Impact Sound Insulation of Floors
Using
Recycled Polyurethane Foam

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SUMMARY

Noise is the most common cause of complaint to environmental health officers in England and impact noise through ceilings has been identified as being particularly disturbing to occupants of dwellings. Floating floors incorporating a resilient layer are an accepted method of reducing impact noise and traditionally rockwool or mineral fibre quilts have been used. Flexible polyurethane open cell foams are now used in some systems in thinner layers than mineral fibre quilts and are more pleasant to handle. These have been the subject of research at Sheffield Hallam University and laboratory investigations of their static and dynamic properties suggested that reconstituted open cell foam produced from scrap polyurethane might offer advantages over virgin open cell foam which is used in some floating floor systems. This paper briefly describes the laboratory tests carried out on open cell polyurethane foams and presents results from the first field tests on flooring systems comprising reconstituted foam now available in the market.

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1 INTRODUCTION

Environmental health officers in England receive more complaints concerning unwanted noise than about any other single issue. The 1993/94 annual report by the Chartered Institute of Environmental Health found an increase of 10.5% in the number of complaints about noise over the previous year [1]. In conversion flats the most disturbing noise was found to be impact noise from dwellings above [2] and one accepted method of reducing impact noise through ceilings is to install a "floating floor" in the room above where the walking surface is laid on a resilient layer thus decoupling it from the rest of the structure [3]. Floating floors in dwellings most commonly use mineral fibre slabs as a resilient layer although closed cell foams such as flooring grade polystyrene are also used.

Despite their initial good acoustic performance, as floors comprising mineral fibres are walked on their brittle fibres rub together and this action can, in the long term, result in the loss of resilience. These materials are unpleasant to handle and their fibres can pose a potential health risk should they become airborne. Polyurethane foams do not pose such problems and lightweight floating floors comprising low density flexible virgin open cell polyurethane foams as the resilient layer have been developed [4]. The behaviour of these foams is the subject of research at Sheffield Hallam University, UK.

This research programme is concerned with investigating the static and dynamic performance of polyurethane foams used under floors and the development of useful laboratory tests for predicting the acoustic performance of flooring systems comprising these materials. As a result of this work, reconstituted polyurethane foam was identified as having characteristics which suggested that it would be particularly useful as a resilient layer in low profile floating floors. This in turn led to a programme of laboratory and field tests for a manufacturer wishing to produce such flooring systems. As a result of this research work, floating floors comprising reconstituted foam have now been launched on the market.

This paper presents some results from laboratory tests on open cell polyurethane foams and samples of flooring systems incorporating them. It describes how these tests were used to develop flooring systems incorporating reconstituted foam and illustrates the improvements obtained from these systems on wooden and concrete floors.

2 BACKGROUND

Acoustically, the main problem with all resilient layers is that if they are sufficiently stiff to give a floor the required stability they are less capable of providing a high degree of acoustic isolation and a balance has to be struck between mechanical and acoustic properties [5]. Tests to determine the compressive behaviour of virgin and reconstituted foams were carried out according to BS 4443 [6] and typical results are shown in Figure 1.

For the virgin foam, there is a clearly defined yield point around a stress of about 5kPa after which the foam suffers a rapid increase in strain up to nearly 40% without any increase in stress. This behaviour is typical of low density virgin open cell polyurethane foams [7,8] and once the yield stress for such a foam used in a floating floor is exceeded a rapid deflection will be perceived by anyone walking across it.

The compressive stress-strain characteristics for all the reconstituted foams investigated have differed from those of virgin foams in that they do not exhibit a clearly defined yield point. Indeed all have shown a virtually linear increase in stress with strain up to around 40%. This suggested that floors comprising these materials as a resilient layer might not exhibit the sort of deflection typical of virgin foams and that using reconstituted foam was worthy of further investigation.

Reconstituted foam was also considered attractive because it is produced from a waste product and should therefore offer the potential for energy saving. The scrap foam used in its production is derived from both the production of virgin slabstock foams and from recycled foam from furniture and other applications. According to the Polyurethane Foam Association, despite efforts to minimise waste in the production of polyurethane foam, up to 30% can become scrap after cutting and shaping foam for different applications [9]. By recycling the scrap a useful material is produced from what might otherwise be a potentially expensive disposal problem and the cost of foam used in end product manufacturing can be reduced. In the USA recycling scrap polyurethane foam is a substantial part of the industry and carpet underlay, for example, is often produced from recycled foam. In the UK recycling is not so developed although some companies see the potential of utilising scrap foam and are seeking to develop their existing recycling facilities in order to improve efficiency and quality control of the production process.

3 DYNAMIC BEHAVIOUR OF FOAMS

The only standard identified for the assessment of the dynamic properties of materials used as resilient layers in floating floors is BSEN 29052-1 [10]. This standard determines the dynamic stiffness of the materials by identifying the resonant frequency of a standard system comprising a sample of the test material. This method was adopted in the test programme with one slight departure from the recommended test set up [11] and virgin and reconstituted foams with densities ranging from 21 to 65 kg/m^3 and 62 to 230 kg/m^3 respectively were tested.

Systems with low natural frequencies usually give useful vibration isolation over a greater range of frequency and it was found that reconstituted foams having density of less than 80 kg/m^3 gave the standard test system a lower natural frequency than any of the virgin foams tested. It was felt that results from these tests, together with their stress-strain characteristics, suggested that reconstituted foam might offer advantages over virgin foam for use in low profile floating floor systems.

The publication of the results from this first series of laboratory tests has led to outside interest in the project being expressed from industry. An industrial partner joined the programme with a view to develop and produce sound reducing flooring systems. Reconstituted foam was decided upon as the resilient layer but the best density and thickness of the material had to be decided upon. Static and dynamic tests similar to those described previously were carried out and an example of data from the dynamic tests is shown in Figure 2.

In the above test the load plate required by BS EN 29052-1 was placed on sections of flooring cut to the specified size and the natural frequencies of the systems were obtained. It can be seen that the 8mm thick layer gave the system a lower natural frequency and that this might mean better vibration isolation. This was supported by results from vibration transmissibility tests. As a result of the laboratory tests, reconstituted foam of density 78 kg/m^3 was selected for use in the flooring products and 8mm was chosen for the thickness of the foam layer for systems comprising 9mm medium density fibre board and 18mm chipboard. These systems were then produced and tested in the field.

4 FIELD TESTS

A series of field tests according to BS 2750 part 7 were carried out [12] in order to assess the acoustic performance of the different systems. Investigations were carried out on wooden and concrete floors which were rated according to BS 5821 [13] before and after refurbishment with the different floating floor systems. Examples of such floors are illustrated in Figures 3 and 4. The tests on wooden floors were conducted in a large stone fronted house about a hundred years old which is typical of the sort of property often converted into separate dwellings. Two different floors were tested, one on the first floor of the house and the other on the second floor which had absorbent material placed between the joists when it was upgraded. Results from these tests are shown in Figures 5 to 8. Results from tests on a hollow beam concrete floor on the premises at Sheffield Hallam University are given in Figures 9 and 10.

Figures 5 and 6 show test results for the timber floor. An improvement in the Weighted Standardised Impact Sound Pressure Level ($L'_{nT,w}$) of 5 dB was obtained by simply placing the tongued and grooved interlocking medium density fibre board - MDF- and foam system on the existing floor. The MDF system was then replaced by a chipboard system which when tested produced a slightly better performance, 6 dB, which is probably to be expected due to the extra mass added by chipboard compared to medium density fibre board. After the attic floor had been tested the floorboards were lifted and 150mm of rockwool absorbent of density 24 kg/m^3 was laid between the joists which were irregularly spaced with centres between 400 and 480mm. Many of the old floorboards were damaged when lifted and so these were replaced by 22mm thick standard chipboard flooring on which the resilient flooring systems were placed. The results from these tests are illustrated in Figures 7 and 8 showing improvements in $L'_{nT,w}$ of 10 and 8 dB for the chipboard and medium density fibre board systems respectively. Improvements in the performance of the hollow beam concrete floor were 31 and 30 dB for the chipboard and medium density fibre board systems respectively.

5 DISCUSSION

Before its refurbishment the first wooden floor tested in the old house failed to meet the required impact noise insulation rating[3] value for floors in conversion flats ($L'_{nT,w}$ = 65 dB). The chipboard and medium density fibre board systems reduced the $L'_{nT,w}$ values to 62 dB and 63 dB respectively which would be acceptable in England, Wales and Northern Ireland for floors separating flats in converted houses and would also make a discernible difference to occupants of the room below. In the case of the medium density fibre board system this improvement was achieved without raising the upstairs floor level by more than 17mm. When used in conjunction with a new supporting surface and absorbent material between the joists the improvements with the floating floor systems were more significant, $L'_{nT,w}$ of 55 dB and 57 dB for chipboard and medium density fibre board respectively, which are comfortably within the requirements for refurbished dwellings in England.

The improvements observed with these systems on the hollow beam concrete floor are much larger than those seen on the wooden floors tested. For non-acousticians it may seem surprising that improvements in the single figure $L'_{nT,w}$ value should vary so much for the same system on different floors. The systems appear to work better on concrete floors than on wooden floors but the apparent difference in performance is due to the nature of the original floor and the standard method of rating floors laid down in BS 5821. It can be seen that the untreated hollow block concrete floor transmitted higher frequencies much better than either of the wooden floors. These higher frequencies are more easily attenuated by the lightweight resilient floating floors systems and it is this along with the rating method which explains the greater improvements in $L'_{nT,w}$.

Other research has suggested that reconstituted foams may give improved performance at low frequencies [14] which is potentially significant because it is in this frequency range that systems comprising thin layers of flexible open cell foam perform least well. Research work in the USA [15] suggests that the performance of timber floors can be made worse by the addition of a resilient walking surface by increasing the amplitude of vibration at their fundamental natural frequency (usually less than 100 Hz). If it is the case that using reconstituted foam as a resilient layer does not create this adverse effect then a positive contribution to sound control in multiple occupation dwellings will have been made. This remains to be fully investigated however.

The research programme at Sheffield Hallam University has identified reconstituted foam as a useful material in floating floor systems but a laboratory test capable of predicting the performance of floors incorporating such material has yet to be developed. Tests according to BSEN 29052-1 have been useful in comparing the performance of different foam layers and those giving systems lower natural frequencies appear to give better vibration isolation in laboratory tests. However, BSEN 29052-1 states that this test is unsuitable for determining the dynamic stiffness of materials with airflow resistivities of less than 10 kPa s/m^2 where the stiffness due to the enclosed air is significant. This is the case for the reconstituted foams identified as being most useful for use in floors in this study. Furthermore this standard is not applicable for floors which impose a static load of less than 0.4 kPa on the resilient layer. The surface density of 22mm chipboard is around 16 kg/m^2 which means an imposed load of about 0.2 kPa without furniture and fittings which again means that the standard is inappropriate for these flooring systems.

Nothing has been found in the literature regarding tests for predicting the performance of flooring systems comprising low airflow resistivity reconstituted foam although work has been done on systems incorporating closed cell foam by researchers in Japan [16,17]. Future work will concentrate on developing laboratory tests for predicting the likely benefit of using floating floor systems incorporating low airflow resistivity polyurethane foams by seeking correlation with field tests. With more lightweight, low profile sound reducing flooring systems coming into the market it is felt that the development of such tests would be a major contribution to the field.

6 CONCLUSIONS

Flexible open cell polyurethane foams offer advantages over traditional materials used in floating floors. Laboratory tests on virgin and reconstituted open cell polyurethane foam suggest that the latter is more suited for use as the resilient layer in floating floor systems. Field tests on floating floors comprising this foam have shown significant improvements in impact noise insulation in refurbishment projects. These improvements have been obtained without raising floor levels as much as when using systems comprising mineral fibre. In addition, the floors do not exhibit the sorts of deflections observed when the yield point of virgin foam is exceeded.

In addition to its performance, the wider adoption of the use of reconstituted foam should assist in keeping down the cost of virgin slabstock foam as well as alleviating a potentially expensive disposal problem.

A standard test for assessing the usefulness of these materials as resilient layers in floating floors needs to be developed.

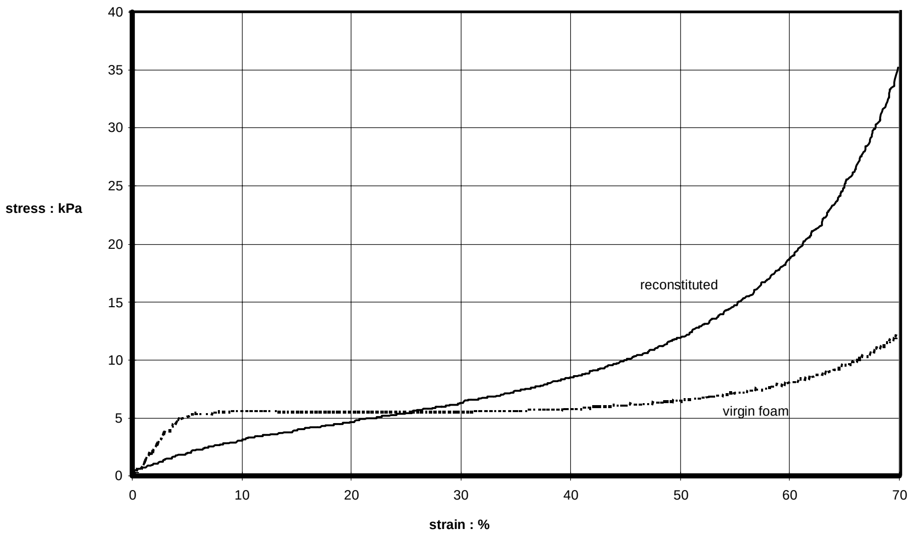


Figure 1: Stress strain curves from the first compression stroke on the foam

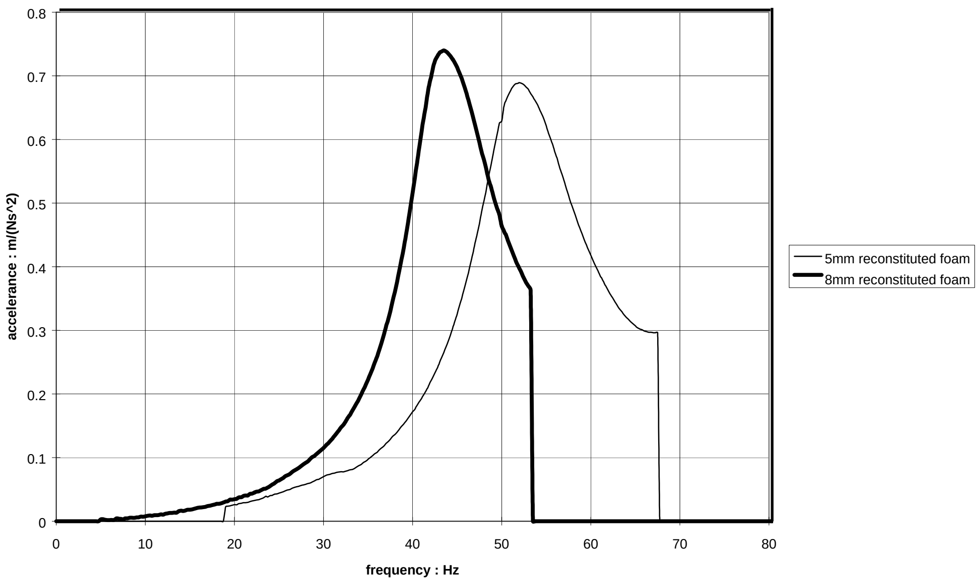
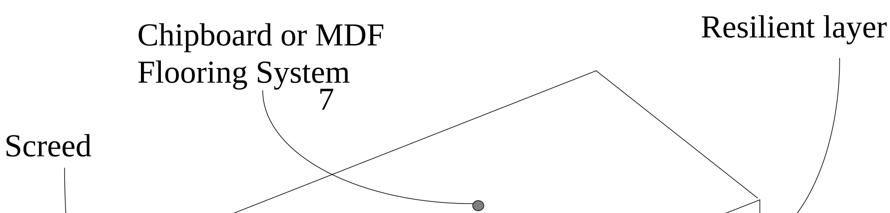


Figure 2: Results from dynamic testing on two thicknesses of 78 kg/m^3 reconstituted foam



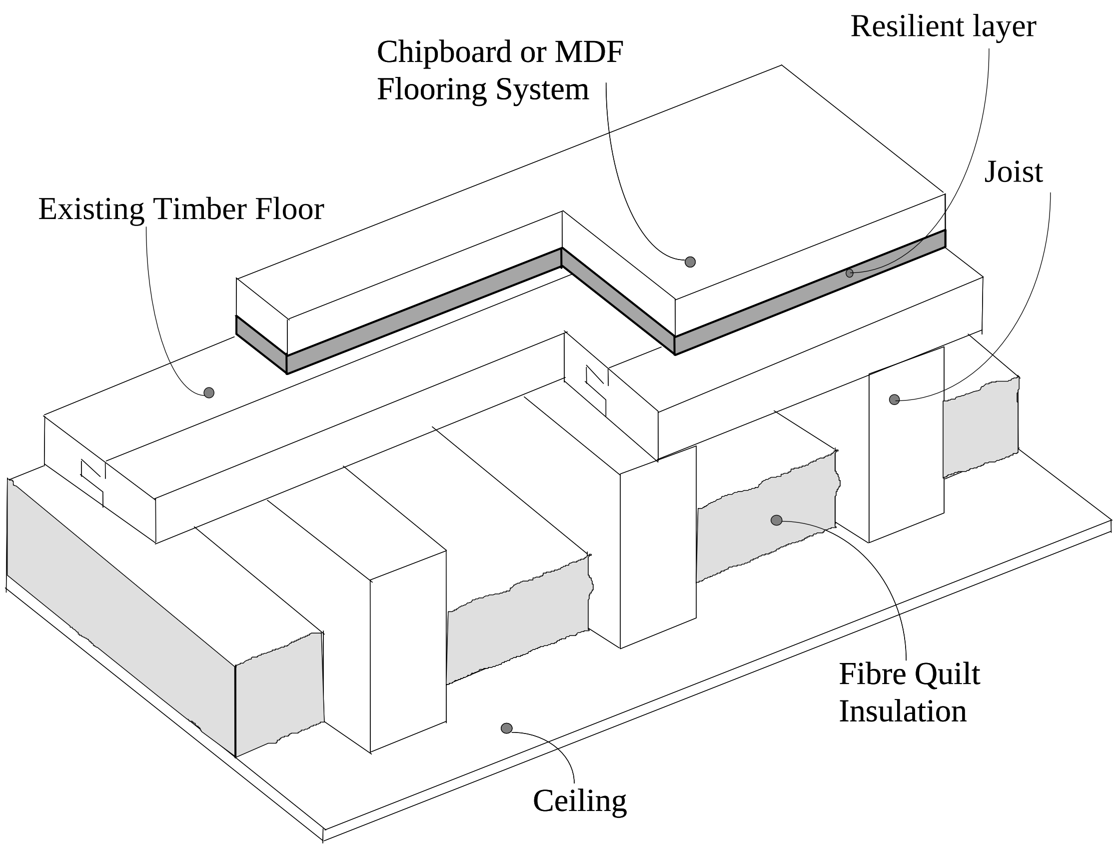


Figure 4: Typical wooden floor

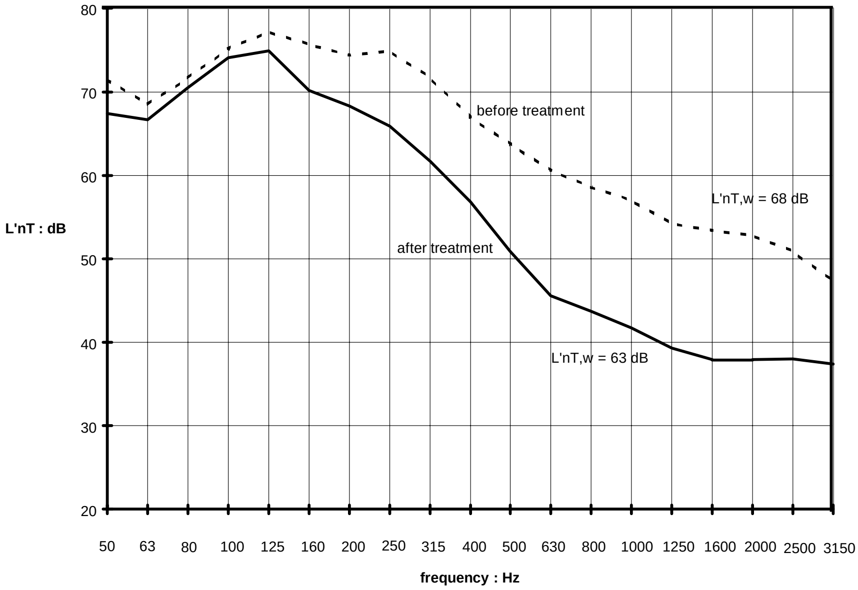


Figure 5: Wooden floor with MDF sound reducing flooring system.

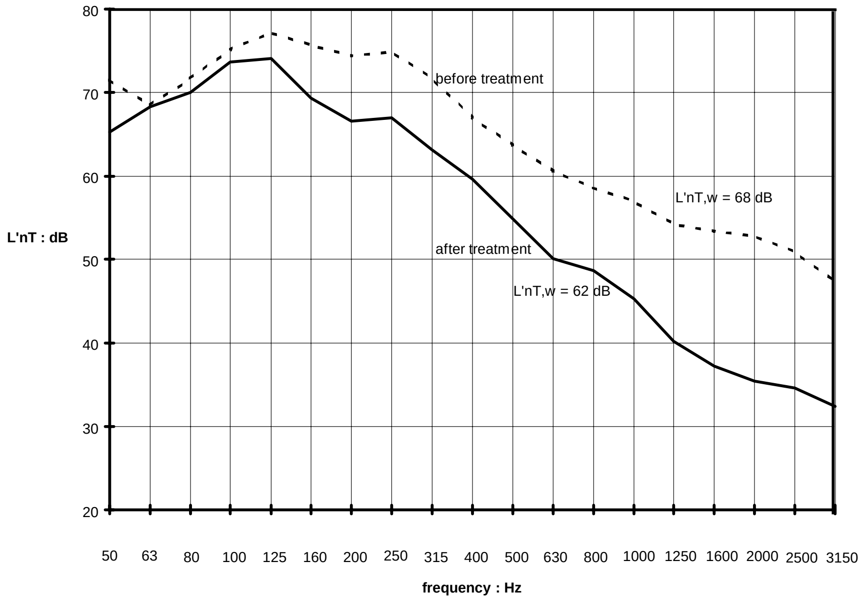


Figure 6: Wooden floor with chipboard sound reducing flooring system

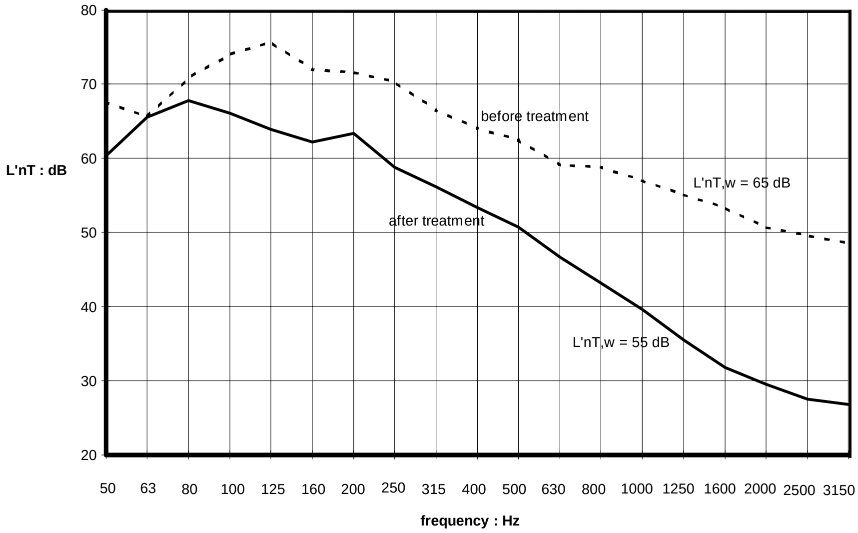


Figure 7: Wooden floor with chipboard system and absorbent material in the cavity.

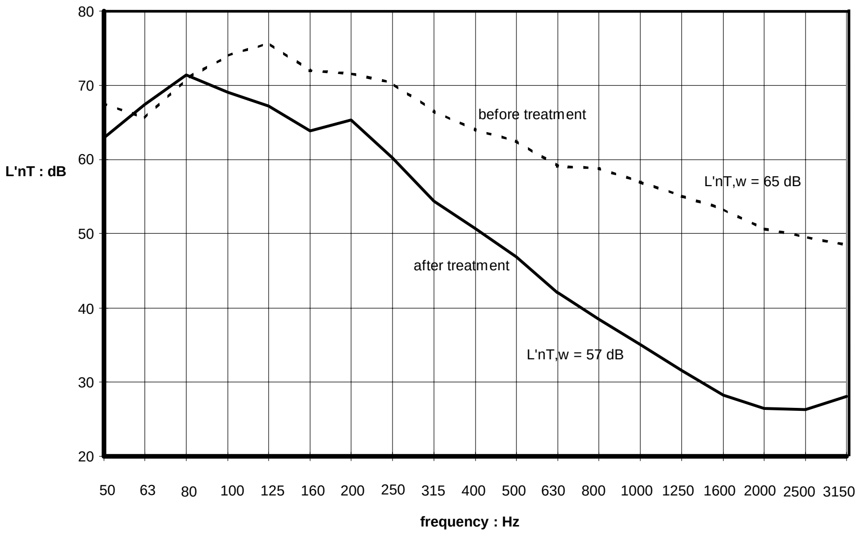


Figure 8: Wooden floor with MDF system and absorbent material in the cavity.

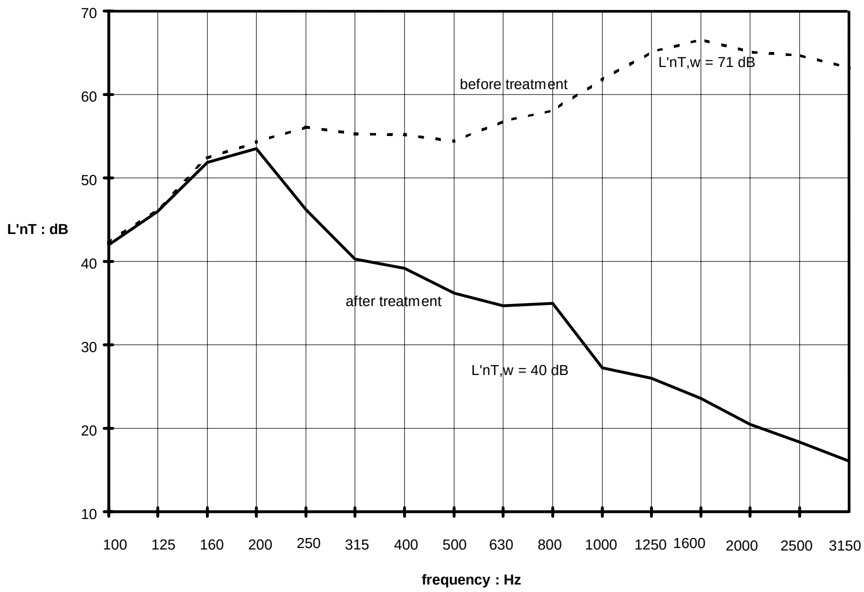


Figure 9: Concrete floor with chipboard and reconstituted foam

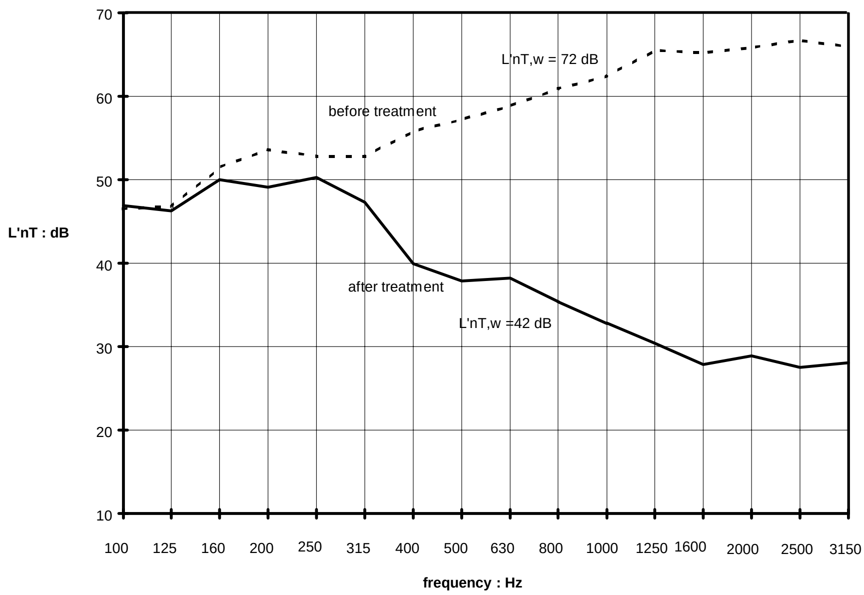


Figure 10: Concrete floor with medium density fibre board and reconstituted foam

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