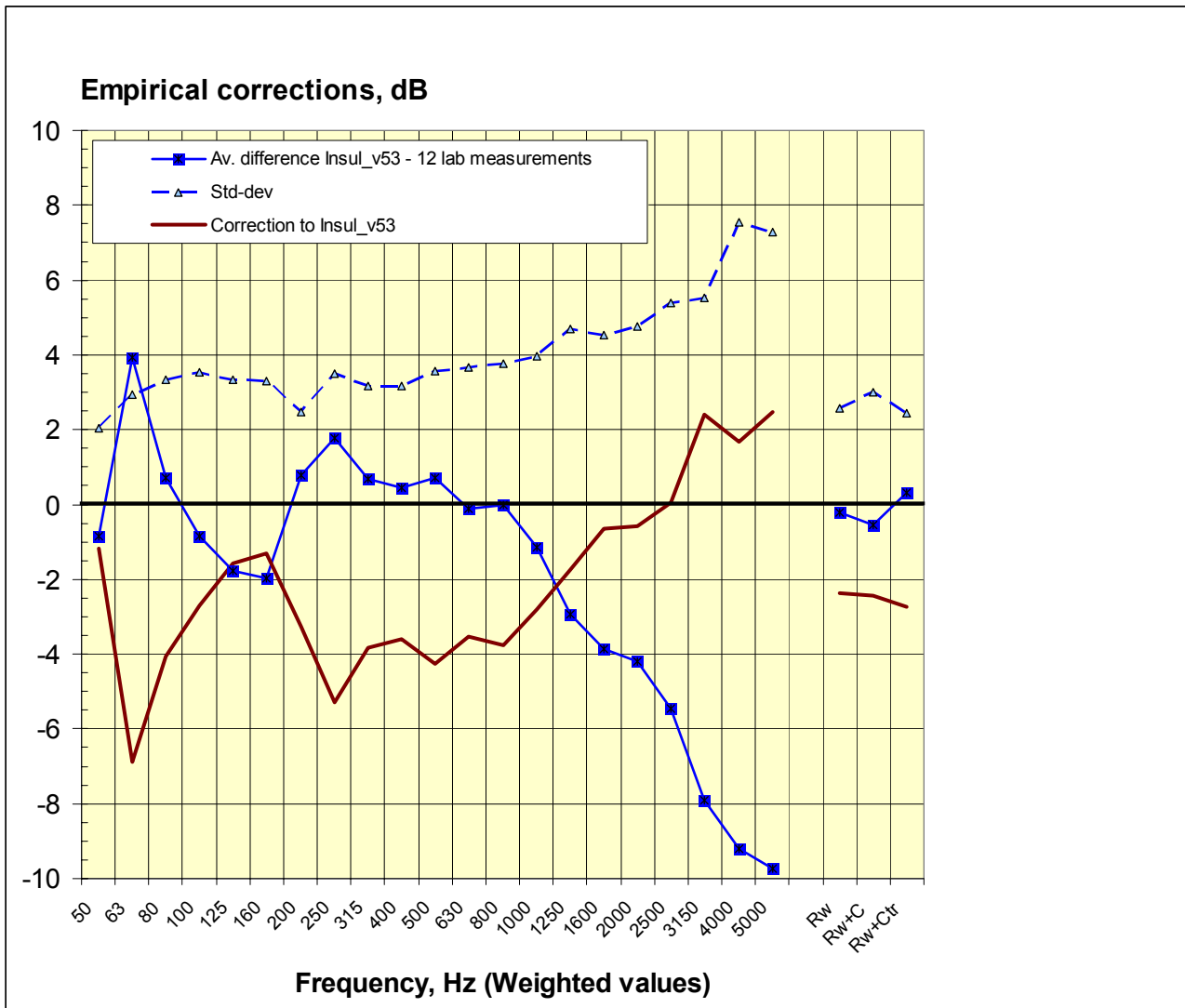


Figure 2. Average and standard deviation between measured data and calculated data. Comparison of 12 light weight external walls with various types of insulation and cladding on wooden battens.

2.4 Calculating and correcting input data for typical constructions

As a rule-of-thumb, one should keep a safety margin between sound insulation *in situ* calculated according to EN 12354 and a required value. This margin has to be defined by the client or the acoustic expert, but it should take into account uncertainty in the building element data, the accuracy of the calculation model and the uncertainty in field measurements. A margin of 3 dB is often advised. The choice of building element data should preferably be corrected for the uncertainty that pertains to the specific construction only, i.e. not correct for the general uncertainty. For instance, data of light weight constructions typically show a larger scatter than heavy constructions, and the safety margin may be chosen differently.

In the database, the correction of input data for light weight building elements were determined as the sum of the average deviation increased by one standard deviation, in third octave bands 50-5000 Hz. For heavy constructions, only the average deviation was used. As an exception to the procedure described, light weight timber joist floors were adopted from laboratory studies and corrected by -3 dB from empirical experience. The performance of these floors tend to be impressive in the laboratory but more moderate in the building. One reason for this difference may be flanking

transmission through the supporting studs and walls, which is not handled by the calculation model in EN 12354. Also, transmission losses at junctions between light weight constructions are not yet well understood, nor documented.

The input data of the constructions listed in [3] were then calculated, corrected and tabulated in the database. Schematic illustrations were made to show each type of construction.

2.5 Verifying data by comparing to other *in situ* measurements

About 30 field measurements will be analyzed in June 2004 and the results presented at the conference, where comparative calculations will be done according to EN 12354 parts 1 (airborne sound insulation) and part 2 (impact sound). The software for the calculations is BASTIAN version 2.1 [5]. The constructions of the actual building will be chosen from the previously established database. However, developing input data for heavy concrete slabs and walls is not a part of this project, they will be chosen according to a previous study and the annex B of EN 12354. In case large deviations are found, a more detailed study will be undertaken to explain the deviation and try to correct the input data accordingly.

3 EXAMPLES

Two types of construction required an extensive work to describe: timber joist floors and external timber stud walls with various types of cladding.

The acoustic performance of timber joist floors in situ and in the laboratory was analyzed by Bodlund [6]. Bodlund concluded, that a large scatter of data must be expected, even within the same building. Therefore, measurements should be taken in several rooms to document conditions before deciding upon measures to improve sound insulation.

Bodlund made some systematic studies in the laboratory at SP (The national testing and research institute). A reference timber joist floor was constructed, where various types of filling material, floorings and suspended ceilings were tested. The data from this study were incorporated in the database, together with results from two experimental studies on modern light weight timber joist floors [7], [8]. These measurement series give an impression on the efficiency of various renovation measures, but calculation results must be interpreted with great care when used to predict the performance of an actual construction, particularly if it is not well documented. Figure 3 shows some examples of slab tested in the laboratory.

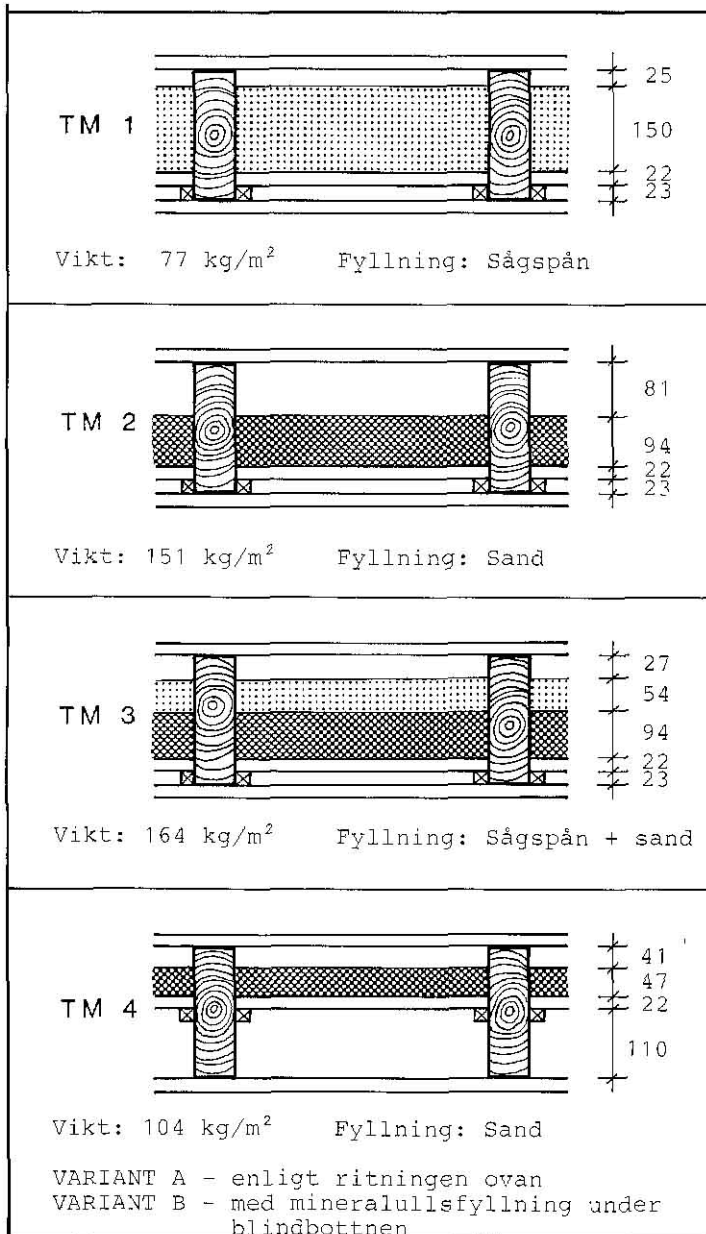


Figure 3. Reference timber joist floor with various filling materials. "Sägsån" means sawdust, "vikt" means weight, "blindbotten" means blind floor. (From SP, ref 5)

The external timber stud walls presented some difficulties with respect to variations in construction. Buildings from the 1930-1960 period have additional cladding (thermal insulation and a new panel). Several alternatives have been calculated according to the above procedure, but results from a large measurement series in the laboratory were also incorporated in the database. The user of the database may then choose a measured value when the construction fits the actual case, and then look at the calculated values to see what change can be expected in acoustic performance when additional layers are suggested.

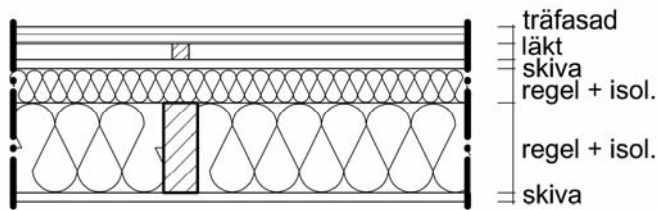


Figure 4. Typical light weight timber stud exterior wall element, with new thermal insulation and panel added. “Regel” - stud, “skiva” -board, “läkt” -batten, “träfasad” -wooden cladding.

4 CONCLUSION

A database of sound insulation data has been established, that describes the constructions typical for older Swedish dwelling houses in a structured way. The data are based on calculations, but efforts have been made to compare calculated results to measured, and to verify that the calculated data are representative for the actual constructions. The database presented is a first step towards a common set of reliable data for older buildings. However, feed back from the users of the database may call for adjustments of the data. Thus, the quality of the data in the database may be improved step by step, and there should be a dialogue between acoustic engineers using the data.

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