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Acoustic Evaluation of Beam and Pot Slabs with Lightweight Regularization Layers – A case study

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ABSTRACT: The objective of this work is to evaluate the acoustic performance of beam and pot slabs with regularization layers made of lightweight concrete.
The study consists on the analysis of the acoustic behaviour of three types of solutions, through the execution of "in situ" measurements for the determination of the airborne sound insulation index and of the impact sound insulation index.
The studied elements have the same support element (concrete slab), but regularization layers made of different materials.
The regularization layers studied were: concrete with granulated expanded polystyrene, concrete with expanded clay aggregates and cellular concrete.
The acoustic performance of the three slabs is evaluated and compared with the performance of conventional solutions in way of evaluating their potentialities.

1. INTRODUCTION

The use of non-conventional solutions, such as the ones that use lightweight concrete regularization layers with natural materials like clay aggregates or new materials like polystyrene, polyurethane foam and granulated expanded polystyrene, could be a way to increase the sustainability in construction since the construction weight is reduced. However, there is a significant lack of information about the acoustic behaviour of these solutions.
The ongoing research and development on new construction technologies and the use of non-conventional materials, should lead to the improvement of the general quality and sustainability of buildings and especially of their comfort. Buildings' acoustic performance has an important role to play in these issues. The acoustic potentialities of beam and pot slabs with lightweight concrete regularization layers are not yet well known and the objective of this work is to contribute to its evaluation.
The study consists on the analysis of the acoustic behaviour of three types of solutions through the accomplishment of "in situ" measurements to determine the airborne and the impact sound insulation indexes.
The studied elements have the same support element (concrete slabs), but regularization layers made of different materials. The regularization layers studied were: concrete with granulated expand polystyrene, concrete with expanded clay aggregates and cellular concrete.
The acoustic performance of the three slabs is evaluated and compared with the performance of a conventional construction solution in order to evaluate their capacities.

2. CHARACTERIZATION OF THE STUDIED SOLUTIONS

2.1 Geometry

The three types of new slabs studied and the conventional one constitute the floors of a set of two storey row houses as Figure 1 shows. The measurements took place inside the apartments, in the bedrooms and in the living rooms.

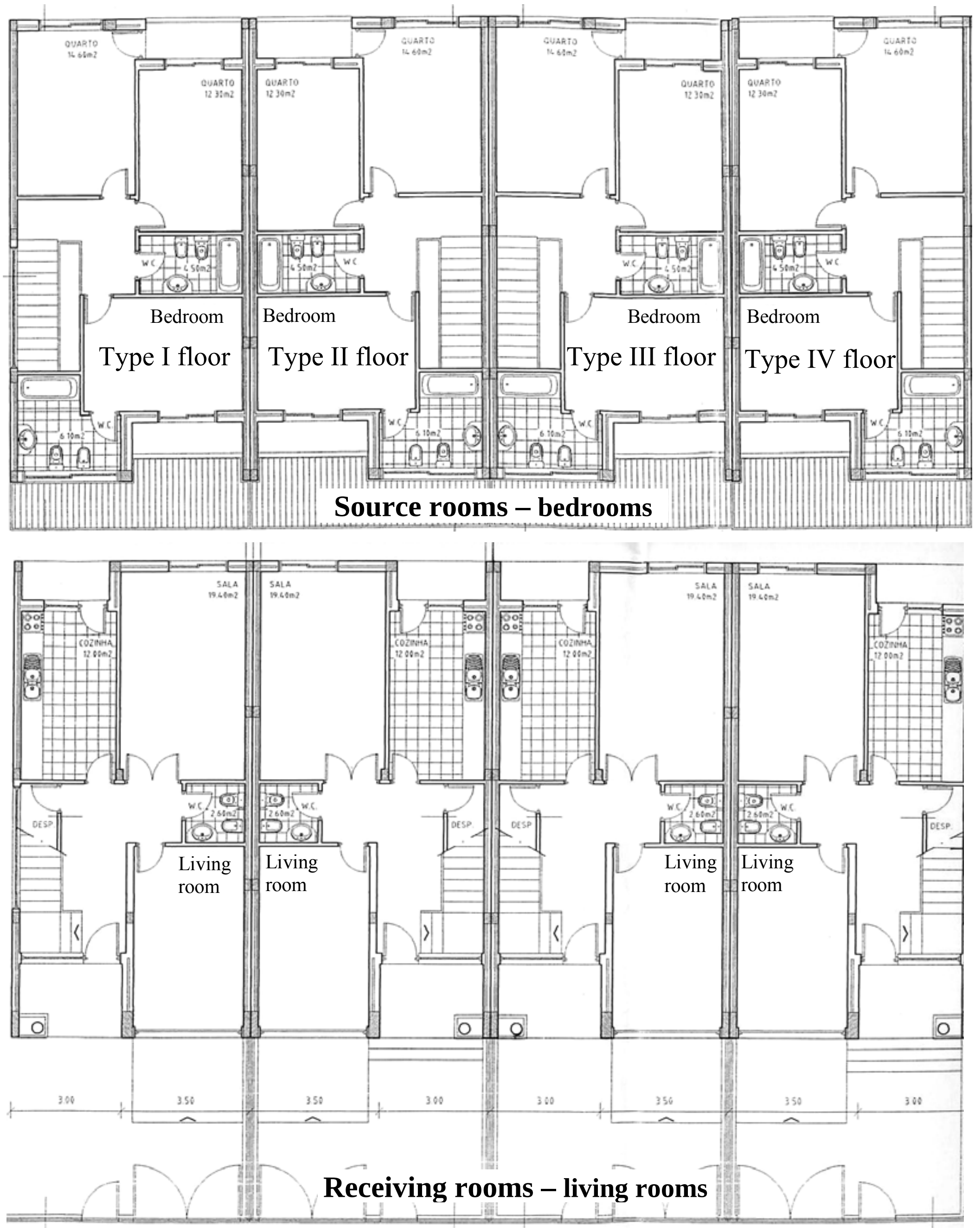

Figure 1 - *Schematic plan of the bedrooms and living rooms*

Table 1 shows the geometrical characteristics of the source and receiving rooms as indicated in Figure 1.

Table 1 - Geometrical characteristics of the rooms

	Floor Area [m^2]	Volume [m^3]
Source rooms – bedrooms	13.3	32.0
Receiving rooms – living rooms	14.5	37.7

2.2 Construction Characteristics

The studied floors have concrete beam and pot slabs as support elements and the following regularization layers: cellular concrete (Type I floor); concrete with expanded clay aggregates (Type II floor); concrete with granulated expand polystyrene (Type III floor); and standard concrete (Type IV floor).

Figure 2 shows schematic sections of the three studied types of floors with non-conventional regularization layers and also the conventional one.

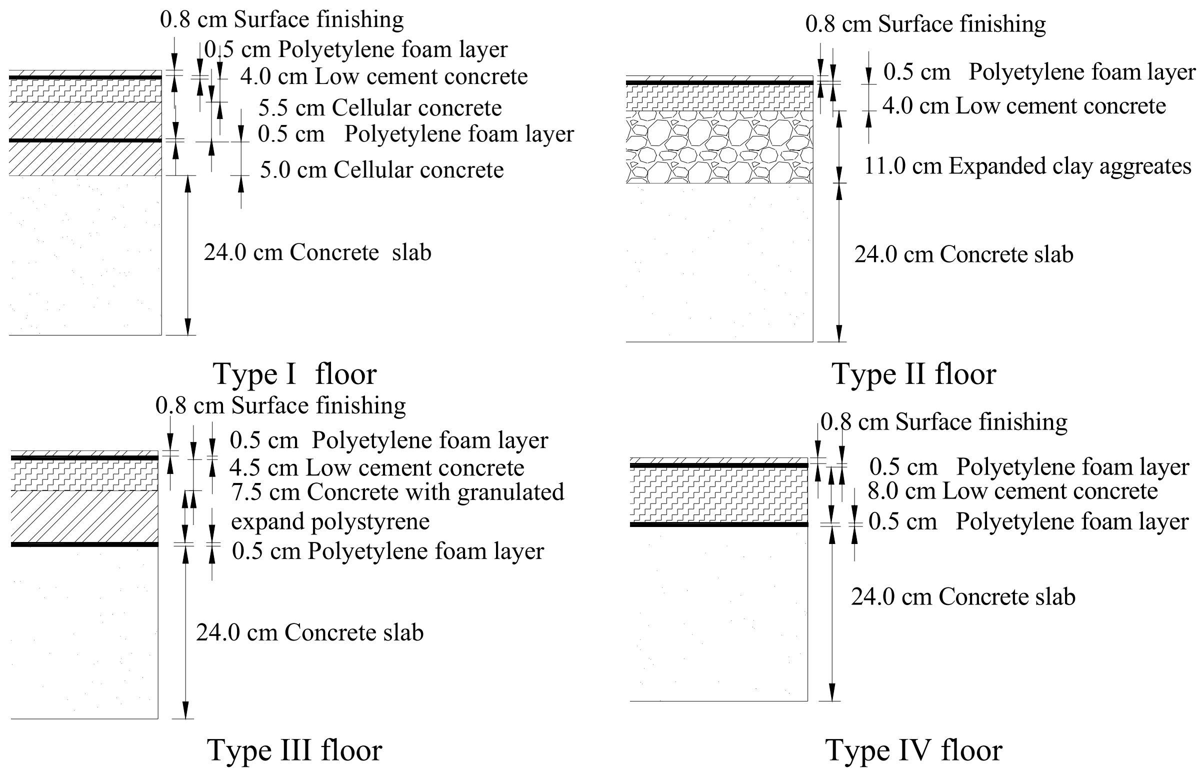

Figure 2 - *Schematic section of the floors*

Figure 2 shows Type I floor with a 24 cm thick concrete slab as support element, 5 cm of cellular concrete as regularization layer, a 0.5 cm thick layer of polyethylene foam, another layer of cellular concrete with 5.5 cm, 4.0 cm of low cement concrete, another 0.5 cm thick layer of polyethylene foam and 0.8 cm of wood as surface finishing.

Type II floor has a 24 cm thick concrete slab as support element, a 11 cm thick layer of expanded clay aggregates, 4.0 cm of low cement concrete, a 0.5 cm thick layer of polyethylene foam and 0.8 cm of wood as surface finishing.
Type III floor has a 24 cm thick concrete slab as support element, a layer with 0.5 cm of polyethylene foam, 5 cm of concrete with granulated expand polystyrene, 4.5 cm of low cement concrete, another 0.5 cm layer of polyethylene foam and 0.8 cm of wood as surface finishing.
Type IV floor has a 24 cm concrete slab as support element, with a 0.5 cm thick layer of polyethylene foam, 8.0 cm of low cement concrete, another 0.5 cm layer of polyethylene foam and 0.8 cm of wood as surface finishing.

3. ACOUSTIC PERFORMANCE EVALUATION

The correct assessment of the acoustic performance of any building must be done through the evaluation of the noise insulation level of each building element. To perform this task, some procedures must be followed.

3.1. Measurement Procedures and Building Acoustic Requirements

The characterization of the acoustic performance of buildings involves measurements of some sound insulation indexes that must be done according to the EN ISO 140 Standards, Parts 4 and 5 [1, 2] and to the EN ISO 717 Standards, parts 1 and 2 [3, 4].
According to the Portuguese Building Acoustics Legislation [5], partition elements must meet some acoustic requirements. In this context, the airborne sound insulation index for partitions between dwellings and for partitions between dwellings and garages must be greater than 50 dB, and for partitions separating dwellings from commercial areas must be greater than 58 dB. The impact sound insulation index for floors separating two dwellings must be less than 60 dB and for floors separating dwellings from commercial areas must be less than 50 dB.
The airborne sound insulation index for partitions between bed or living rooms and common circulation zones of the building must be greater than 48dB and the impact sound insulation index for the same element must be less than 60dB.
The partitions elements between bed or living rooms and vertical circulation paths (stairs), when the building has elevators, must have an airborne sound insulation index greater than 40 dB.
The Portuguese Building Legislation [5] does not have any requirements for partitions between parts of the same residential unit.
For “in situ” measurements, the Portuguese Building Legislation defines an uncertainty index of 3 dB that must be added to the measured airborne sound insulation index and subtracted to the impact sound insulation index in order to take into account that experimental uncertainty.

4. MEASUREMENT RESULTS

The floors noise insulation indexes ($D_{n,W}$ and $L'_{n,\,W}$) have been determined through "in situ" experiments carried out in the four houses.
The experimental results obtained for the airborne and impact insulation indexes can be seen in Table 2 for the four types of regularization layers analyzed.

Table 2 – *Measurements results*

Studied element	**Construction solution**	**$D_{n,\,w}$ [dB]**	**$L'_{n,w}$ [dB]**
Floor between a bedroom and a living room	Type I	47	54
	Type II	42	50
	Type III	48	53
	Type IV	50	55

As Table 2 shows, the four types of floors have different acoustic performances, for both airborne and impact sound insulation.
From the measurements performed it was possible to conclude that the conventional solution (Type IV) has the best airborne acoustic insulation performance due to its higher mass but the worst impact sound insulation performance because the two layers of polyethylene foam, positioned above and bellow the low concrete layer (Figure 2), are not enough to ensure an effective elastic cut on the impact transmission.
The measurements show also that the floors with non-conventional regularization layers have better impact sound insulation indexes due to their lower masses. Type II floor shows the best impact performance because it has less stiffness and mass than the others. It must be stressed that this solution has only one layer of polyethylene foam (in opposition to the others that have two), which allows concluding that its better performance is not due to the presence of this material, but it is closely related to the presence of the expanded clay aggregates layer.
Additionally, Figures 3 and 4 show some spectra results for the same floors. Theses figures show that analysing the acoustic performance of the studied floors in the frequency domain, it is possible to reach the same conclusion as before: Type II floor behaves better than the others.
Figure 3 also shows that Type I and Type III floors have a similar airborne acoustic insulation, except for lower frequencies. In this graph is also visible that, for frequencies between 100 Hz and 630 Hz, the airborne sound insulation is similar for the four types of floors. For frequencies above 630 Hz, the behaviour of the floors becomes different, especially when comparing Type II and Type IV floors. For Type II floor, D_n stabilizes and for Type IV, D_n increases in a higher proportion. The differences between these two curves vary from 10 dB (at 800 Hz) to 19 dB (at 3150 Hz).

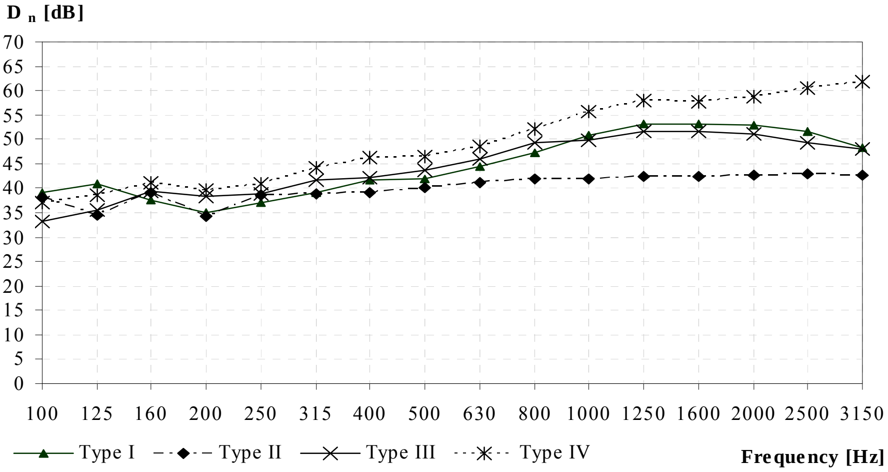

Figure 3 – *Airborne sound insulation of the four types of floors*

In Figure 4 it is visible that all the floors have a similar impact sound insulation, being Type II the one that presents the best performance and Type IV the one that shows the higher impact sound insulation values.

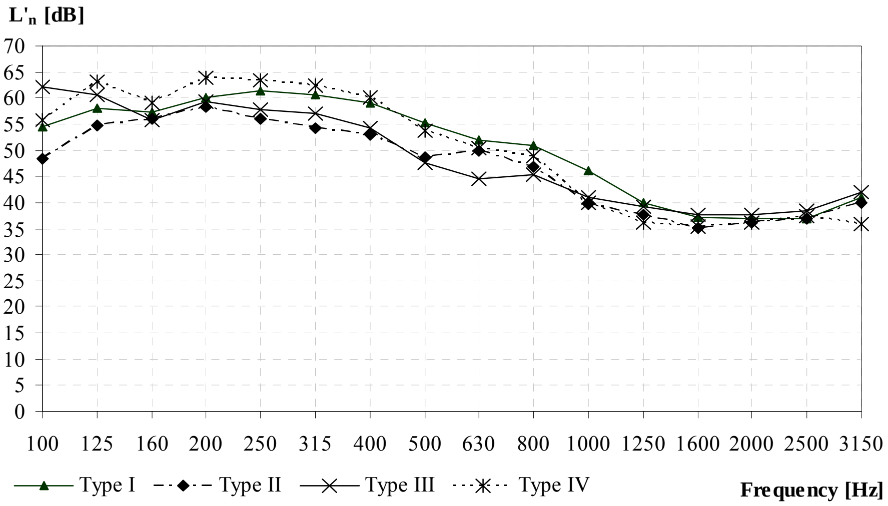

Figure 4 – *Impact sound insulation of the four types of floors*

It is also possible to observe that the differences between the impact sound insulation curves are more notorious for frequencies below 1000 Hz although these differences are not very significant.

In conclusion, according to the Portuguese Buildings Acoustic Legislation [5], the buildings' elements should accomplish the acoustic requirements that are shown in Table 3. For an easier visualization of the potentialities of the studied solutions as partitions elements, Table 3 shows a synthesis of the obtained results and the verification (or not) of the Portuguese Building Requirements, considering the uncertainty index (which means adding or subtracting 3 dB to $D_{n,w}$ or $L'_{n,w}$, respectively).

Table 3 - *Use potentialities of the analysed solutions (V - verify the Portuguese Building Requirements; NV – do not verify the Portuguese Building Requirements)*

	Regulation Requirements		**Construction solution**							
			Type I		**Type II**		**Type III**		**Type IV**	
Acoustic insulation between:	$D_{n,w}$ [dB]	$L'_{n,w}$ [dB]	$D_{n,w}$ [dB]	$L'_{n,w}$ [dB]	$D_{n,w}$ [dB]	$L'_{n,w}$ [dB]	$D_{n,w}$ [dB]	$L'_{n,w}$ [dB]	$D_{n,w}$ [dB]	$L'_{n,w}$ [dB]
bed or living rooms (receiving room) and another dwelling room (source room)	≥ 50dB	≤ 60dB	47+3 (V)	54-3 (V)	*42+3 (NV)*	50-3 (V)	48+3 (V)	53-3 (V)	50+3 (V)	55-3 (V)
bed or living rooms (receiving room) and circulation zones from the building (source room)	≥ 48dB	≤ 60dB	47+3 (V)	54-3 (V)	*42+3 (NV)*	50-3 (V)	48+3 (V)	53-3 (V)	50+3 (V)	55-3 (V)
bed or living rooms (receiving room) and vertical circulation paths (stairs) (source room) when the building has elevators	≥ 40dB	-	47+3 (V)	54-3 (V)	42+3 (V)	50-3 (V)	48+3 (V)	53-3 (V)	50+3 (V)	55-3 (V)
bed or living rooms (receiving room) and garages (source room)	≥ 50dB	-	47+3 (V)	54-3 (V)	*42+3 (NV)*	50-3 (V)	48+3 (V)	53-3 (V)	50+3 (V)	55-3 (V)
bed or living rooms (receiving room) and commercial areas (source room)	≥ 58dB	≤ 50dB	*47+3 (NV)*	*54-3 (NV)*	*42+3 (NV)*	50-3 (V)	*48+3 (NV)*	53-3 (V)	*50+3 (NV)*	*55-3 (NV)*

As Table 3 shows, Type I, Type III and Type IV floors are effective solutions as partition elements, except when separating dwellings from commercial zones (shops, industries services). Type IV floor is the one that has the best airborne sound insulation index.
Type II floor can only be used for partitions between dwellings and vertical circulation paths (stairs) when the building has elevators, due to its low airborne sound insulation index, even considering the uncertainty index.

5. CONCLUSION

In conclusion, from the analysis performed it was possible to verify that, except for the floor with clay aggregates, the studied slabs respect the Portuguese Building Requirements for the airborne and impact sound insulation index of partitions between dwellings, between dwellings and circulation pathways or vertical circulation paths and garages.
None of the studied floors achieve the exigency level for partitions between dwellings and commercial, industrial or services zones.
This study showed that the conventional floor still is the one that presents the best performance in what concerns airborne sound insulation. The new solutions, in spite of showing a better impact sound insulation, do not yet meet all the acoustic requirements of the Portuguese legislation. This means that it's necessary to proceed with the research on these materials and solutions in order to improve their quality.

6. ACKNOWLEDGEMENT

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7. REFERENCES

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