State of field measurement of facade sound insulation in buildings: Evaluation of Proficiency Testing data according to ISO 140-5

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Background: In the field of acoustics, the series of standards ISO 140 describe the methods for measurement of airborne and impact sound insulation.

- ISO 140-5:1998 specifies the testing procedures to evaluate the insulation of building facade elements and whole facades.
  - ⇒ using the broadband emission of a loudspeaker as an artificial sound source, or by real noise available on the spot where the element is located.
- ACUSTILAB, as a network of laboratories within EUROLAB-España, promotes a project to get a tool for the verification of the technical competence through the development of an interlaboratory comparison program in this scope.

Methodology: limitations of the standard.

- According to ISO 140-5, from year 2011 three rounds have been organized and one more is in course at the national level on an annual basis.
  - ⇒ **the global parameter is $D_{ls,2m,nT}$ (dB) measured for a whole facade in bands of a third of octave at a frequency range 100 to 5000 Hz.**
- Some factors of influence make noise levels more stable (good repeatability): the minor spatial sampling and the use of a single source position.
- The directional characteristics constrain the type of noise source and the positions of the external loudspeaker influence on the value of SD_R.
  - ⇒ a series of planned stages related to the supervision, follow-up and control of the measurement item are considered in a **monitoring phase** to assure the stability of the scenario and the homogeneity of the sound levels

Statistical design and performance evaluation.

- The protocol outlines a statistical treatment based on ISO 5725-2 for the determination of SD_r and SD_R in a standardized measurement method.
  - ⇒ the consensus value, once rejected the outliers, is calculated from the mean of five results reported by fourteen participants and taken as **assigned value**, based on the distribution of participants data after verification of normality.
- To define the variability, the **values of SD_r and SD_R** are calculated with a probability level of 95%, expressed in terms of repeatability and Reproducibility:

$$\Rightarrow \quad r = 2{,}8 \times SD_r \qquad R = 2{,}8 \times SD_R$$

Difficulties to assess precision guidelines.

- The assessment of the validity of R is not feasible since regulatory values to use as a prescribed reference are not available,
  - ⇒ ISO 140-2 gives indications to state interlaboratory precision that unfortunately cannot be applied to the current measurement scope.
- To evaluate the laboratory participation, the corresponding combined performance scores are calculated on the basis of the determination of **SSZ values** (quadratic sum of comparable Z-scores).
- If this assessment is carried out along the rounds up to date, it might possible to determine those participants with an overall satisfactory performance over time.

Results.

- The assigned values in each frequency for every PTs round are displayed in *Fig.1* showing a high consistency among them.
  - ⇒ **the noise source is considered sufficiently homogeneous**, as stated in the stage for monitoring the scenario.

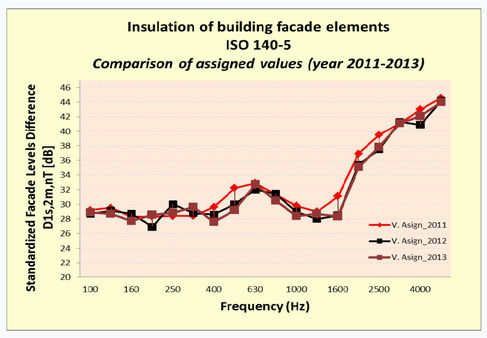

Fig. 1

- The establishment of the statistical protocol requires that, for a given PTs round with measurements at a certain frequency, the distribution of results from the laboratories taking part in the intercomparison were computed as shown in *Fig.2*

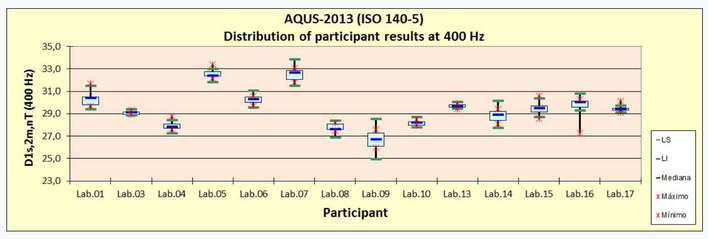

Fig. 2

- Thus, the global results calculated for the assigned value and the repeatability and reproducibility values are expressed in *Table 1*.

ISO 140-5 $D_{ls,2m,nT}$ / Frec (Hz)	Valor Asignado (p = 14)	Límite de Repetibilidad (r)	Límite de Reproducibilidad (R)
100	28,7	3,15	4,98
125	29,1	2,59	6,50
160	28,7	2,34	7,08
200	26,9	3,22	7,61
250	30,0	2,61	4,96
315	28,8	2,29	5,43
400	28,6	2,03	5,19
500	30,0	1,67	5,18
630	32,0	1,67	4,13
800	31,4	1,56	3,32
1000	29,0	1,45	5,57
1250	28,0	1,71	6,19
1600	28,5	1,48	6,18
2000	35,4	1,56	3,24
2500	37,5	1,83	4,04
3150	41,3	1,21	2,90
4000	40,9	1,25	5,49
5000	44,2	0,89	3,88
$D_{ls,2m,nT,W}$	32	1,2	2,31
$D_{ls,2m,nTA}$	30,6	1,06	2,62

Table 1

References.

ISO 5725-1:1994, "Accuracy (trueness and precision) of measurement methods and results: General principles and definitions"

ISO 5725-2:1994, " Basic method for the determination of repeatability and reproducibility of a standard measurement method"

EN ISO 140-5:1998, "Field measurements of airborne sound insulation of facade elements and facades"

EN ISO 140-2:1998, "Measurement of sound insulation in buildings and of building elements: Determination, verification and application of precision data"

Analysis and discussion.

- As a summary, 89% of participants show satisfactory results, while 7% are considered as questionable or unsatisfactory; only 4% of participants detected as outliers during the rounds.
  - ⇒ despite a slightly broader distribution was observed in the first PTs round, the evolution of Z-scores is taken as **representative for the objectives of the intercomparison**.
- After application of the statistical protocol to compute the PTs results, the values of SD_R are calculated, as an indication of the reliability of the interlaboratory comparison.
- A comparison of R values in each frequency and PT round is charted in *Fig.3*. Due to the own features of facade sound insulation measurement, the uncertainty reported by the participants is mostly greater at low frequencies, so the obtained R values over time confirm this fact.

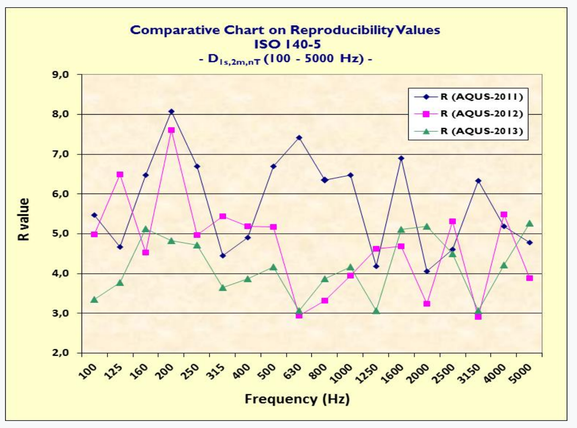

Fig. 3

⇒ the degree of global variability along the rounds is not considered suitable to establish any precision guidelines on the basis of these results, so it seems appropriate to select just those laboratories which systematically have better performance over time.

- The accumulated values of SSZ for all the participants, are shown in *Fig.4*, given the number of PT rounds in which every laboratory has taken part.
  - ⇒ according to the chi-squared distribution, since the statistically acceptable SSZ value is stated in 28.9 (for the combination of 18 frequency values), as a whole it is observed that the majority of participants show an adequate global performance.

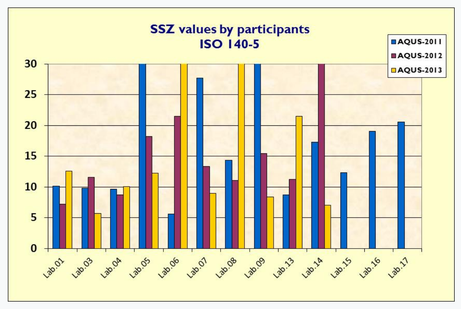

Fig. 4

Setting-up reproducibility guidelines.

- Considering the variability of the global results, it is decided to pose a simulation by defining an arbitrary precision criteria where **the most reliable participants are selected** among the ones which regularly achieve SSZ values lower than 15.0, set as a sort of performance rating.
- Once computed, four laboratories meet that criteria on the measurement of the parameter $D_{ls,2m,nT}$ (100-5000 Hz), so they meet with this empirical rule based on past involvement.
  - ⇒ referring to our proposal, some tentative values of reproducibility are suggested, as it is shown in *Table 2* and *Fig.5*.

Frec - kHz	R (SD_R expert)	R - proposal -
100	3,8	6
125	3,8	6
160	5,1	6
200	5,5	5
250	4,0	5
315	4,3	5
400	3,3	4
500	3,7	4
630	2,5	4
800	2,1	4
1000	2,8	4
1250	3,4	4
1600	3,8	4
2000	3,1	4
2500	3,9	4
3150	3,8	5
4000	3,5	5
5000	3,4	5

Table 2

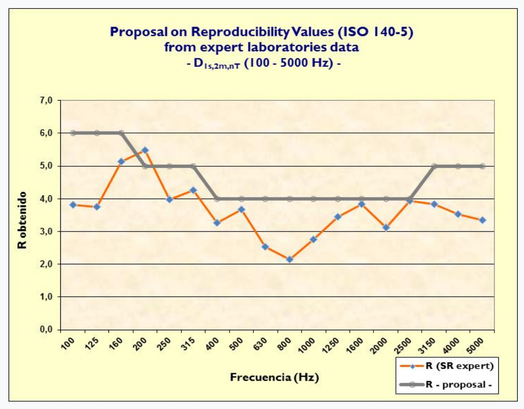

Fig. 5

- These **simulated values of reproducibility** should be considered just as a mere probationary proposal derived from experimental data, so in future those numbers must be confirmed in a dedicated collaborative trial in a controlled scenario, in order to determine both repeatability and reproducibility values within experimental conditions according to the existing practice.

Conclusions and next steps.

- The completion of the activities related to this project must be aimed at the establishment of some **guidelines from a Collaborative Study** for the assessment of the measuring method performance.
- Therefore, an approach based on a Proficiency Test Scheme, focused on the method rather than on the laboratories, should confirm the proposed reference values for each frequency in terms of minimum precision level **to determine the Reproducibility Standard Deviation** in measurements according to ISO 140-5 (under revision by ISO 16283-3) .
  - ⇒ both the applicability and practicability of the agreed method must be deeply considered since a collaborative trial requires substantial effort and should only be applied to methods that have received adequate prior testing.
- The goal is to provide **reliable and updated criteria** for the evaluation of the reproducibility values, particularly in scopes where nowadays there is no available normative reference or this is very poor, so laboratories might have a sort of reference values that allows the assessment of the precision criteria in PT schemes.

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