Impact sound insulation: measurement and prediction in hollow constructions of the Basque Country

PACS ref: 43.55. Rg

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ABSTRACT

There is considerable interest in being able to predict the acoustical comfort in dwellings during the design stage and there is a need to validate and improve current prediction methods by carrying out measurements in real buildings throughout Europe. However, much of the current research is being directed at the prediction of airborne sound transmission yet for floors it is often impact sound transmission that is the greater problem.

This paper presents some results of some impact sound transmission measurements carried out in Spain and compares these measurements with prediction models.

A typical Spanish dwelling was chosen to check the applicability of two prediction models: SEA [1] and EN12354 [2]. The measurements and predictions were made between bedrooms in two adjacent floors for a standard impact sound source (B&K 3204 tapping machine). Sound pressure level measurements were made in the room underneath the tapping machine and in the room beside (diagonal) to check the accuracy of the predictions.

DESCRIPTION OF THE BUILDING

The test house was a new nine-floor building with twelve dwellings per floor, in Bilbao. The construction is typical of buildings in the Basque Country and constructed as follows (see fig. 1):

- Hollow 'beam and pot' concrete floor with a wooden block top surface, with a total thickness of 39cm and an estimated surface mass of 500 kg/m^2.
- Hollow clay brick walls (thickness 7 cm) with 1,5 cm of gypsum on each side. The total thickness is 10 cm and total surface mass about 100 kg/m^2.
- Double-leaf façade, composed of an external brick layer, thermal insulation (polyurethane foam) and a hollow 7cm clay brick with gypsum (same brick that the internal walls). There are no ties connecting both leafs of the façade.

Laboratory measurements of sound insulation were carried out on these constructions (in accordance with EN ISO 140-3 [3] and EN-ISO 140-6 [4]) to give the necessary input data for the CEN model [5].

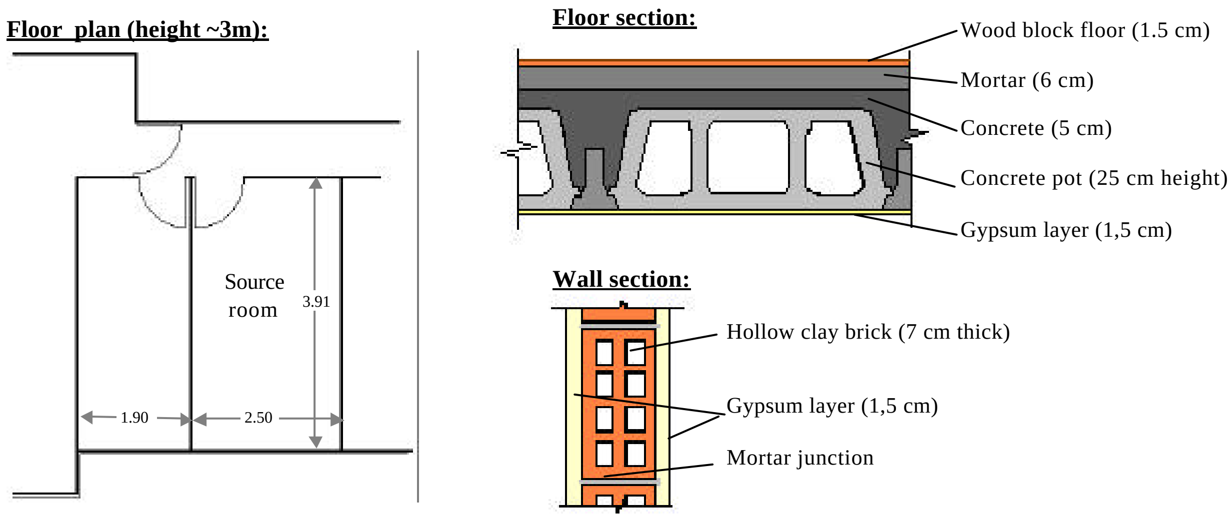

Fig. 1: Floor plan and construction details of the test building

RESULTS

Three different predictions were made:

- EN 12354-2 model using measured vibration reductions indexes K_{ij}.
- EN 12354-2 model using the equations for vibration reduction index found in *annex E* of EN 12354-1.
- SEA model

All models calculated the contribution of the direct path (where present) and all the flanking paths that involve transmission across one structural junction. The contribution of longer paths was not included.

In order to simplify the calculations, the influence of the doors and windows were neglected and the internal leaf of the façade wall was taken to be the same as the internal walls.

Both EN 12354 models included corrections for the measured structural reverberation time of the different elements. The structural reverberation time was measured *in situ* for both floors and walls, using an impact source. As no loss factor measurements were available for the laboratory floor, results from a similar floor were used [6].

The SEA model is similar to the EN 12354 model and if the same assumptions are made then the same results are obtained. However, in the SEA model no experimental data was used. The force exciting the floor was based on the known properties of a tapping machine and from this the power input was calculated [1]. The damping of the elements was computed assuming a typical value for the internal loss factor (0.015) and adding this to the computed edge losses.

The structural transmission (K_{ij} in the EN 12354 model) was computed from all the properties of the walls and floor and not simply on the ratio of the surface densities (as in EN 12354).

It would be reasonable to assume that the EN 12354 model that used measured values of Dv should be the most accurate as it has the least amount of calculated data. The EN 12354 model with calculated K_{ij} has some calculated data but has measured data for other properties. The SEA model has only calculated data.

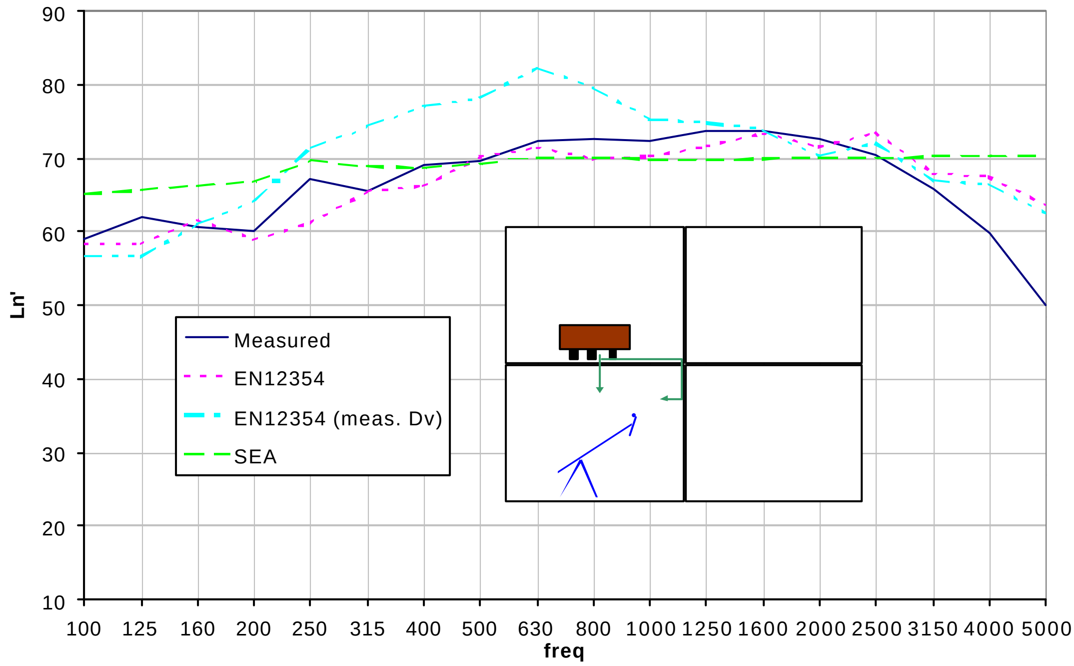

Fig. 2: Measured and predicted impact sound levels (room underneath).

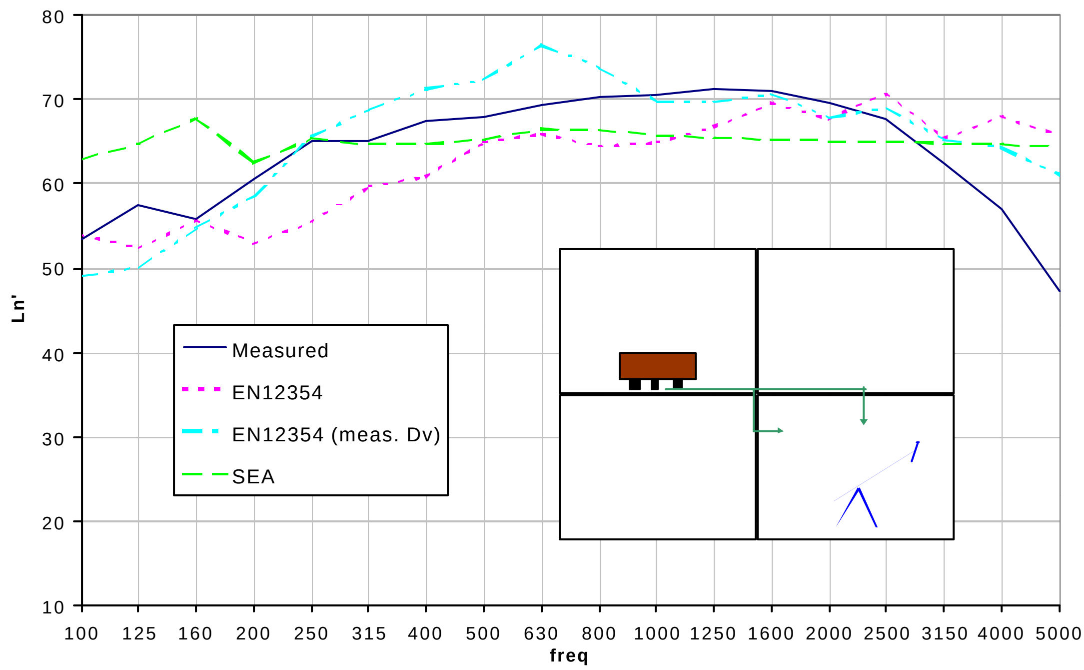

Fig. 3: Measured and predicted impact sound levels (room diagonal).

All the models give reasonable agreement with the measured data with the variations being within the expected range.

The overall index, useful for most normative purposes (Ln'_w according to EN ISO 717-2 [7]), is

Ln'_w	***Measured***	***EN12354***	***EN12354 (measured. Dv)***	***SEA***
room underneath	**77**	**78**	**79**	**76**
roon diagonal	**74**	**74**	**75**	**71**

Fig. 4: Overall index (Ln'_w) obtained with the different models.

There is good agreement between measured and predicted values.

MEASURED VIBRATION REDUCTION INDEX

A key parameter in determining the flanking transmission is the vibration reduction index, which is a measure of attenuation across a structural junction. In addition to the sound pressure level measurements, vibration measurements were made for comparison with the predicted values. Although both the walls and floors are hollow the predicted values were computed assuming that they were homogeneous. Measurements of the vibration reduction index between two floors and between a floor and a wall were carried out. Measurements were made both on the upper side of the floor (on the wood block) and on the underside (ceiling). Significantly different results were obtained showing that the wood block flooring is not rigidly bonded to the concrete. This was not expected. These different measured results lead to different values of K_{ij} as shown in Fig 5.

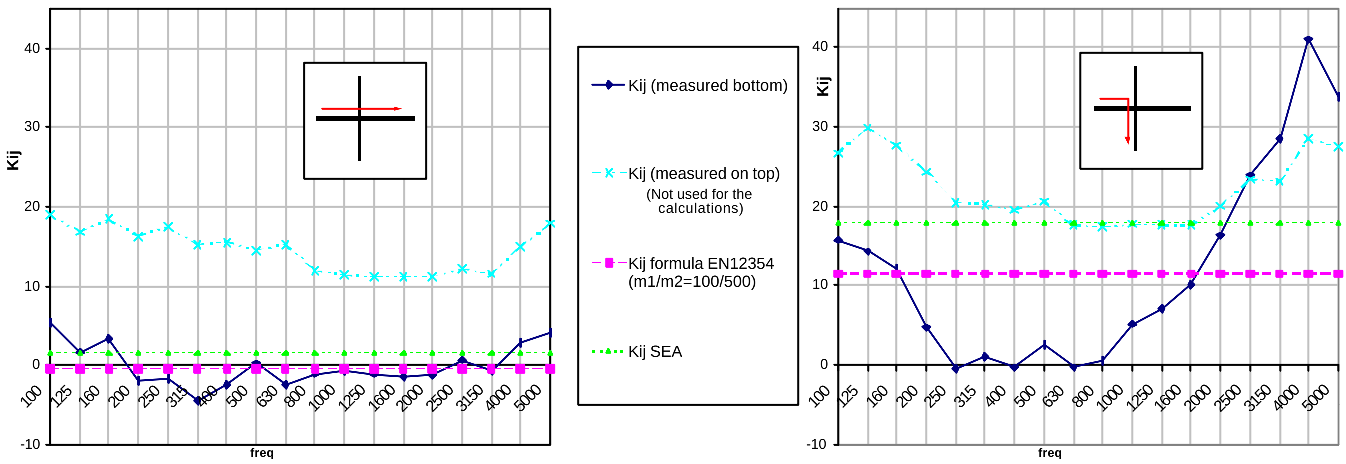

Fig. 5: Vibration reduction indexes K_{ij}.

The calculations in the EN 12354 model with the measured Dv included in this paper are those corresponding to the K_{ij} measured on the bottom (radiating side) of the floor. Using the K_{ij} measured on the wood block results in large errors in the predicted values of impact sound level.

The measured values of $K_{floor-floor}$ placing the accelerometers in the radiating side of the floor (bottom) show good agreement with the expected theoretical values from EN 12354 and SEA. However there is poor agreement between the expected and actual values with $K_{floor-wall}$.

DISCUSSION & CONCLUSIONS

The results show that, contrary to expectations, both sides of a 'beam and pot' floor (with a timber block layer) may vibrate with different levels even though there is no elastic layer inside it. This behaviour needs to be studied in more detail to identify the origin of this difference. Architects or acoustics consultants using the new EN12354 must take this into account to avoid large differences between the expected and the measured values of sound insulation. For example when calculating the airborne sound transmission between two adjacent rooms in a dwelling (EN 12354 –1:2000), the radiation from the floor and from the ceiling may be very different.

Although the overall calculations of sound pressure level agree well with measured data there is much poorer agreement with the vibration reduction index, which is a key component of the calculation. A consequence of differences in the values of K_{ij} is that the different models give different paths as the dominant path. For example the EN 12354 models indicate that radiation from the walls is more important than the floor (for both rooms) whereas the SEA model indicates that radiation from the floor is more important than the walls (see example in fig. 6).

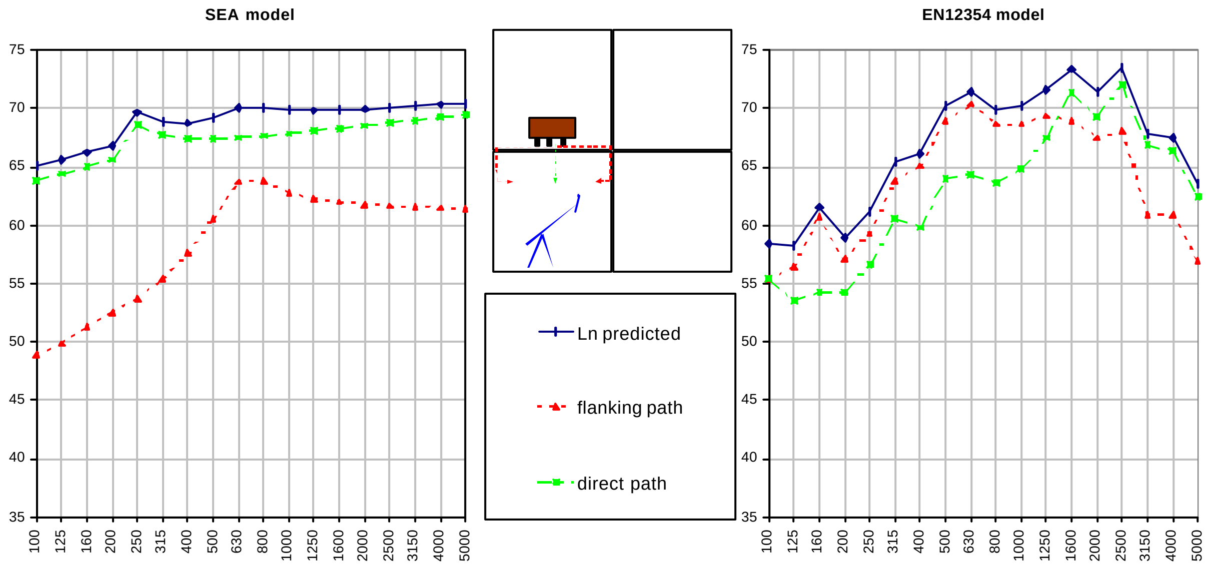

Fig. 6: direct and flanking paths for SEA and EN12354 models (transmission to the room underneath). Shown EN model uses the calculated K_{ij}.

This shows that good agreement between the measured and predicted overall SPL is not evidence that the underlying model is correct and could lead to incorrect decisions being made when trying to improve sound transmission. For example in this case the SEA model suggests that a lining under the floor (perhaps a suspended ceiling) would improve sound insulation whereas the EN 12354 models suggest this would be ineffective except at high frequencies.

The deviations found in all the models show the importance of having trustworthy input data. There is currently very little data for typical Spanish constructions and further work is necessary to build up a reliable database of information on loss factors, etc…

Further work is needed to measure and characterise the vibration reduction indexes K_{ij} for typical Spanish buildings where hollow elements for floors and walls are common. The effect of the placement of the wall on the floor also needs to be examined to determine the differences in K_{ij} between a floor and a wall when the wall meets the floor under the beam, under the pot or when the beam direction and wall direction are perpendicular. This may have contributed to the poor results for structural transmission from the floor to the wall.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support of the Basque Government and in particular the support of Agustín De Lorenzo, Head of Building Regulations.

REFERENCES

[1] R.J.M Craik, *Sound Transmission Through Buildings Using Statistical Energy Analysis*, Gower (1996)

[2] EN 12354-1,2: *Building acoustics - Estimation of acoustic performance of buildings from the performance of elements. Part 1: Airborne sound insulation between rooms; Part 2: Impact sound insulation between rooms* (2000).

[3] EN ISO 140-3: *Acoustics – Measurement of sound insulation in buildings and of building elements. Part 3: Laboratory measurements of impact sound insulation of building elements* (1995).

[4] EN ISO 140-6*: Acoustics – Measurement of sound insulation in buildings and of building elements. Part 6: Laboratory measurements of airborne sound insulation of floors* (1998).

[5] *dBMAT – Base de Datos del Comportamiento Acústico de Materiales,* Dirección de Vivienda y Arquitectura, Gobierno Vasco (2000). ['dBMAT- Database of the Acoustic Behaviour of Materials'. Edited in Spanish by the Basque Goverment]

[6] *Estudio sobre Modelos de Predicción de Transmisión de Ruidos en Viviendas del País Vasco*, Dirección de Vivienda y Arquitectura, Gobierno Vasco (2002). ['Prediction Models of Sound Transmission in Dwellings of the Basque Country'. Basque Government. In Spanish.]

[7] EN ISO 717-2: *Acoustics – Rating of sound insulation in buildings and of building elements. Part 2: Impact sound insulation* (1996).