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Natural vegetal fibbers as a new resilient layer for floating floors

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This paper presents a new use for a product made with low cost natural fibbers from vegetal by-products (coconuts coir) to be used as a resilient layer for floating floors to increase impact sound insulation. The acoustic behaviour was characterized by in situ measurements using concrete floors in accordance with standards EN 140-7 and 717-2. The use of this material in floating floors showed in laboratorial measurements a weighted impact sound improvement index (ΔLw) of 18 and 22 dB. On site, the improvement of the floating floor regarding the naked structural slab was found to be from 15 to 27 dB. Predictions based on current models were also made for the solution in study. As conclusion, the consequences of real construction applications of this product are commented regarding the reproduction of the now achieved results. Note of some limitations are also given regarding the methodology bias that can be introduced in the final results, particularly when in presence of structures with reduced airborne sound insulation.

1. INTRODUCTION

Floating floors are usually based upon the interposition of a resilient layer between the user final surface and the structural support element. This layer could be of some different varieties: polyurethane in foam or extruded tiles, air bubbles in a PVC envelope, rubber or a mixture with rubber, cork or expanded cork, rock wool or glass wool, or natural fibbers. Most of these solutions are only feasible if used together with an inertial slab to provide enough rigidity for final pavement decoration. This inertia slab is also crucial in the improvement of the sound insulation both to percussion and airborne sound sources.

Natural solutions for resilient layers are not common. The solution presented in this paper is based upon the coir, a natural coarse fibre obtained from the tissues surrounding the seed of the coconut palm, *cocos nucifera*. The base material is largely available in tropical countries and is assumed today to be a pollution problem regarding his quantity (the total world coir fibre production is about 250,000 tonnes). Its fibbers revealed good durability and stability even if submitted to moistly environments. Industrially processed based upon a low energy waste allows to manufacture tilling material of different thickness with regular sizes. These tiles are the base material used in the tests as resilient layer for pavements.

The discussion presented in this paper deals with on site behaviour of the above solution compared with laboratorial data and other design models available in literature. It was possible to study several identical solutions in order to get statistical significance, and all the solutions were studied during construction in order to measure the improvement of the assignment of the different constructive layers. That allowed to understand the real efficiency of the solutions and mainly to trace the limits of the standard EN 12354.

The acoustic behaviour of each construction solution is characterized in accordance with standards EN 140-7 and 717-2. The single number parameter used to characterize sound insulation to percussion sources is the weighted normalized impact sound pressure level $L_{n,w}$ (measurements in laboratory) and $L'_{n,w}$ (in situ measurements). It was also useful to measure the airborne sound insulation that is characterized by a single number parameter denominated weighted sound reduction index R_w (measurements in laboratory) and weighted normalized level difference $D_{n,w}$ (on site measurements).

Figure 1. (Left) *Example of a natural vegetal fibber commercial product.*
Figure 2. (Right) *Building Band One (block II and I).*

2. CHARACTERIZATION OF THE SITUATION

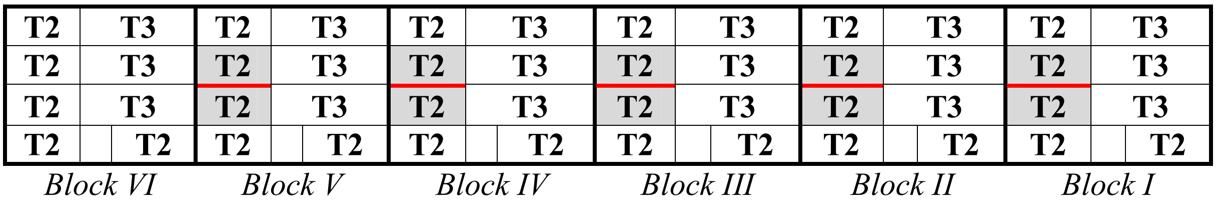
2.1. Natural vegetal fibbers

Natural vegetal fibber, specially the one that is obtained from coconut, was introduced in Europe in early 16th century after the Portuguese navigator Vasco da Gama reached India by sea (but the first European to see it was perhaps the Venetian Marco Polo two centuries before). At the time, the main use was in mattress, ropes and cushions. Handicraft also used it in thermal insulation for houses and even in cloths. With the 19th century industrial revolution and the use of fast producing technologies, these fibbers were mainly used in industrial insulation, rarely in houses for both thermal and acoustical insulation. Recently, supported by advanced technologies and in respect for environmental rules, new products were developed with these fibbers. These new products respond to environmental concerns, low energy manufacture, recyclable products and solid waste use. That is the case of coconut fibber (Figure 1), that according with international standards could be labelled as an ecological product.

The external husk of coconut is made of a fibrous *mesocarp* that after a natural dry process leaves the coconut and creates an environmental problem in some tropical countries. This fibber is not naturally recyclable and even under water or in moist environments does not show symptoms of decay. After a six months cure in water the fibber is dried in open air and prepared for industrial processing that consists in a textile process in two steps (card and compress) after witch it is cut either in tiles or blankets. There are no chemicals and no final misuse because all the cutting edges are again reprocessed. Density and thickness are obtained in the compression step. Commercial products available in the market are of four kinds: Tiles (the one studied in this paper); Blankets in roll; Bands; Mixed with cork known by the name "*CorKôco*".

2.2. The building studied

The floors studied are in a newly constructed building in Gondomar (near Porto, Portugal). The complex is made of two similar buildings in band. Each band has six blocks of four floors with two dwellings per floor (see Figures 2 and 3). In each floor one dwelling has two bedrooms (*T2*) with a total area of 121 m^2 and the other has three bedrooms (*T3*) and a total area of 139 m^2. There were several similar situations available to test.



T2	T3	T2	T3	T2	T3	T2	T3	T2	T3	T2	T3
T2	T3	T2	T3	T2	T3	T2	T3	T2	T3	T2	T3
T2	T3	T2	T3	T2	T3	T2	T3	T2	T3	T2	T3
T2	T2	T2	T2	T2	T2	T2	T2	T2	T2	T2	T2
Block VI		*Block V*		*Block IV*		*Block III*		*Block II*		*Block I*	

Figure 3. *Frontal scheme of Band One building with the studied floors in red and respective tested dwellings in shadow (T2 and T3 stand for dwellings with 2 or 3 bedrooms).*

2.3. The solution for pavements between dwellings

The basic solution for the pavement consists of a structural slab with 0.23 m made of pre-stressed prefabricated concrete beams and brick blocks as lost formwork with a global weight of 230 kg/m^2. Above this slab there is a light mortar layer made to include piping or electricity cables and to provide a soft surface. Above this surface two different solutions are available:

- A resilient layer of natural fibber consisting of a tiling of 0.01 m thickness covered by a PVC layer to stop the access of concrete to fibber. An inertia slab with 0.10 m of concrete is placed above the resilient layer. The final surface is either a granite tiling or a wood floorboard.
- Wood beams to support a resilient band and the final floorboard.

Three different solutions (*A*, *B*, and *C*) were studied, all of them in a *T2* dwelling and each solution was studied in three different construction phases. The Figure 4 and Table 1 present the structure of data obtained by local measurements.

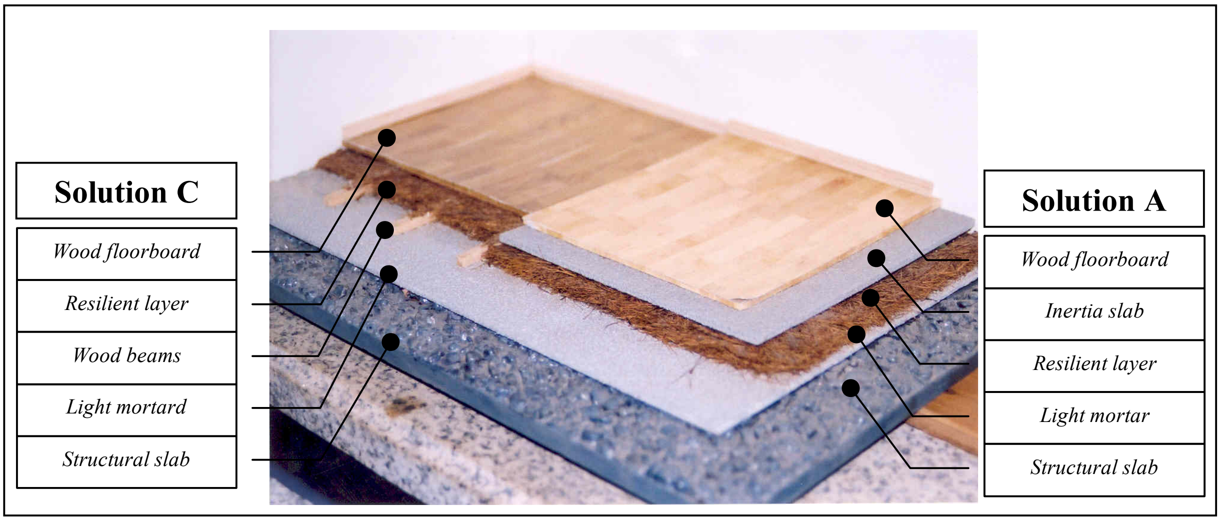
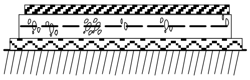
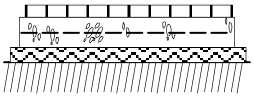
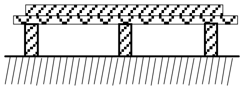


Figure 4. *Commercial model of the pavement both with (A) and without (C) an inertia slab.*

Table 1: *Lay out of measurements.*

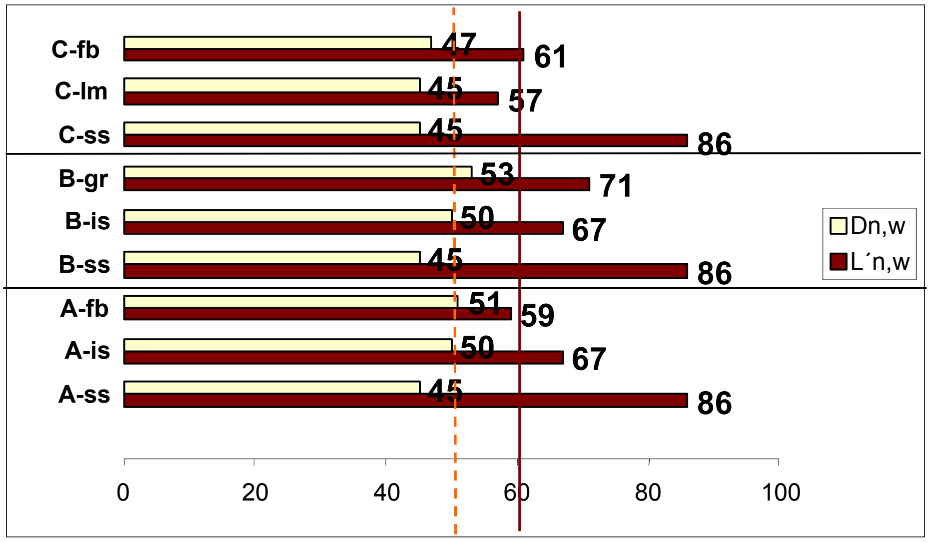
Solution	Measurement code	Construction phase	Solution scheme
A	*A.ss* *A.is* *A.fb*	1st - Structural slab 2nd - Inertia slab 3rd - Floorboard	
B	*B.ss* *B.is* *B.gr*	1st - Structural slab 2nd - Inertia slab 3rd - Granite	
C	*C.ss* *C.lm* *C.fb*	1st - Structural slab 2nd - Light mortar 3rd - Floorboard	

3. RESULTS

3.1. On site measurements

As synthesised in Table 1, three different constructive solutions (*A*, *B*, and *C*) were tested during construction. Each solution was measured at least in three places using standards EN 140-7 and 717-2 and averaged result values were calculated (see Table 2).

Table 2: *Results obtained from site measurements (values in dB). The vertical lines show the Portuguese legislation limits (Dn,w ≥ 50 and L'n,w ≤ 60 dB).*



Just the solution *A* (inertia slab with floorboard) of the three measured on site fulfils entirely the Portuguese law on sound insulation between dwellings. The Portuguese *decreto-lei* 129/2002 of May 11, states that between dwellings $D_{n,w}$ values must be greater or equal than 50 dB and $L'_{n,w}$ must be lower or equal to 60 dB/1/3 octave (but it allows for a 3 dB margin, that is, 47 dB and 63 dB are the real limits). The evolution of $D_{n,w}$ values during the three different phases of construction shows a continuous improvement, growing from 45 dB (corresponding to the structural slab) to 53 dB in the granite solution. The 0.10 m inertia slab contributes to an increase of 5 dB in the overall behaviour regarding $D_{n,w}$.

Regarding the evolution of $L'_{n,w}$ values in the three solutions, it is interesting to observe that both the granite finish and the wood fibreboard contribute to an increase of 4 dB instead of a reduction. This will be motive for further discussion (chapter 5.3).

3.2. Laboratorial measurements

Data available from the supplier of the natural fibber tiling previously tested in laboratory (LNEC) according with EN 140-8 and 717-2 gave the results shown in Figure 5 for the *A* solution (wood floorboard over inertia slab) and for the *C* solution (wood floorboard over wooden beams). The physical characteristics of the natural fibber used were: thickness: 0.010 ± 0.002 m, specific weight: 115 ± 5 kg/m^3, Young's modulus: 0.023 GPa, damping: 0.01.

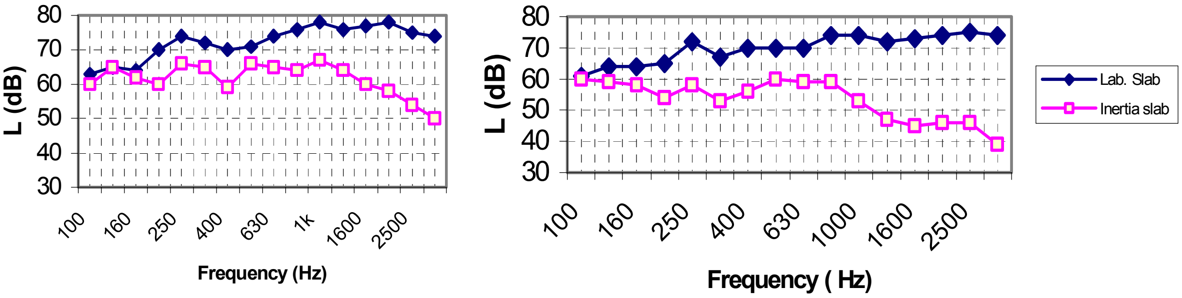
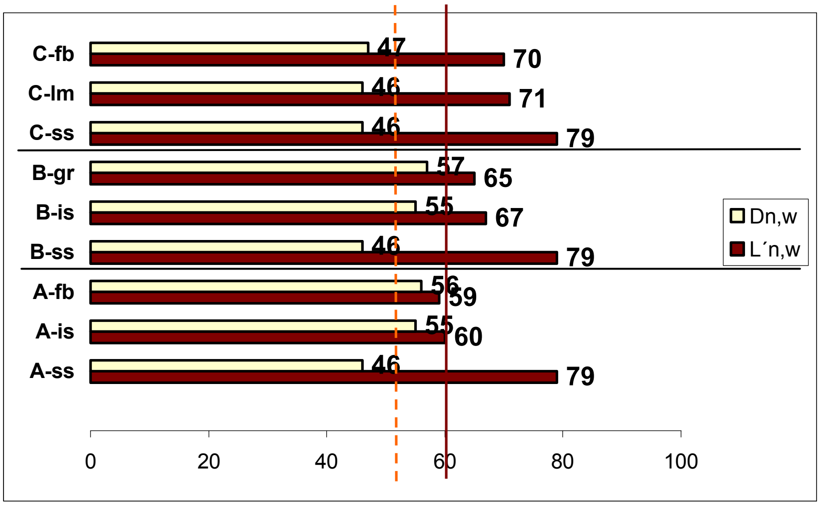


Figure 5. *Results in laboratory measurements (left: Solution C, ΔL_w = 18 dB; right: Solution A ΔL_w = 22 dB).*

Table 3: *Results obtained from models (values in dB). The vertical lines show the Portuguese legislation limits (Dn,w ≥ 50 and L'n,w ≤ 60 dB).*



3.3 Model prediction

All three solutions were studied by theoretical methods in order to evaluate local divergence due to flanking transmission and to other influent reasons. The sound reduction of elements both airborne and structural was modelled as described by Gerretsen [1] and the global transmissions were calculated under the EN 12354-1/2/3 procedures. Results are presented in Table 3.

5. DISCUSSION AND CONCLUSIONS

5.1. Natural fibber as resilient layer

Tests results confirm a good contribution of the floating floor with the natural fibber to sound insulation both to structural and airborne sounds ($\Delta L'w$ = 19 dB with an inertia slab or 29 dB for wood beams without an inertia slab). Regarding the structure borne sound, the values from laboratory tests have good reproducibility on site, but it was found to be a good practice to reduce them by 5 to 7 dB as safety measure due to site conditions.

5.2. Results from models

The theoretical models used gave good results for airborne sound insulation for the basic solution (*.ss*) but were optimistic (5 dB) when related to the floating slab contribution with an inertia slab. In this case, a 4 or 5 dB reduction is also suggested as a good practice. Concerning impact sound insulation, conclusions cannot be stated because there is a divergence of results. In the naked structural slab, theoretical results are rather optimistic (7 dB) compared with the data from on site solutions. The model results for the final solutions are correct for the wood finish (*A*) but rather optimistic (6 dB) for the granite solution (*B*).

5.3. Discussion on the contribution of airborne transmission to the weighted impact sound pressure level

Site tests *B.gr* and *C.fb* showed an increase in $L'n,w$ between inertia slab test (*.is*) and final one (*.gr* and *.fb*) when it should be expected a reduction. The *B* and *C* solutions showed an increase of 4 dB (= 71 - 67 or = 61 - 57).

The explanation could be found in the airborne sound transmission to the receiving room due to the sound radiation from the final surface solution. As seen in the results (Table 2), airborne sound insulation increased 3 and 2 dB in solutions *B* and *C*. The answer may remain in the analysis of the average sound level in the emission room. As it was measured, the emission room *Leq* values of 95 dB and 97 dB in both solutions *B* and *C* that are respectively 10 dB and 12 dB higher than the ones measured with the inertia slab without finish. It is expected that in low frequencies (where the airborne sound insulation does not goes higher than about 34 dB), some airborne transmission could condition the sound field in the receiving room. The increase of 4 dB in the $L'n,w$ values could be partially explained by the increase in the emitting airborne sound field.

REFERENCES

1. E. Gerretsen, Calculation of airborne and impact sound insulation between dwellings, *Applied Acoustics* **19**, pp. 154-200, (1986).