# IMPACT NOISE INSULATION PERFORMANCE OF VINYL FLOOR WITH THE FLOATING FLOOR TECHNIQUE

## *DESEMPENHO DE ISOLAMENTO AO RUÍDO DE IMPACTO DE PISOS VINÍLICOS COM A TECNICA DE PISOS FLUTUANTES*

## *DESEMPEÑO DE AISLAMIENTO AL RUIDO DE IMPACTO DE PISOS VINÍLICOS CON LA TÉCNICA DE PISOS FLOTANTES*

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### ABSTRACT
This study evaluated the acoustic performance of impact noise in prefabricated ribbed slabs with prestressed joists, using vinyl flooring as a covering and testing the efficiency of floating floors with different resilient materials. The tests were carried out by the Brazilian standards ABNT ISO 16283-2 and ISO 717-2 to determine the standard weighted impact sound pressure level (L'nT,w) in each composition tested to check that they met the minimum requirements of the Brazilian performance standard ABNT NBR 15.575-3. As a result, of the 13 vinyl flooring samples studied in the 4 cm subfloor system, only one did not satisfy the minimum requirements (82 dB). At the same time, eleven were classified at the minimum level, ranging from 67 to 80 dB, and one at the intermediate level (64 dB). Based on these results, six samples were selected for testing with the floating floor system solution using nine resilient materials. Most of the compositions showed intermediate performance levels, ranging from 62 to 56 dB, with 23 samples having a higher level (≤ 55 dB).

### KEYWORDS
Impact noise; Acoustic performance; Sound insulation; Vinyl floors.

### *RESUMO*
*Este estudo avaliou o desempenho acústico em termos de ruído de impacto em lajes pré-fabricadas nervuradas com vigotas protendidas, utilizando pisos vinílicos como revestimento e, também, testando a eficiência de pisos flutuantes com diferentes materiais resilientes. Os ensaios foram realizados conforme as normas brasileiras ABNT ISO 16283-2 e ISO 717-2 para determinar o nível de pressão sonora de impacto padrão ponderado (L'nT,w) em cada composição testada, a fim de verificar se atendiam aos requisitos mínimos da norma brasileira de desempenho ABNT NBR 15.575-3. Como resultado, das 13 amostras de pisos vinílicos estudadas no sistema de piso com contrapiso de 4 cm, apenas uma não atendeu aos requisitos mínimos (82 dB). Ao mesmo tempo, onze foram classificadas no nível mínimo, variando de 67 a 80 dB, e uma no nível intermediário (64 dB). Com base nesses resultados, seis amostras foram selecionadas para testes com a solução de sistema de piso flutuante, utilizando nove materiais resilientes. A maioria das composições apresentou níveis intermediários de desempenho, variando entre 62 e 56 dB, com 23 amostras com um nível superior (≤ 55 dB).*

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## *PALAVRAS-CHAVE*
*Ruído de impacto; Desempenho acústico; Isolamento sonoro; Revestimentos vinílicos.*

## *RESUMEN*
*Este estudio evaluó el desempeño acústico en términos de ruido de impacto en losas prefabricadas nervadas con viguetas pretensadas, utilizando pisos vinílicos como revestimiento y, además, probando la eficiencia de pisos flotantes con diferentes materiales resilientes. Los ensayos se realizaron de acuerdo con las normas brasileñas ABNT ISO 16283-2 e ISO 717-2 para determinar el nivel de presión sonora de impacto estándar ponderado (L'nT,w) en cada composición probada, con el fin de verificar si cumplían con los requisitos mínimos de la norma brasileña de desempeño ABNT NBR 15.575-3. Como resultado, de las 13 muestras de pisos vinílicos estudiadas en el sistema de piso con contrapiso de 4 cm, solo una no cumplió con los requisitos mínimos (82 dB). Al mismo tiempo, once fueron clasificadas en el nivel mínimo, variando de 67 a 80 dB, y una en el nivel intermedio (64 dB). Con base en estos resultados, se seleccionaron seis muestras para pruebas con la solución del sistema de piso flotante, utilizando nueve materiales resilientes. La mayoría de las composiciones presentaron niveles intermedios de desempeño, variando entre 62 y 56 dB, con 23 muestras en un nivel superior (≤ 55 dB).*

## *PALABRAS CLAVE*
*Ruido de impacto; Desempeño acústico; Aislamiento sonoro; Revestimientos vinílicos.*

## 1. INTRODUCTION

With population growth and urban expansion in cities, verticalization has become an alternative to meet the demands of housing and commerce in city centers. In this way, NBR 15575: all parts  has been one tool used to encourage better housing conditions by establishing minimum performance requirements for various factors, including acoustic performance.

The acoustic performance of the various systems that make up a home responds to the environmental issues they are exposed to, such as noise pollution, climate change, and the different demands of users. Since 2009, the World Health Organization (WHO) has defined noise pollution as the second largest source of pollution on the planet and a public health problem, as it can cause sleep disturbances, changes in blood pressure, and stress, among others.

Impact noise is caused by a mechanical vibration transmitted by the solid medium, that is, by the structural path; in this case, it can be transmitted by the internal and external vertical sealing systems, the roofing system, and the floor. The floor system, more specifically, is one of the boundaries between autonomous housing units, characterized by a minimal set of slabs and floor covering.

However, investigations into the acoustic performance of flooring systems are becoming increasingly complex as there are increasingly new materials and construction techniques used in civil construction. In this way, each material that makes up the floor system directly impacts the sound spectrum of impact noise insulation; therefore, insulation varies according to the floor covering, the subfloor's thickness, and the slab type adopted.

The characterization of the impact noise insulation performance of ceramic floors demonstrates that the rigidity of these coverings directly affects low frequencies, making it necessary to use resilient materials combined with the floating floor technique to mitigate sound transmission if the proposal is to achieve the higher levels recommended by NBR 15575-3. However, when the floor covering is laminated wood, there are possible compositions that achieve better performance without the floating floor technique, as these coverings have greater damping of low frequencies due to their surface density.

The choice of the slab system is also an essential factor, not only for structural reasons, as they will win, but also for acoustic performance. Slabs with a homogeneous composition (solid slabs) have greater mass, thus helping with insulation, compared to slabs with a heterogeneous composition (slabs filled with ceramic tiles, Styrofoam, etc.).

Vinyl floors, in turn, are a type of covering that is easy to install and maintain and are suitable for all types of use, even for hospital environments, due to their ease of replacing parts and cleaning . As for acoustic performance, vinyl blankets, even though they are not as rigid as other coverings, did not present sufficient sound attenuation in a sample with a reinforced concrete slab, having lower performance than laminate floors, for example. Some investigations demonstrate the toxicity capacity of this type of coating, mainly due to resins from petroleum, chemical additives, and organic compounds that can affect human health.

## 2. RESEARCH GOAL

This research evaluates the impact noise insulation performance of flooring systems composed of a prefabricated ribbed slab with ceramic tiles and prestressed joists, a 4-centimeter subfloor, and vinyl floor covering combined with the floating floor technique. Different materials are tested, such as expanded polyethylene blanket, expanded polypropylene, recycled rubber, glass wool, and polyester wool (PET).



## 3. METHODOLOGY

The Brazilian Standard ABNT NBR 15.575-1 (ABNT, 2021a) was a milestone in Brazilian civil construction, launched in 2013 and updated in 2021, establishing the minimum performance requirements for buildings. For acoustic performance, specifically in flooring systems and impact noise, the required performance criteria are divided into three categories: minimum (M), intermediate (I), and superior (S) (ABNT, 2021c). Furthermore, the measurement methodology is described by the ISO 16.283-2 standard. The values provided for in NBR 15.575-3 (ABNT, 2021c) were used to classify the performance of floor systems in terms of impact noise for cases of separation of autonomous housing units, as shown in Table 1.

| Separation element | $L'_{nT,w}$ (dB) | Performance |
|---|---|---|
| The floor system of self-contained over-bedroom housing units | 66 to 80 | Minimum (M) |
| | 56 to 65 | Intermediate (I) |
| | ≤ 55 | Superior (S) |
| Flooring systems for areas for collective use over bedrooms in autonomous housing units | 51 to 55 | Minimum (M) |
| | 46 to 50 | Intermediate (I) |
| | ≤45 | Superior (S) |

**Table 1:** Performance Criteria for Weighted Standard Impact Sound Pressure Level ($L'_{nT,w}$).
**Source:** (ABNT, 2021c)

### 3.1 Test location

The tests were carried out in (information suppressed for blind evaluation) a chamber built specifically for impact noise measurement tests. The set comprises two adjacent chambers overlapping and separated by a prefabricated ribbed slab composed of prestressed beams and ceramic tiles 13.5 cm thick. The walls are made of structural masonry made of 19 cm-thick concrete blocks, and the septa of the blocks were filled with 1:4 mortar (cement: sand). The walls have 3 cm of plaster on both sides, with a final thickness of 25 cm.

The chamber consists of an emission room, with an area of 14.33 m², and a reception room, with an area of 14.33 m² and a volume of 56.32 m³, vertically adjacent. Figure 1 illustrates the floor plan (A) and section (B).

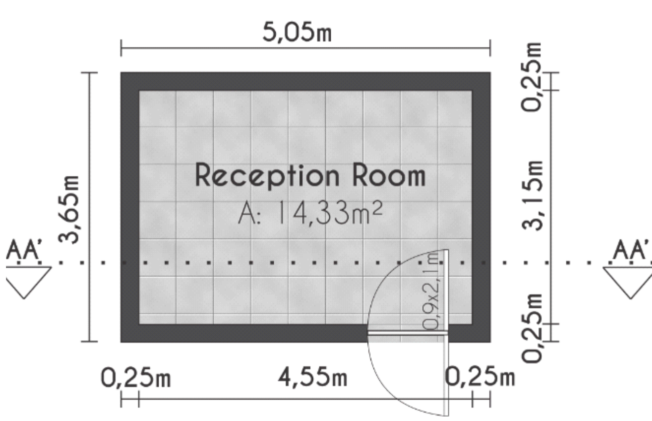
The impact noise insulation measurements in floor systems were made to simulate the field situation, as the laboratory has conduits in the slab and walls and does not disconnect the building structures from the chambers.

### 3.2 Instruments of tests

The ISO 10140-3 and ISO 10140-3 Standards require that the minimum dimensions of the subfloor exceed 0.35 by 0.35 meters. Therefore, 1 × 1 meter plates were used. The subfloor slabs were produced with mortar, and the volumetric proportions of cement and sand were 1:4, reaching an average compressive strength of 20 MPa.

Table 2 describes the equipment used in the measurements. The manufacturer defines the sound level meter (sound pressure level meter) as class 1. Therefore, it is a meter for free fields (open areas) but has a correction for use in diffuse fields (closed environments), used for measurements in an environment such as the laboratory.

The calibrator used follows the CETAC-LCA-PC06 "sound pressure level meter calibration" and CETAC-LCA-PC-03 "sound pressure level meter calibration" procedures found in IEC 61672-3:2013 and IEC 60942:2017 for the calibration of the sound pressure level meter and sound level calibrator. The equipment was calibrated before use by an accredited institute. Figure 2 demonstrates the dodecahedral omnidirectional source (A), the standard impact machine (B), and the sound pressure level meter (sonometer) (C).



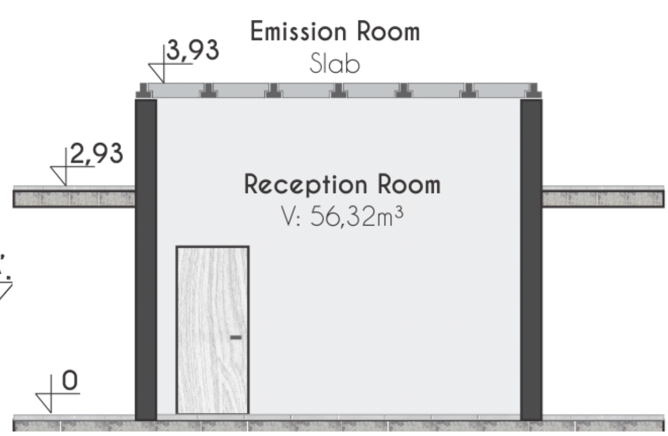




**Figure 1:** (A) Floor plan (B) Section AA
**Source:** Authors.

| Equipment | Manucaturer | Model |
|---|---|---|
| Amplifier | 01 dB | AMPLI 12 |
| Sound level calibrator | 01 dB | 4230, class 1 |
| Dodecahedral acoustic source | 01 dB | OMNI 12 |
| Standard Impact Machine | 01 dB | CALPEST-one |
| Sound Pressure Level Meter | 01 dB | Black Solo, class 1 |
| Capacitive microphone | GRAS | MCE 212 |
| Microphone preamplifier | Metravib | PRE 21 S |
| Termo-hygrobarometer | Instruterm | THB 100 |

**Table 2:** Instruments used in the tests.
**Source:** Authors.

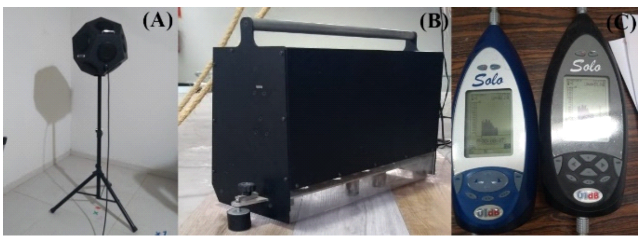



**Figure 2:** Instruments used in the tests.
**Source:** Authors.

### 3.3 Measurements procedures

NBR 15575-3 explains that tests to determine impact noise performance in flooring systems must follow the ISO 16283-2 standard . Which defines the measurement procedures to determine the standard impact level ($L'_{nT}$) and frequency bands in thirds of an octave, between 100 and 3150 Hertz (Hz), and the weighted standard impact level ($L'_{nTw}$) with data processing through ISO 717-2 . The standard ISO 16283-2 (ABNT, 2020b) determines four positions of the standard impact machine and fixed microphone in the reception room for tests in rooms with a volume of less than 20 m².

The standard ISO 16283-2 (ABNT, 2020b) defines reverberation time measurements, residual noise, and standardized impact sound pressure level as required. Therefore, the reverberation time was measured using the interrupted noise method described by NBR ISO 3382-2. Three microphone positions were used for measurements for each sound source position. Two measurements were made for each microphone position to determine the reverberation time, totaling 12 points. The microphone height used in the tests was 1.30 m, 1.90 m, and 2.3 m for the M1 and M6 microphones, M2 and M5, and M3 and M4, respectively. The distance between the microphone and the sound source used to measure the reverberation time is shown in Figure 3.

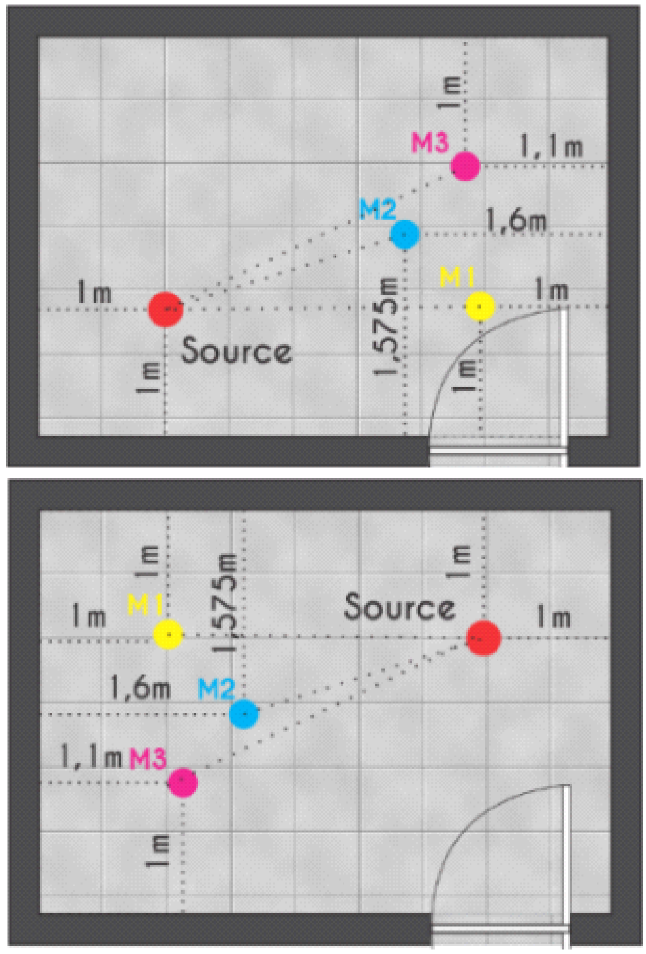



**Figure 3:** Positions of source and microphones in measurements of reverberation time.
**Source:** Authors.

Figures 4 and 5 demonstrate the positioning of the standard impact machine in the emission room (at 45º about the joists) and the fixed microphones in the reception room, respectively.

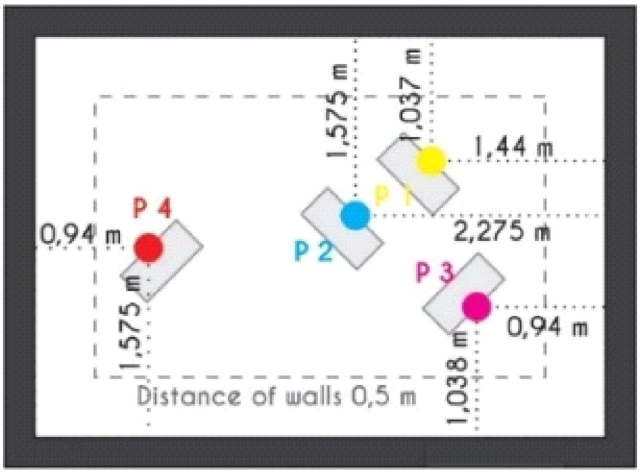



**Figure 4:** Position of standard impact machine.
**Source:** Authors.

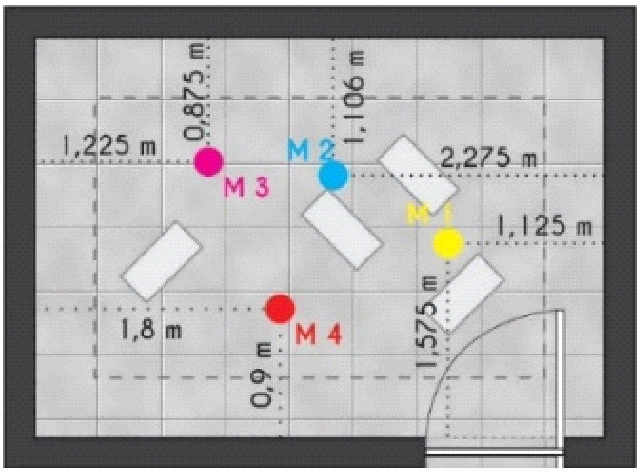



**Figure 5:** Position for fixed microphone.
**Source:** Authors.

### 3.4 Vinyl flooring test samples

Table 3 shows the test samples divided into four groups. Table 4 describes the characteristics of the floors used.

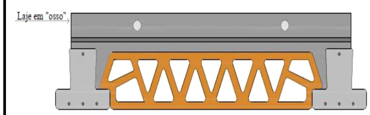
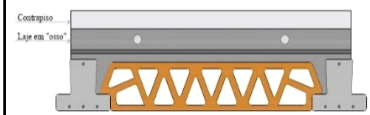
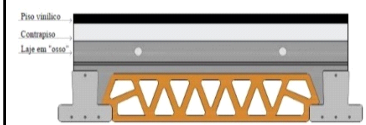
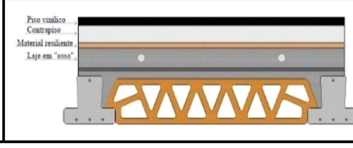
| | Composition | Installation |
|---|---|---|
| A | Slab |  |
| B | Slab + Subfloor (4 cm) |  |
| C | Slab + subfloor (4 cm) + vynil floor |  |
| D | Slab + resilien-te material + subfloor (4 cm) + vynil floor |  |

**Table 3:** Tested floor systems.
**Source:** Authors.

| Vynill floor ( VF) | Model | Thick-ness | Dimen-sion (m) | Density (kg/m$^3$) | Fire re-action (class) |
|---|---|---|---|---|---|
| 1 | Plate | 5 | 0,5×0,5 | 1039 | III A |
| 2 | Blanket | 2,4 | 2×25 | 895,93 | III A |
| 3 | Blanket | 1,2 | 2×42 | 916,67 | III A |
| 4 | Blanket | 0,7 | 2×12 | 1314,29 | III A |
| 5 | Ruler | 4 | 0,2×1,22 | 1763 | II A |
| 6 | Ruler | 3 | 0,22×1,83 | 1833,33 | II A |
| 7 | Ruler | 2 | 0,192×1,23 | 1800 | II A |
| 8 | Ruler | 2 | 0,184×0,95 | 1880 | II A |
| 9 | Ruler | 4 | 0,20×1,22 | 1915 | II A |
| 10 | Blanket | 1,4 | 2×20 | 1300 | II A |
| 11 | Blanket | 1,6 | 2×25 | 1250 | II A |
| 12 | Blanket | 0,6 | 2×25 | 1774,69 | III A |
| 13 | Blanket | 1,8 | 2×25 | 1444,44 | III A |

**Table 4:** Definitions of vinyl floor coverings.
**Source:** Authors.

### 3.5 Tested resilient materials samples

The resilient materials that were used for the tests will be presented below. It is worth mentioning that, in some cases, more than one material was considered for the same group, which could be from the same manufacturer with different thicknesses or from other manufacturers with the same thickness.

Glass wool consists of fibrous material from sodium and silica (glass and sand), covered with a waterproof film. It can be found in sheets or rolls. The glass wool used has the following characteristics: density of 60 kg/m$^3$, weight of 1.30 kg/m$^2$, and thickness of 15 mm.

Polyester wool (PET) is a fibrous material produced from recycled PET bottles with a waterproof film coating and is available in rolls. Three blankets of this material were tested, having the following characteristics: 5 mm, with a density of 20 kg/m$^3$; 8 mm, with a density of 30 kg/m$^3$; and 10 mm, with a density of 60 kg/m$^3$.

Expanded polypropylene (EPP) is a polypropylene resin combined with other elements to be expanded later. Its main characteristics are high resistance to impacts, chemicals, and lightness. The material is sold in rolls. Only a material with a thickness of 2 mm and a density of 42 kg/m$^3$ was tested.

Expanded polyethylene (EPE): This thermoplastic, made from ethylene, is chemically resistant and expands when subjected to the extrusion process, leaving it with a foamy characteristic. The material is sold in rolls. Three blankets were tested, presenting characteristics: 5 mm with a density of 20 kg/m$^3$, 5 mm with a density of 25 kg/m$^3$, and 10 mm with a density of 65 kg/m$^3$.

Recycled rubber: produced from recycled tire granules bonded with polyurethane. Only a 5 mm thick material with a 600 kg/m$^3$ density was tested.

## 4. RESULTS AND DISCUSSIONS

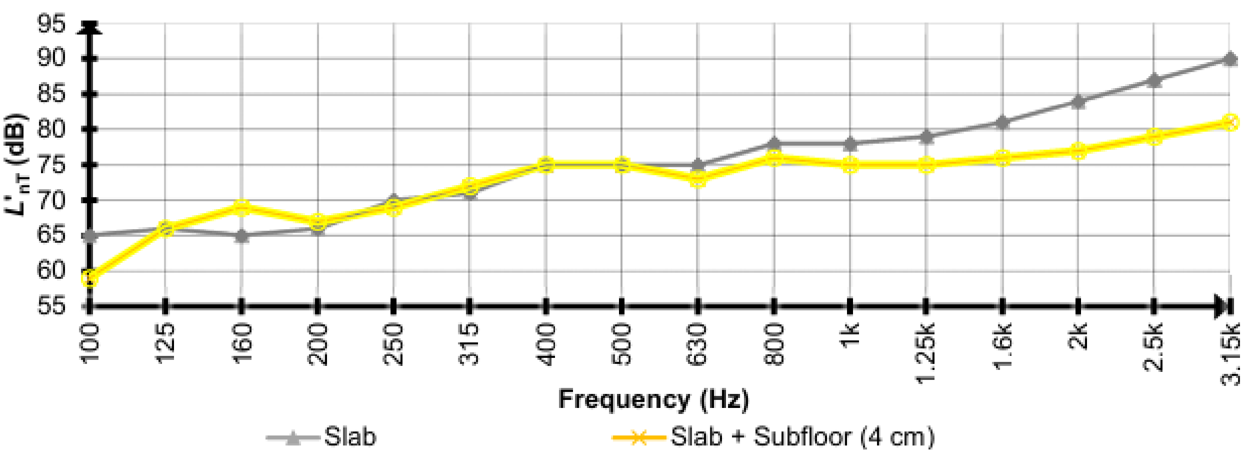
The results and discussion session will be presented in the following sequence: (i) two reference samples; (ii) thirteen samples of vinyl coverings; (iii) of the thirteen vinyl covering samples, six were selected for use in floating floor systems, highlighting the two best, the two intermediate and the two inferior samples;

### 4.1 Reference samples

The slab sample corresponds to the raw structural system without a subfloor. Figure 6 shows the impact noise insulation graph in a bone slab, performance remains below 70 dB at low frequencies and has an isolation peak in the 160 Hz range. In the following ranges, the curve remains increasing, reaching close to 90 dB at high frequencies. The L'nT,w is 91 dB, well above the minimum 80 dB required by NBR 15.575-3 (ABNT, 2021c).

In the sample with a subfloor, it is possible to observe a behavior similar to the bone slab, remaining below 70 dB at low frequencies, with an isolation peak in the 100 Hz range, continuing to increase in the following bands, reaching close to 80 dB in the bands of high frequencies. The L'nT,w is 84 dB, above the minimum determined by the standard.






**Picture 6:** Reference samples.
**Source:** Authors.

#### 4.1.1 Vynil floor samples

Figure 7 shows the acoustic performance for impact noise insulation of the floor system consisting of slab, subfloor, and vinyl coverings.

Thirteen samples of different floor coverings are included, six of which stand out for the study's application of the floating floor technique.

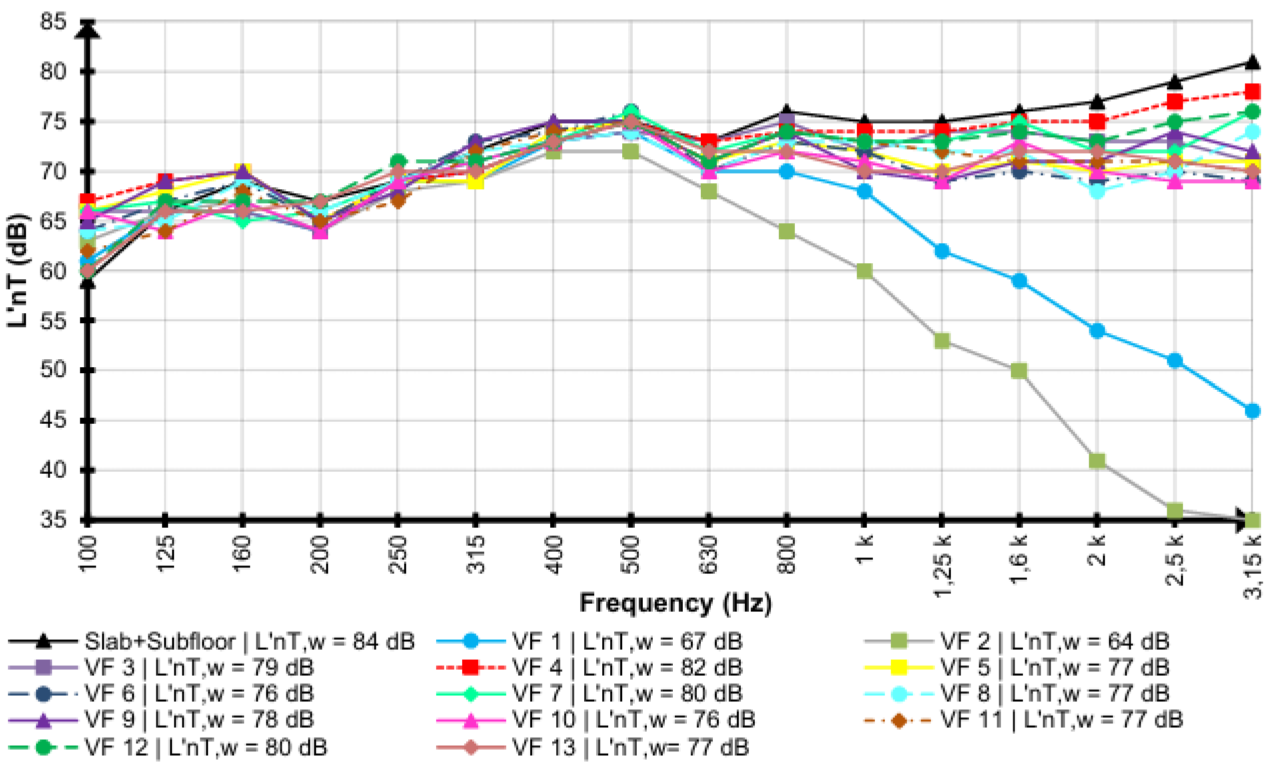
In this study, only one sample of vinyl sheet was tested (VF 1–5 mm vinyl sheet). The curve increases up to 500 Hz, and the graph decreases from the frequency range of 630 Hz, with the best results occurring in the high-frequency bands. The L'nT,w is 67 dB, falling within the minimum level by NBR 15.575-3 (ABNT 2021c). When considering the reference curve (slab + subfloor), it can be seen that up to 630 Hz, the curves present similar values at almost all frequencies since, from this point onwards, the difference between the values increases. The reference curve is rising, and that of VF 1 is decreasing.

The vinyl plank samples show similar behavior at all frequencies. However, the reference curve increases from the 1 kHz frequency band onwards. From the floor samples, the curves are dispersed but present a significant difference at high frequencies, where the results are better.

When considering L'nT,w, all samples fall within the minimum level determined by the performance standard: VF 6 = 76 dB and the highest of VF 7 = 80 dB.

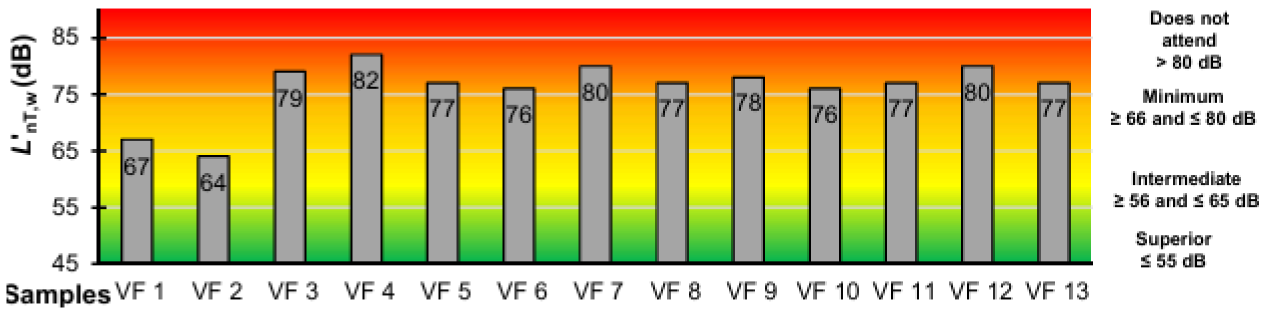
All vinyl blanket samples show similar behavior; however, the VF 2 curve sharply decreases from the 500 Hz frequency range onwards, with the most significant difference compared to the reference curve at high frequencies. In Figure 8, the L'nT,w results of the samples are compared to the performance levels indicated by NBR 15.575-3:2013 (ABNT, 2021c) to classify them according to the criteria that take into account the floor system, separating autonomous housing units.






**Picture 7:** Performance of samples with Vynil floors

**Source:** Authors.




**Picture 8:** Classification of samples in the performance requirements of NBR 15575-3
**Source:** Authors.

### 4.1.2 Floating floor samples

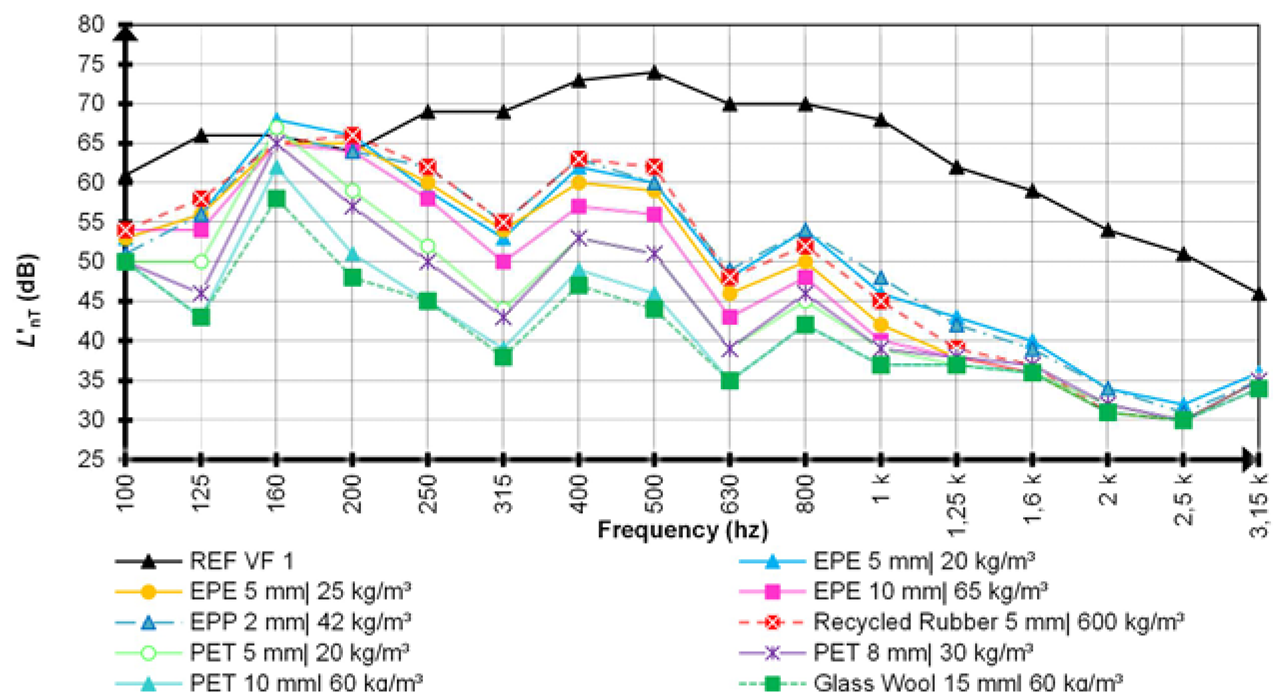
Six samples of vinyl flooring were meticulously chosen, with the two most promising results, VF 2 = 64 dB and VF 1 = 67 dB, two intermediate results, VF 6 = 76 dB and VF 5 = 77 dB, and, finally, the two least favorable results, VF 7 = 80 dB and VF 4 = 82 dB. These results, as depicted in Figure 9, provide a comprehensive overview of the performance of the floating floor system, composed of the slab, resilient materials, subfloor, and 5 mm vinyl board (VF 1).

Three types of expanded polyethylene were tested: 5 mm with 20 kg/m$^3$, 5 mm with 25 kg/m$^3$, and 10 mm with 65 kg/m$^3$ (EPE). The expanded polyethylene samples have curves with similar behavior, there is a loss of performance in the ranges of 160, 400 and 800 Hz, in addition, they present values above the reference curve at 160 Hz and 200 Hz.

From the loss of insulation at 800 Hz, the curves decrease and reach the best performance in the 2.5 kHz range, with 32 dB for the 5 mm sample and a density of 20 kg/m$^3$ and 30 dB for the other 5 mm sample and the 10 mm sample. The L'nT,w of the 5 mm EPE sample with a density of 20 kg/m$^3$ is 56 dB and is classified at the intermediate level of the performance standard. However, for a sample with the same thickness and density of 25 kg/m$^3$, the L'nT,w is 55 dB and 53 dB for a sample with a thickness of 10 mm, both of which fall within the upper level of the standard.

A sample of expanded polypropylene was tested with a thickness of 2mm and a density of 42 kg/m$^3$ (EPP). The L'nT,w of the EPP sample is 56 dB, with classification at the intermediate level by NBR 15.575-3 (ABNT, 2021c).






**Picture 9:** Performance of floating floor samples with VF1.
**Source:** Authors.

For the slab + polyester wool + subfloor (4 cm) + vinyl floor (5 mm) (PET) system, polyester wool was tested in three variations: 5 mm with 20 kg/m³, 8 mm with 30 kg/m³ and 10 mm with 60 kg/m³. The polyester fleece materials demonstrated remarkably similar curves despite their different manufacturers, densities, and thicknesses. Notably, there was a more significant performance loss than the reference in the 160 Hz range, with a value of 67 dB, for the 5mm sample. However, the best performance of PET wool was observed in the high-frequency bands, reaching a peak of 30 dB in the 2.5 kHz band for all three blankets.

The 5 mm sample achieved a L'nT,w of 50 dB, while the intermediate 8 mm sample reached a L'nT,w of 49 dB, classifying it as the top level of the performance standard. The best performance was found by 10 mm PET wool, reaching a L'nT,w of 46 dB.

When considering the results obtained, together with the thicknesses and densities, it can be concluded that the sample with the smallest thickness (5 mm) and lowest density (20 kg/m³) achieved the worst result. The sample with intermediate thickness (8 mm) and intermediate density (30 kg/m³) obtained an intermediate result. Finally, the thicker blanket (10 mm) and higher density (60 kg/m³) achieved the best outcome.

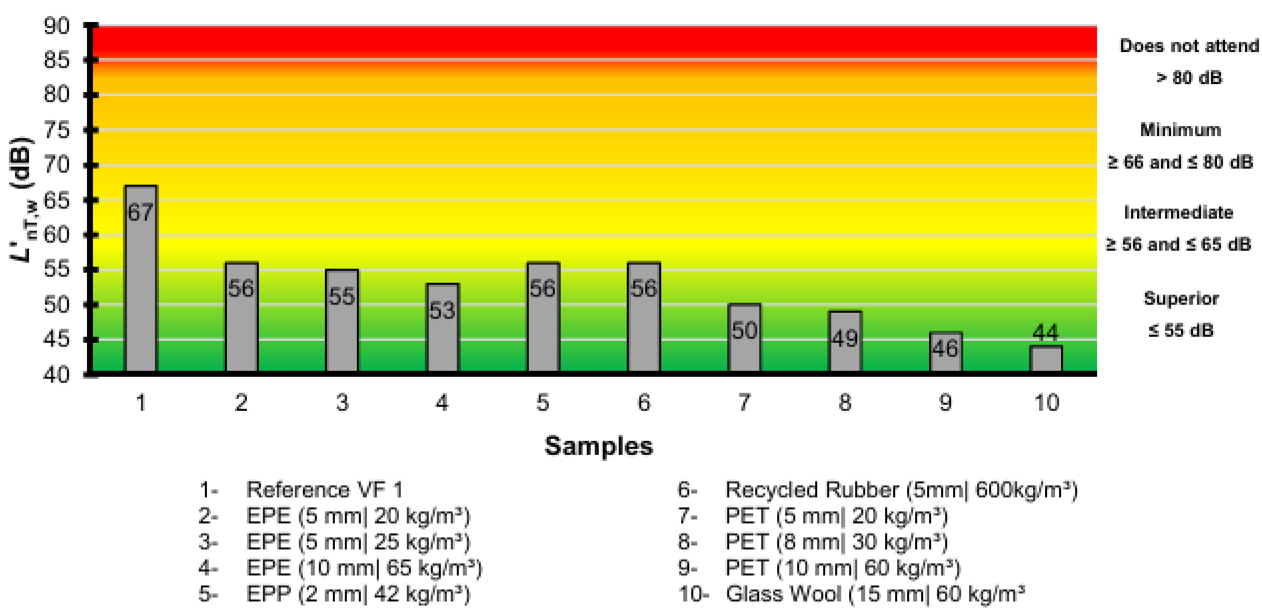
Thus, the best acoustic performance for the floating floor system with vinyl flooring 1 and polyester wool is related to the thickness and density of the resilient material; that is, they are directly proportional.

The acoustic performance for the system: slab + glass wool (15 mm and a density of 60 kg/m³) + subfloor (4 cm) + vinyl covering (5 mm) obtained a L'nT,w of 44 dB, reaching the level higher than the performance standard, being the lowest value found among all the samples tested, with a difference of 23 dB about the reference sample. When observing the graph, it can be seen that the addition of resilient materials caused the curves of the floating floor system to show similar behavior, with the most significant insulation losses occurring in the 160 Hz range, with 5 mm of expanded polyethylene and 20 kg/m³, the worst peak was reached (68 dB). The best performances occur in the 2.5 kHz range, with practically all samples being close to 30 dB.

The worst performances occur in the low and medium frequency bands. The best results happen in the high frequencies, where the curves stabilize. Glass wool typically performs best. Still, in this case, 10 mm polyester wool showed similar performance, with a better result than glass wool at low and medium frequencies and the same at high frequencies.

Figure 10 demonstrates the classification of samples according to the requirements of standard NBR 15575-3 (ABNT, 2021).






**Picture 10:** Classification of floating floor samples + VF1 in the performance requirements of NBR 15575-3

**Source:** Authors.

It can be seen that most of the materials are at the upper level (≤ 55 dB), and there are three samples at the intermediate level (≥ 56 and ≤ 65 dB). The 5mm expanded polyethylene blankets (density of 25 kg/m³) and 10 mm are classified at the top level, with L'nT,w 55 and 53 dB, respectively.

Therefore, the other 5 mm blanket (density of 20 kg/m³) is placed in the middle and close to the upper one with a L'nT of 56 dB, with the expanded polypropylene and recycled rubber. Finally, the polyester wool and glass wool blankets are included in the upper level, with the 5 mm PET wool (L'nT,w = 50 dB), the 8 mm (L'nT,w 49 dB), and the 10 mm (L'nT,w = 46 dB), whereas the glass wool presented the lowest and best results of all with L'nT,w = 44 dB.

In this way, all resilient materials tested can be used in conjunction with the construction system of a prefabricated ribbed slab with prestressed joists and a 4 cm subfloor with a 5 mm vinyl board, falling within the requirements of NBR 15.575-3 (ABNT, 2021c) for the floor system, separating autonomous housing units.

Figure 11 demonstrates the impact noise insulation performance of the floating floor samples with the 2.4 mm thick vinyl blanket, which presented the best insulation result for the compositions without floating floors at 64 dB (VF 2).

Three expanded polyethylene (EPE) samples were tested: 5 mm with 20 kg/m³, 5 mm with 25 kg/m³, and 10 mm with 65 kg/m³. The curves of the expanding polyethylene samples have similar behavior, with a performance loss in the ranges of 200, 400, 800, and 3150 Hertz. In addition, they present values above the reference curve at 200 Hz for blankets with a thickness of 5 mm.

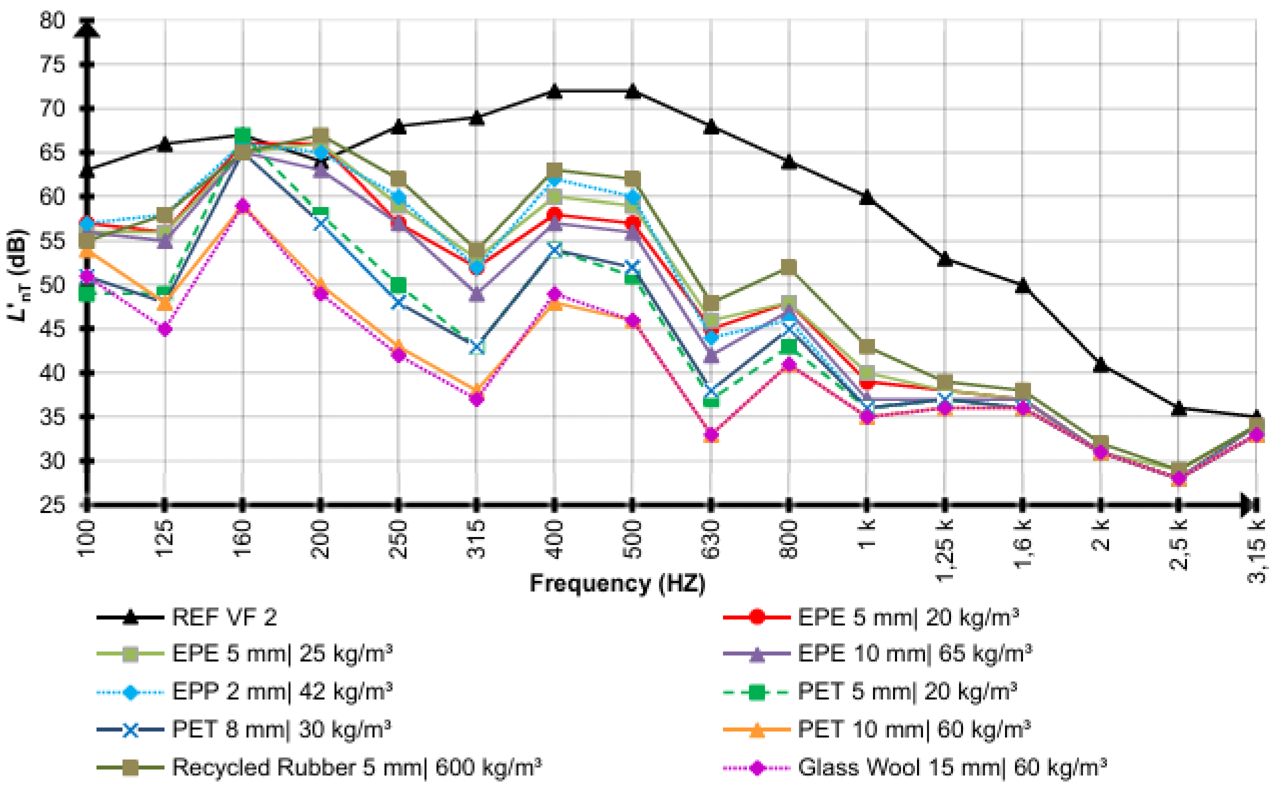
From 800 Hz onwards, the curves descend and reach their best performance at 2500 Hz. The L'nT,w of the two 5mm EPE samples is 54 dB; the 10 mm sample showed 53 dB of performance. The three samples are classified at the top level of the NBR 15.575-3 performance standard (ABNT, 2021c).

The composition slab + expanded polypropylene (2 mm) + subfloor (4 cm) and vinyl blanket (2.4 mm) present the L'nT,w of the expanding polypropylene is 55 dB, which is classified at the top level by the performance standard.

The performance curve of the expanded polypropylene (EPP) sample is similar to that of the expanded polyethylene (EPE) samples. It presents lower performance at low frequencies, with values above the reference curve at 200 Hz. Performance improves from the 1000 Hz frequency range onwards, reaching the best performance at 2500 Hz.

The recycled rubber sample's performance curve






**Picture 11:** Performance of floating floor samples with VF2

**Source:** Authors.

shows similar behavior to the previous ones, with a more significant insulation loss than the reference curve in the 200 Hz range. Furthermore, it presents performance loss points in the 400 and 800 Hz ranges. At 800 Hz, the curve shows decreasing behavior, with the best performance at 2.5 kHz. The L'nT,w of the recycled rubber sample is 56 dB, which is at the intermediate level.

The performance curves of PET blankets exhibit a consistent pattern, with insulation loss peaks at 160, 400, and 800 Hz. Notably, the most impressive performance is observed at high frequencies, with a peak of 28 dB in the 2500 Hz range. This key finding underscores the importance of high-frequency insulation performance.

The 5 and 8 mm thick samples both achieved a L'nT,w of 49 dB, ranking them at the top level of the performance standard. However, the 10 mm PET blanket stands out with a L'nT,w of 45 dB, one of the best results among all the tested flooring and resilient materials samples.

Moreover, the system slab + polyester wool (10 mm) + subfloor (4 cm) + vinyl floor (2.4 mm) ranks at the top level for this classification. It demonstrates its suitability for areas of collective use over autonomous units.

Adding glass wool to the floating floor system caused the performance curve to be below the reference curve. The most significant insulation loss is 59 dB in the 160 Hz frequency range. From this range onwards, the difference between the sample and reference curves increases, presenting a performance peak at 630 Hz. The most significant isolation gain occurs in the high-frequency bands.

The resilient materials samples showed curves with similar behavior. Most insulation weaknesses occur in the 160 Hz frequency range, with 5 mm polyester wool with a lower density (20 kg/m$^3$) achieving the worst result (67 dB). However, recycled rubber showed a loss of performance at 200 Hz. The best insulation performance occurs in the 2500 Hz range, with almost all samples reaching 28 dB.

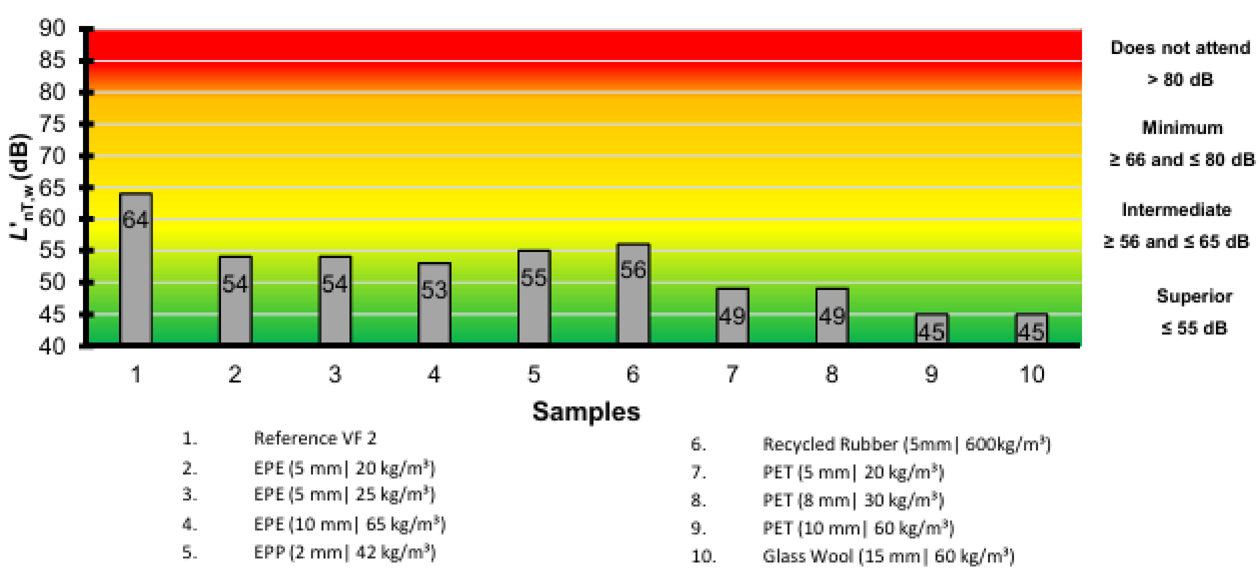
Furthermore, this system's best results are found in the high-frequency bands, where the curves stabilize. The worst performances occur in the low and medium-frequency bands.

Next, there are expanded polyethylene (EPE) blankets, which show similar behavior throughout the curve. However, the 10 mm blanket obtained better results than the other two samples, all of which were equal at high frequencies.

Glass wool and polyester wool samples fill the bottom with the chart, and glass wool typically performs best. Still, in this case, 10 mm polyester wool showed similar performance, with glass wool performing better at low frequencies and equal at medium and high frequencies. It is worth mentioning that the choice between glass wool (15 mm) and polyester wool (10 mm) depends on the cost/benefit and the possibility of using a thinner or thicker blanket. The other pet wools perform well, close to glass wool in the high-frequency bands.

Figure 12 shows the classification and comparison of the results in L'nT,w of the samples with the levels determined by NBR 15.5757-3 (ABNT, 2021) for the criterion that considers the floor system separating autonomous housing units.






**Picture 12:** Classification of floating floor samples + VF2 in the performance requirements of NBR 15575-3
**Source:** Authors.

It can be seen that the majority of resilient materials for the floating floor technique are found at the upper level (≤ 55 dB), and only one sample is at the intermediate level. In this way, all the materials studied can be used in conjunction with the prefabricated ribbed slab system with prestressed joists and a 4cm subfloor with a 2.4mm vinyl blanket, falling within the requirements of the performance standard for the floor system separating autonomous housing units.

Figure 13 demonstrates the results obtained in the tests of the floating floor system tested with the vinyl blanket sample with a thickness of 0.70 mm (VF 4), which received the worst result of all samples tested, with L'nT,w of 82 dB.

With the change of floors, it is possible to see that the behavior of the curves with the EPE samples is similar to the others previously studied. However, the curves present linearity, varying between 50 and 70 dB, with peak performance loss in the frequency ranges of 200, 400, and 500 Hz, and at 200 Hz, the loss exceeds the reference curve of the vinyl coating. They present improved isolation in the 315, 630 and 1000 Hz bands, in addition, the best performances occur in the medium frequency bands, varying between 55 and 50 dB. The L'nT,w of the two samples with a thickness of 5 mm is 62 dB, while the L'nT,w of the 10 mm EPE is 61 dB.

The expanded polypropylene (EPP) blanket's performance curve shows insulation loss in the 200, 400, and 800 Hz ranges, with the 200 Hz range exceeding the reference curve. The best isolation occurs in the frequency ranges of 100, 315, 630, and 1000 Hz, after which the curve stabilizes below 55 dB. The sample has a L'nT,w of 62 dB.

The recycled rubber performance curve varies between 50 and 70 dB, presenting insulation loss in 200, 400, and 800 Hz ranges. At 200 Hz, the loss exceeds the reference curve by 2 dB. The best acoustic insulation behaviors occur in the ranges of 100, 315, and 630 Hz, and from 1250 Hz onwards, the curve decreases. The L'nT,w of the recycled rubber sample is 61 dB.

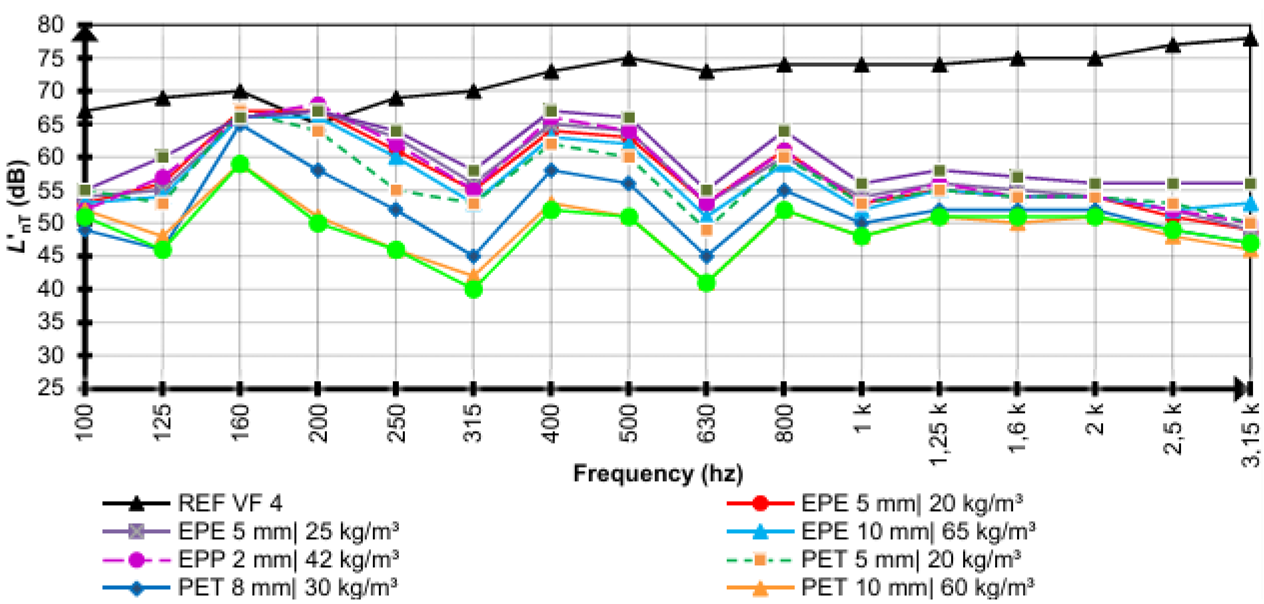
The expanded polypropylene (EPP) blanket's performance curve shows insulation loss in the 200, 400, and 800 Hz ranges, with the 200 Hz range exceeding the reference curve. The best isolation occurs in the frequency ranges of 100, 315, 630, and 1000 Hz, after which the curve stabilizes below 55 dB. The sample has a L'nT,w of 62 dB.

The recycled rubber performance curve varies between 50 and 70 dB, presenting insulation loss in 200, 400, and 800 Hz ranges. At 200 Hz, the loss exceeds the reference curve by 2 dB. The best acoustic insulation behaviors occur in 100, 315, and 630 Hz ranges, and the curve decreases from 1250 Hz onwards. The L'nT,w of the recycled rubber sample is 61 dB.

In all samples, PET wool has three performance losses in the 160, 400, and 800 Hz bands. The best performances are at 125, 315, and 630 Hz frequencies, reaching close to 40 dB.

The 5 mm polyester wool obtained a L'nT,w of 61 dB, the 8 mm blanket is 58 dB, and the 10 mm blanket is 56 dB, all classified at the intermediate level by the performance standard (ABNT, 2021).

The performance curve of this arrangement, with the addition of 15 mm glass wool, showed the most significant difference in the reference curve compared to the other samples studied. Furthermore, there was a considerable loss of performance in the 160 Hz range, reaching 59 dB.




**Picture 13:** Performance of floating floor samples with VF4

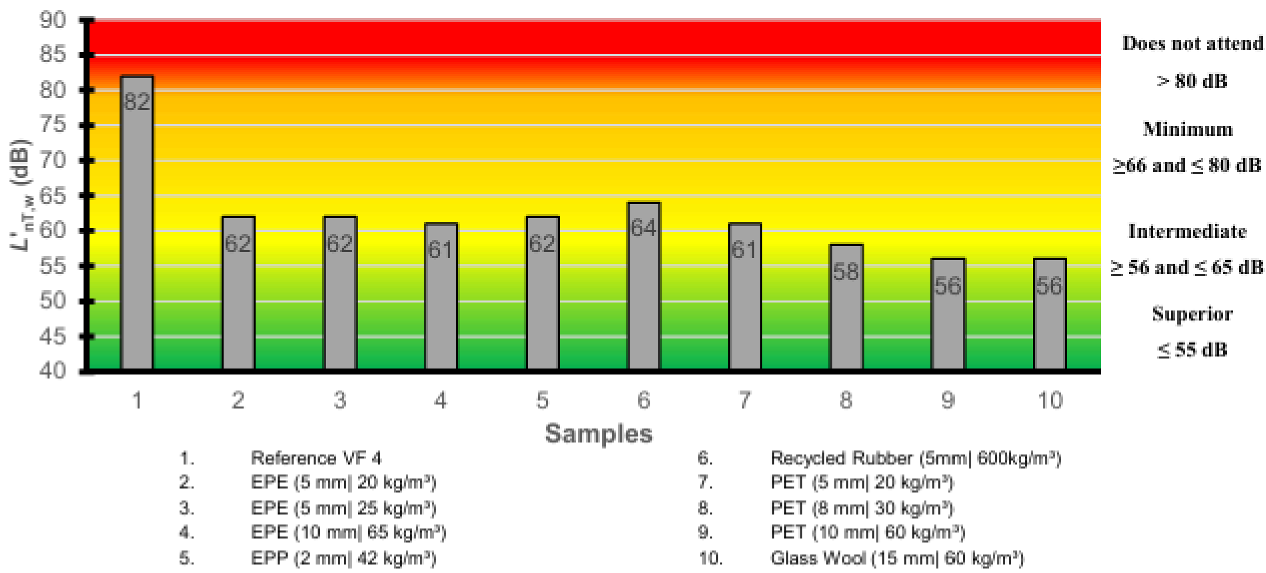
**Source:** Authors.

Now, the best L'nT occurs at frequencies of 315 and 630 Hz, close to 40 dB.

The sample has a L'nT,w of 56 dB, reaching the intermediate level of the performance standard. The result is the same as that of pet wool, with a thickness of 10 mm and a difference of 26 dB in the reference sample.

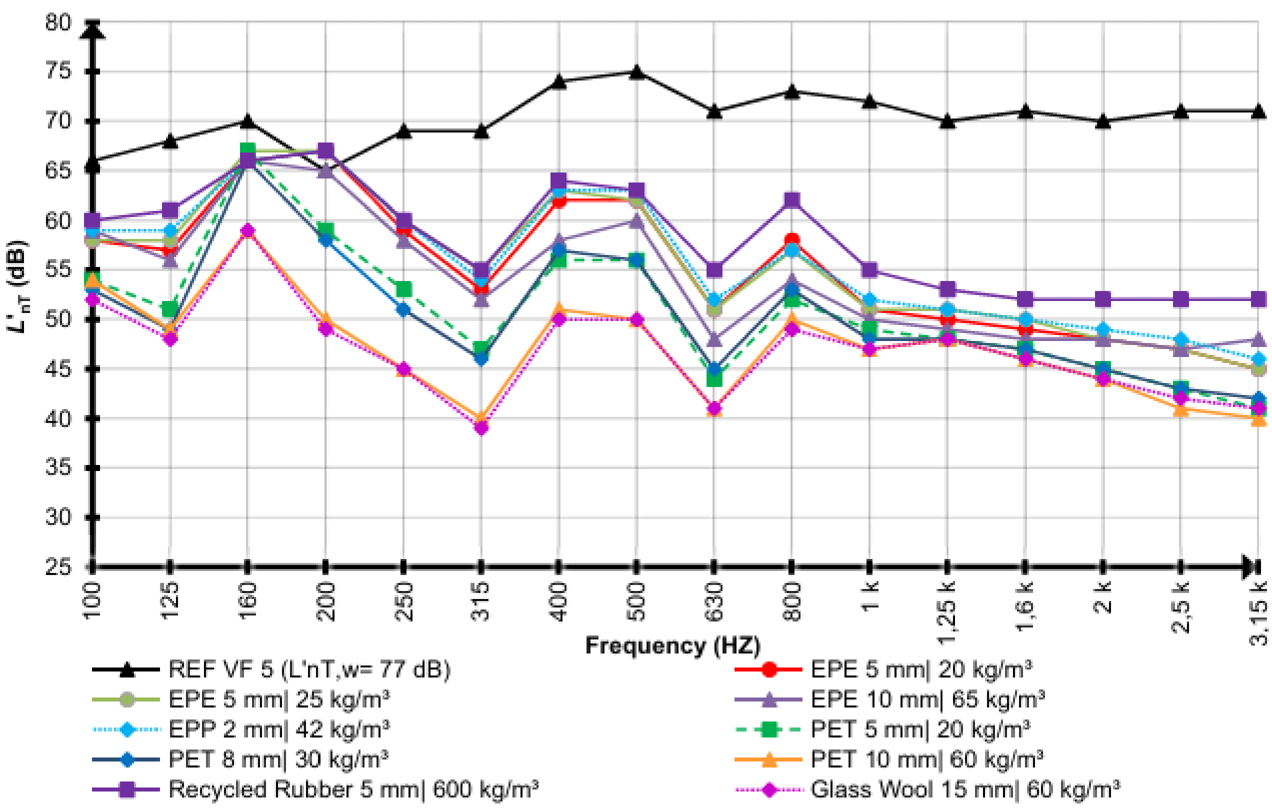
Figure 14 demonstrates the classification of samples according to the requirements of the performance standard, NBR 15575 (ABNT, 2021c).

The results obtained in the tests of the floating floor system tested with the vinyl floor sample 5 with a thickness of 4 mm, which received the second-worst result (80 dB), are shown in Figure 15. Emphasizing that this floor is laid clicked, one piece fits into the other.




**Picture 14:** Classification of floating floor samples + VF4 in the performance requirements of NBR 15575-3

**Source:** Authors.




**Picture 15:** Performance of floating floor samples with VF5

**Source:** Authors.

EPE blankets present insulation loss at 200, 500, and 800 Hz frequencies. At 200 Hz, the loss is more significant in 5 mm blankets and the same in 10 mm blankets, about the reference. The best isolation results occur in the 125, 315, and 630 Hz bands.

Expanded polyethylene with a thickness of 5 mm and different densities showed very similar behaviors, having the same or very close values at various frequencies. According to the performance curve, they present better isolation at high frequencies. The L'nT,w of the 5 mm samples is 59 dB, while the 10 mm sample was 58 dB.

The EPP sample presents performance losses at 200, 400, and 500 Hz frequencies; at 200 Hz, the decrease is more significant than the reference curve. Now, the best isolation occurs in the 315 and 630 Hz bands. From 1000 Hz onwards, the curve decreases. The L'nT,w is 59 dB, being classified at the intermediate level by the performance standard (ABNT, 2021c).

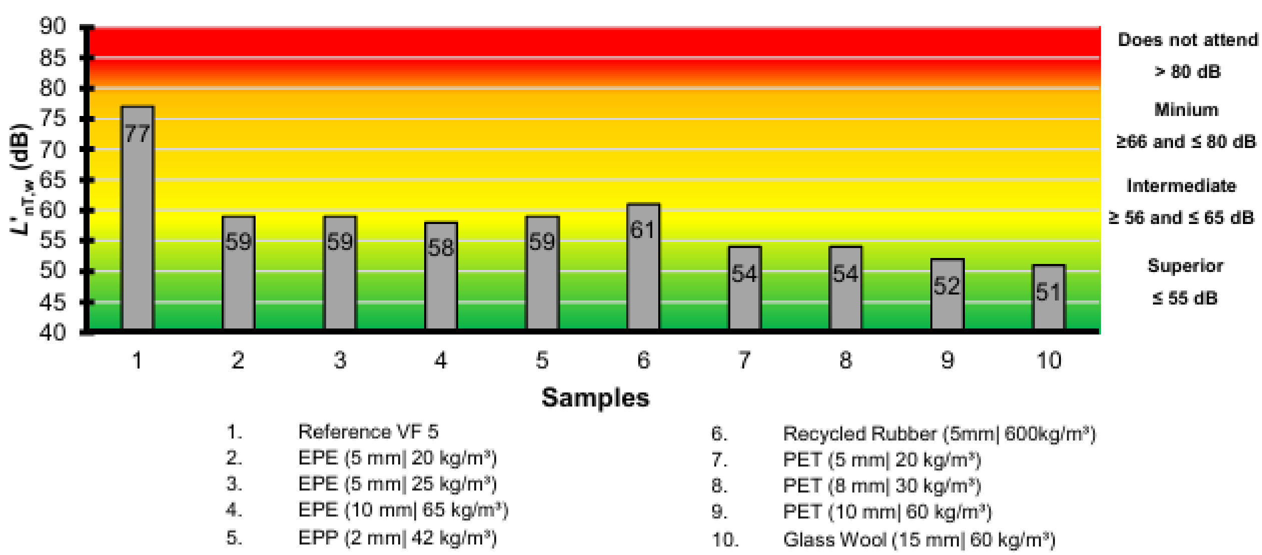
It presents a performance loss at 200, 400, and 800 Hz, with 200 Hz exceeding the reference curve. Now, the best isolation occurs at 315 and 630 Hz.

The pet wool samples show similar behavior, with the values of the curves of the 5 and 8-mm blankets coinciding at various points in the frequency bands. Now, the curve of the 10 mm sample stands out, presenting better results in practically its entire extension.

Performance losses occur at frequencies of 160, 400, and 800 Hz. Isolation peaks occur at frequencies of 125, 315, and 630 Hz. The curve decreases from 1000 Hz onwards.

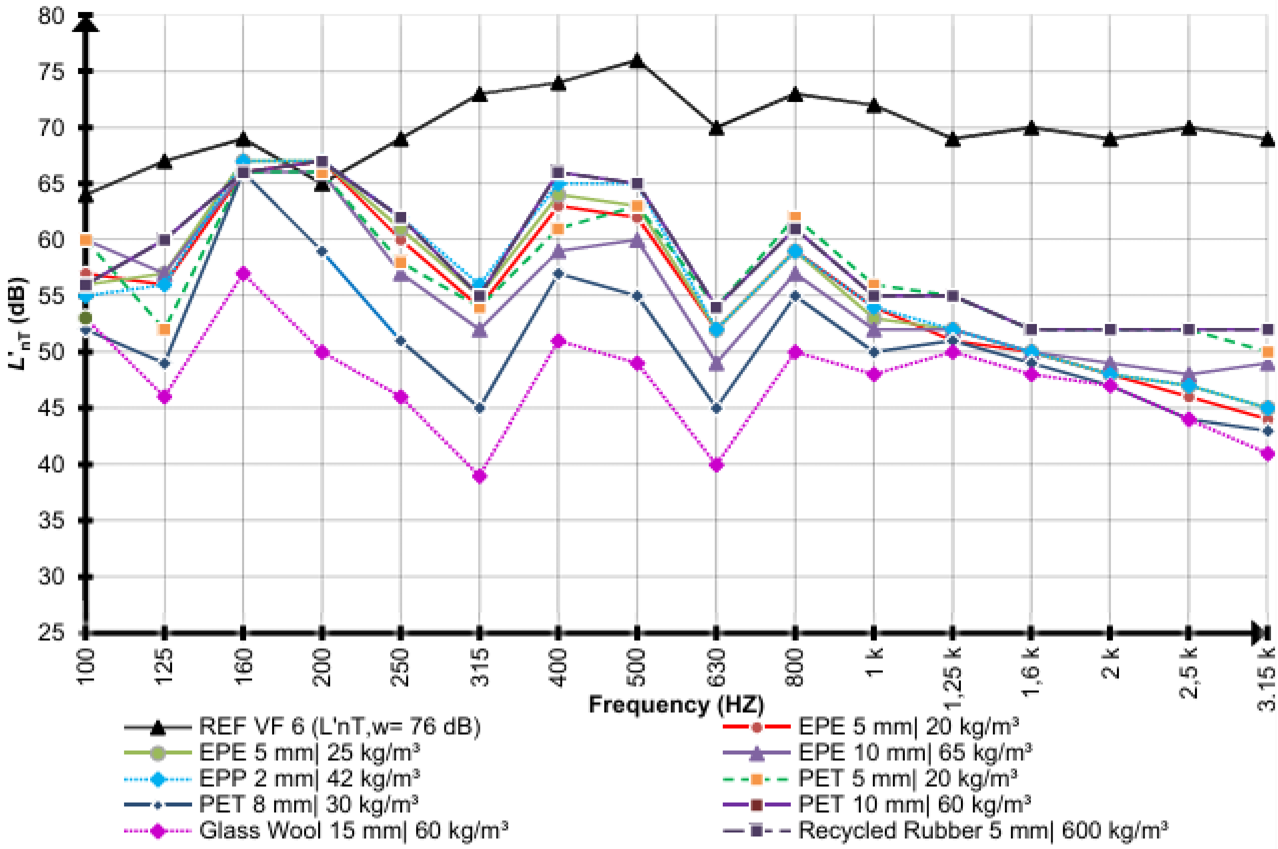
It can be seen that five samples of resilient materials are classified at the intermediate level (≥ 56 and ≤ 65 dB), and four samples are classified at the upper level (≤ 55 dB), as shown in Figure 16. In this way, it is possible to understand that This flooring system can be used to attenuate impact noise.

Figure 17 shows the results obtained in testing the floating floor system with a sample of vinyl covering (VF6), 3 mm thick, which obtained an intermediate result, with L'nT,w of 76 dB.




**Picture 16:** Classification of floating floor samples + VF5 in the performance requirements of NBR 15575-3

**Source:** Authors.




**Picture 17:** Performance of floating floor samples with VF6

**Source:** Authors.



Expanded polyethylene (EPE) curves have similar behavior. For the 5mm blankets, performance loss occurs at 200, 400, and 800 Hz, whereas for the 10 mm blanket, it occurs at 200, 500, and 800 Hz, and for all samples, the loss of insulation at 200 Hz exceeds the reference curve. Isolation gains occur at frequencies of 125, 315, and 630 Hz. Furthermore, from 1000 Hz onwards, the curves are decreasing, obtaining the lowest value at 3150 Hz. The L'nT,w of all samples is 59 dB.

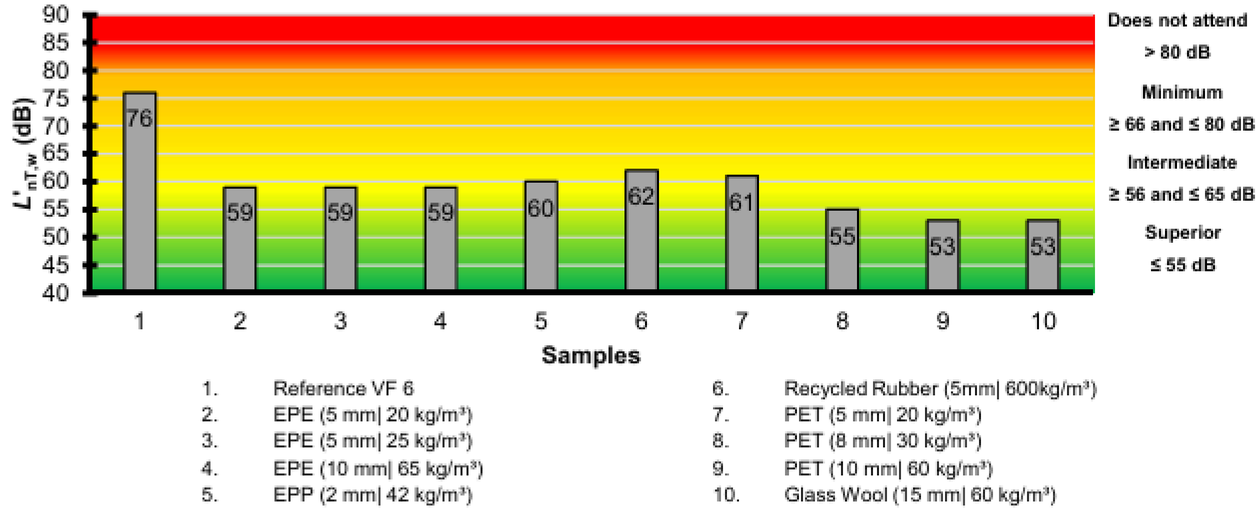
The curve shows a performance loss for the EPP sample at 160, 200, 400, 500, and 800 Hz frequencies. At 200 Hz, the loss is more significant than the reference curve. From 800 Hz onwards, the curve decreases with the best isolation results. The L'nT,w is 60 dB, classified at the intermediate level by the NBR 15575-3 performance standard (ABNT, 2021c).

The acoustic performance curve of recycled rubber varies between 50 and 70 dB, presenting insulation loss in the ranges of 200, 400, and 800 Hz, and at 200 Hz, the loss exceeds the reference curve by 2 dB. The best insulation values now occur at 100, 315, and 630 Hz frequencies. From 1600 Hz onwards, the curve stabilizes at 52 dB, the best results found. The L'nT,w of the recycled rubber sample is 62 dB, classifying it, according to NBR 15.575-3 (ABNT, 2021c), at the intermediate level.

For samples with polyester wool (PET), the performance loss is present in the curve of the 5 mm blanket in the bands 160, 200, 500, and 800 Hz. At 200 Hz, it exceeds the reference curve by 1 dB, and for the other two samples (8 mm and 10 mm), the losses are 160, 400, and 800 Hz. The best isolation values occur at 125, 315, 630, and 3150 Hz.

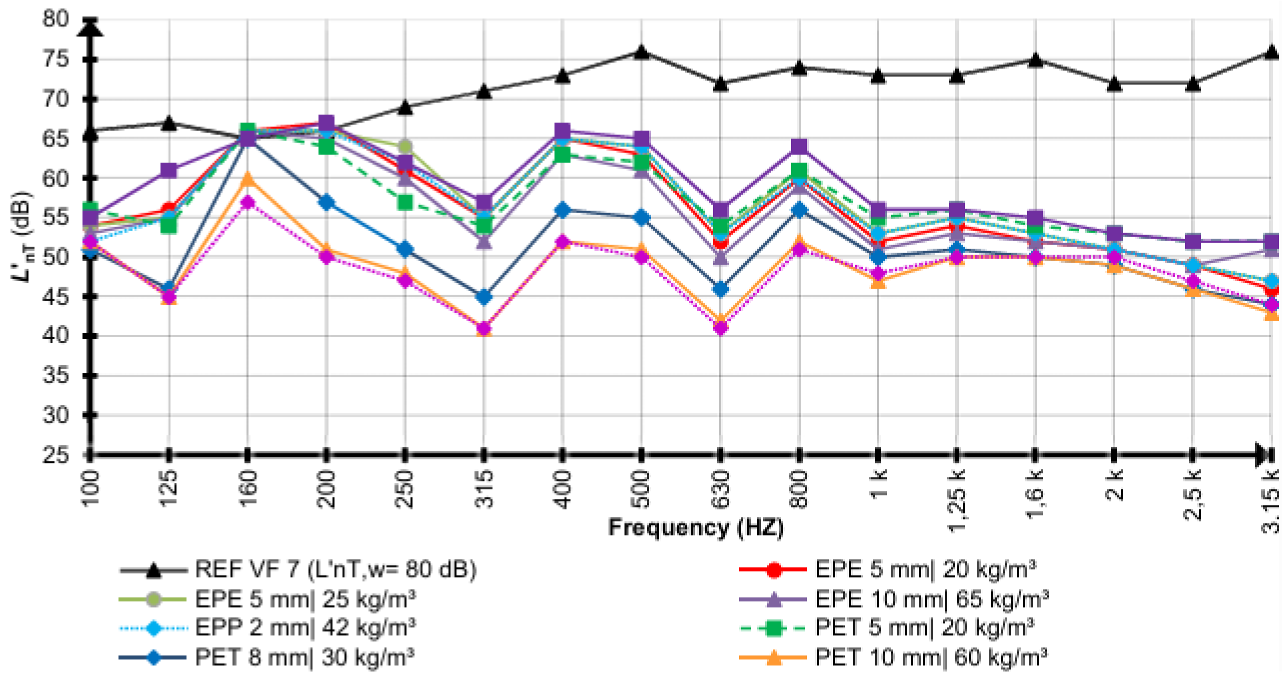
The 5 mm polyester wool obtained a L'nT,w of 61 dB, classifying it as the intermediate level. The 8 mm and 10 mm blankets are, respectively, 55 and 53 dB, classified at the top level by the NBR performance standard 15575-3 (ABNT, 2021c).

The curve of the floating floor system with glass wool showed the most significant difference in the reference curve. Performance losses occur at 100, 160, 400, 800, and 1250 Hz frequencies. The best isolation values occur in 125, 315, 630, and 3150 Hz bands. The L'nT,w is 53 dB, classified at the top level by the NBR 15575-3 performance standard (ABNT, 2021c). Figure 18 demonstrates the classification according to the NBR 15575-3 performance standard (ABNT, 2021c) for the tested samples, and Figure 19 shows the performance of the floating floor with the VF7 sample.




**Picture 18:** Classification of floating floor samples + VF6 in the performance requirements of NBR 15575-3

**Source:** Authors.




**Picture 19:** Performance of floating floor samples with VF7

**Source:** Authors.

EPE blankets show similar behavior, varying between 45 and 70 dB. At 160 and 200 Hz frequencies, the results obtained from expanded polyethylene blankets exceed the reference points. With this system implemented, the noise will be more significant at these frequencies than laying only the vinyl floor 7.

There is a gain in acoustic insulation at frequencies of 315, 630, 1000, and 3150 Hz. The samples present loss of insulation at different points: for the 10 mm blanket, the loss occurs in the 160 Hz range; for the 5 mm blanket with a density of 25 kg/m³, the loss is constant in the 160 and 200 Hz bands and, for another 5 mm blanket with a density of 20 kg/m³ the loss is at the frequency of 200 Hz.

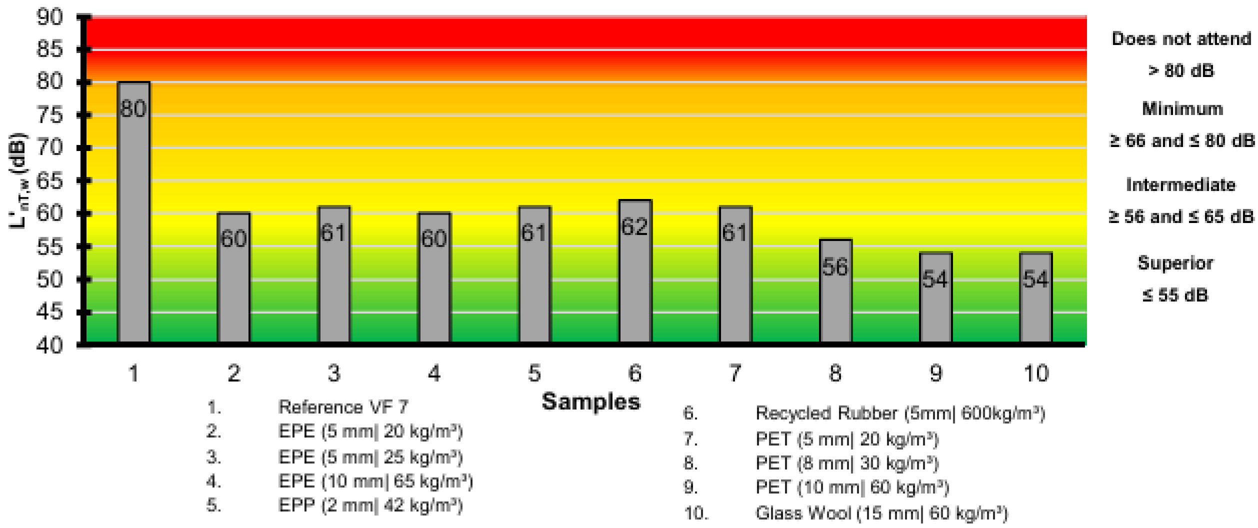
The system with the expanded polypropylene (EPP) sample presents insulation loss at frequencies of 160, 200, 400, and 800 Hz, and in the first two bands, they exceed the points of the reference curve. Now, isolation gains occur in the bands of 100, 315, 630, and 1000 Hz, and from this frequency onwards, the curve decays until reaching 47 dB at the frequency of 3150 Hz. The L'nT,w is 61 dB, classified at the intermediate level according to the performance standard.

The performance curve of recycled rubber varies between 50 and 70 dB. Performance loss occurs at 200, 400, and 800 Hz; at 200 Hz, the loss is more significant than the reference curve point. Isolation gains occur in the ranges of 100, 315, and 630 Hz, and from 1000 Hz onwards, the curve decreases, obtaining the best isolation results.

The curves of the pet wool samples show similar behavior, making it possible to visualize and identify the blankets according to thickness and density, verifying that the curve with the best result is for the 10 mm sample. The loss of insulation occurs in the frequency ranges of 100, 160, 400, and 800 Hz; in addition, the 5mm blanket presents a more significant loss in the 160 Hz range than that of the reference curve and, at the same point, the 8mm sample mm got the same result.

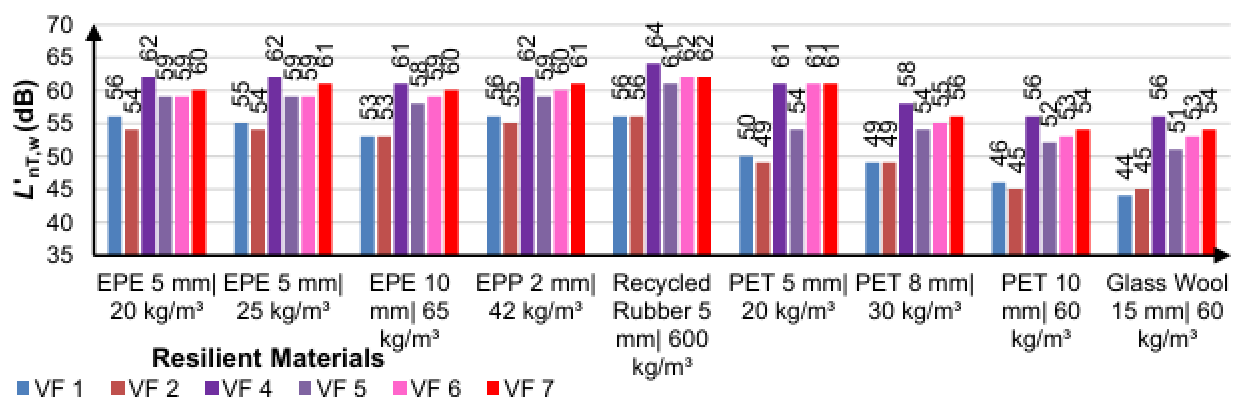
The glass wool sample curve obtained the most significant distance to the reference curve, varying from 41 to 57 dB. Performance loss occurs in frequency bands of 100, 160, 400, and 800 Hz. Isolation gains occur in 125, 315, 630, and 3150 Hz bands.

The results obtained (L'nT,w) in the samples of vinyl coverings tested in the floating floor system were compared with those of the respective resilient materials. Figure 20 shows the comparison with the requirements of NBR 15575 (ABNT, 2021c) and the Figure 21 shows this comparison, which was separated according to the group of resilient materials, presenting the column with the value obtained from that material in the six coatings tested.




**Picture 20:** Classification of floating floor samples + VF7 in the performance requirements of NBR 15575-3

**Source:** Authors.




**Picture 21:** Comparison between all floating floor system samples

**Source:** Authors.

## 5. CONCLUSIONS

Concerning the acoustic performance of the construction system of the ribbed prefabricated slab with prestressed joists and ceramic tiles, the bone slab obtained a L'nT,w of 91 dB, which is a very high value compared to other existing slabs. To this end, it was noted that the choice of construction typology directly influences the quality and performance of the building and the type of solution to the problem that will be specified and recommended. Adding the 4 cm subfloor improved performance by 7 dB, as the L'nT,w is 84 dB. That is, the increase in thickness improved the system's acoustic performance. However, it still does not meet the minimum required by the performance standard.

The result achieved by VF 2 (2.4 mm vinyl blanket) is due to the manufacturer considering the floor acoustic. Attenuating up to 19 dB, it attenuated more significantly at 20 dB. VF 1 (5 mm vinyl sheet) is also regarded as acoustic. With 15 dB isolation, however, it managed to attenuate 17 dB. This realization clarified that vinyl floors with acoustic treatment could attenuate impact noise as a simpler solution than installing a floating floor. However, the cost of applying each system should be considered, as vinyl flooring with this specification tends to have a higher value than others.

The results of the floating floor technique compared with the criteria determined by NBR 15.575-3 (ABNT, 2021c) for flooring systems separating autonomous housing units, with the chosen six vinyl flooring samples. The floors VF 1 (5 mm vinyl sheet) and VF 2 (2 mm vinyl sheet) obtained the best results in all samples of resilient materials tested. Of 18 samples, 14 were classified at the top level and the rest at the intermediate level but very close to the upper one with 56 dB. The worst results were found using recycled rubber blankets, the worst being 64 dB. However, all are classified as intermediate level.

To the worst result found in the simple system (slab + subfloor + vinyl floor) of VF 4 (0.70mm blanket) with L'nT,w = 82 dB, which did not reach the minimum level, the use of resilient materials attenuated 26 dB in glass wool and 10 mm PET wool, in addition, all samples fell into the intermediate level. In this way, all floating floor systems studied fit the requirements stipulated by NBR 15.575-3 (ABNT, 2021c) when considering the criteria for separating autonomous units at intermediate and higher levels.

As the study demonstrated, using vinyl flooring combined with the floating floor technique, a new construction method with limited research in the field, can achieve adequate acoustic performance levels for impact noise insulation, meeting established standards. Future perspectives in this area include exploring new resilient materials that could further enhance the efficiency of acoustic insulation systems and analyzing performance across different types of slabs and coverings. Additionally, further studies could consider the long-term durability of the materials used, and the environmental impact associated with the lifecycle of these floorings. These advancements could contribute to developing efficient and sustainable construction solutions, meeting the growing demands for acoustic comfort in urban environments.

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WML: conceptualization, formal analysis, investigation, methodology, visualization, writing - original draft, writing - review & editing and data curation.

GM: resources, supervision, writing - review & editing, project administration and funding acquisition.

EHLS: formal analysis and writing - review & editing.

CTR: formal analysis and writing - review & editing.

GME: conceptualization, formal analysis, methodology, visualization, writing - original draft and writing - review & editing.

**Conflict declaration:** nothing to declare.