INNOVACIONES EN PISOS FLOTANTES ALIGERADOS EN APLICACIONES DE GIMNASIO Y DEPORTES

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ABSTRACT

Gym and fitness spaces on residential/commercial buildings, pose a great challenge for integration into their environment and are a well-known conundrum to acoustical consultants. Multi-disciplinary gym activities generate a large range of noise and vibration in terms of induced energy level and frequency content. Gym floor lightweight solutions, where a variety of impact levels is generated, remains quite challenging for acousticians.

To improve the isolation efficiency and making the gym floors less dependent on the impact level, a new concept has been developed. Laboratory and in-situ testing has been completed under different drop weight energy levels showing significantly improves of structure-borne noise isolation.

RESUMEN

Gimnasia y fitness espacios en edificios residenciales/comerciales, representan un gran desafío para la integración en su entorno y son un enigma para los consultores acústicos. Las actividades de gimnasio multidisciplinar generan una gran variedad de ruido y vibración con respecto al nivel de energía inducida y el contenido de frecuencia. Las soluciones de pisos para gimnasios, donde se generan una variedad de niveles de impacto, siguen siendo un gran desafío para los especialistas en acústica.

Para mejorar la eficiencia del aislamiento y tener pisos flotantes que sean menos dependientes del nivel de impacto, se ha desarrollado un nuevo concepto. Las pruebas de laboratorio y in situ se han completado bajo diferentes niveles de energía de caída de peso que muestran mejoras significativas del aislamiento al ruido estructural.

1 INTRODUCTION

1.1 General

Over these past years, a clear evolution of solutions has been seen with golden standards for structure borne noise isolation solutions for gym & sport floors being:

- ✓ "Dry solutions": when fast installation and removability/replaceability are at stake – in combination with integrated flooring / impact tiles,
- ✓ "Wet solutions": when high performance structure-borne noise isolation with limited deformation (e.g. according to sport performance criteria) is an issue – poured in situ floating floor solutions on bespoke resilient support systems.

Since last 5 years, acoustic comfort awareness has increased consistently and as a result more and more "unacceptable noise" complaints in spaces neighbouring gym & sport facilities with golden standard dry solutions were noted.

CDM has a long-term REX since 1970´s in gym and sport floor isolation, mainly with high performance floating floor systems for gym and multi-disciplinary sport halls installed in immediate vicinity of spaces with specific high performance acoustic requireme. By combining (1) wet floating floor solutions for gym & sport floors, (2) dry floating floor solutions for the building renovation and (3) an extensive research program started in 2014 to better understand the main driving parameters behind structure borne noise isolation, innovative high performance "dry solutions" were successfully introduced[1].

The extensive research program was split in 2 main phases

- ✓ Phase 1 (2014-2016): understanding the impact of each of the constituting elements (laboratory and in field measurements) based upon vibration transmission techniques (10 to 2000 Hz) with own developed test bench – results reported Euronoise 2018 [1].
- ✓ Phase 2 (2017-2018): with Phase 1, findings an in depth continued research program to understand: (1) influence of number and damping degree of light weight panels, (2) resilience of the support system, (3) the impact energy level, and (4) the importance of an innovative system letting the floating floor "free float" with reduced friction on the resilient support system. This Phase 2 integrated extensive measurements in lab (more guided by normalized structure borne noise isolation parameters in function of energy impact levels) and in situ experience.

Today, high performance dry solutions based upon a combination of load distributing light weight panels and added damping & resilience are becoming common place and accepted as new golden standard capable of meeting the evolved acoustic comfort criteria more and more defined by the lower part of the frequency spectrum and in function of energy impact levels.

In this paper, we present the main results of the Phase 2 project focused on dry solutions.

1.2 Typical Light Weight Gym/Sport floor Set Up

A typical dry gym & sport floating floor set-up has 4 layers- each having their impact on functionality, user comfort and structure borne noise isolation, Fig. 1.

- ✓ Layer 1: aesthetics are taken care by the floor covering (rubber/plastic roll-out, seamless (poured) and hard wood)
- ✓ Layer 2: impact isolation & shock absorption are taken care by the impact isolation layers (mainly resin bonded rubber crumb products in different shapes)
- ✓ Layer 3: load distribution towards the supporting structural floor is taken care by light (plywood, chipboard, fibre-cement...) or heavy (poured in situ concrete) weight panels introducing bending stiffness to the overall system.
- ✓ Layer 4: the resilient support interface above the structural floor (springs, elastomer pads,..).

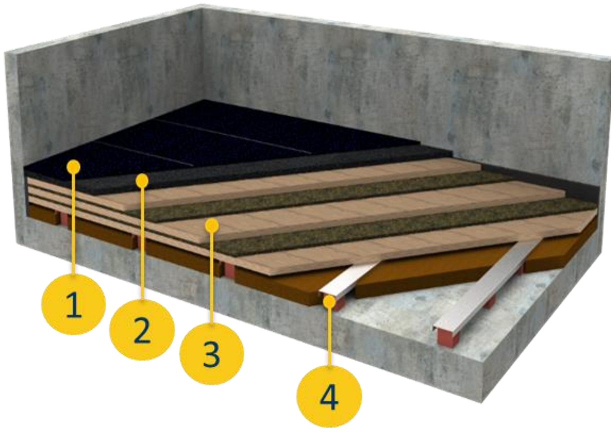


Fig. 1 - *Essential elements in a dry floating floor for sport & gym applications*

1.3 dBooster™ Technology

A dry floating floor is made of a combination of different panels where the bottom panel always must be ductile with sufficient bending strength to support the other panels. To reduce the noise radiation under impact loads, it is best to provide the combination of panels with an as low as possible radiation efficiency.

Panels with best ductility/strength ratio are wood based panels (plywood, chip board, MDF). These panels have low damping and show dips in the coincidence and resonance controlled regions of transmission loss (figure 2).

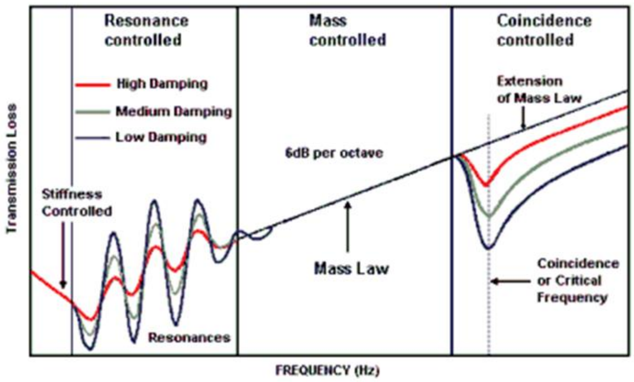
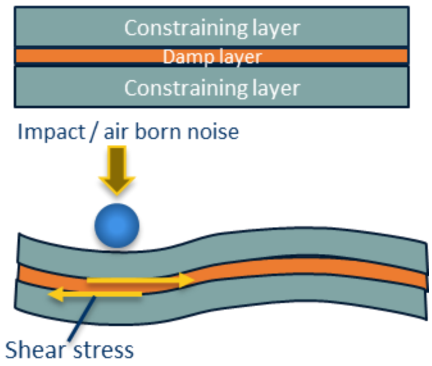


Fig. 2 – *Damping effects on transmission loss in resonance and coincidence controlled regions*

These dips in the resonance and coincidence controlled region are mitigated by well-known CLD (constrained layer damping) techniques with high damping viscoelastic acoustic membranes[5], figure 3.

The combination of wood based panels with CLD membranes offers best mix of bending strength with high ductility, high damping and low radiation efficiency, figure 3. The impact on the panels results in shear stress of the damping layer that controls the panel displacement and converts the mechanical energy (vibration) into the heat[3].



Panel composition	Overall Thickness (mm)	Surface weight (kg/m³)	Rw (dB)
Plywood (15 mm)	15	8,4	18
Plywood(6 mm) + CDM-DAMP-1 + Plywood(6 mm)	15	9,4	29
Plywood(6 mm) + CDM-DAMP-2 + Plywood(6 mm)	15	8,3	30
Plywood(6 mm) + CDM-DAMP-3 + Plywood(6 mm)	15	9,5	30

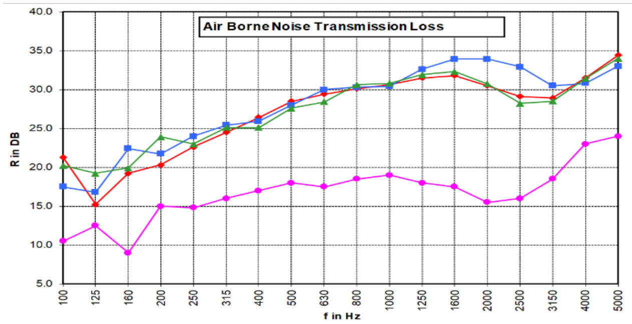


Fig. 3 – *Top: CLD (constrained layer damping) mechanism on converting impact energy into the heat by shear stress, Bottom: Effect of CLD on transmission loss (internal CDM)).*

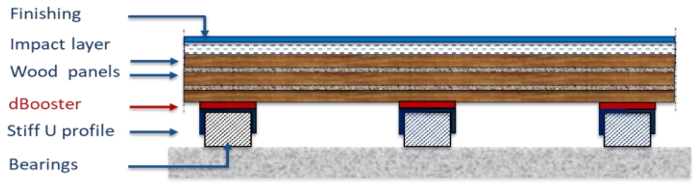


Fig. 4 – *conceptual detailed section with constituting elements*

Reducing the panel fixation conditions by leaving it free floating with reduced friction in the interface with the supports, results in acoustically more efficient performance[6].

This mechanism boosts the structure borne noise isolation (hence “dBooster™” technology) in the resonance and coincidence controlled regions of the floating floor set-up. The “dBooster™” resilient strip materializes the free-float/reduced friction condition between a stiff U profile with capacity to withstand the imposed impact energy and the lightweight load distribution panels. The dry FF is thus kept in place by limited but sufficient friction between the bottom panel of the dry FF and the resilient support.

To evaluate the proposed “free floating/reduced friction” concept different mock-ups has been tested in-situ[7]. The free-floating system (“dBooster”™) showed an additional 5dBA improvement of the noise reduction (figure 5).

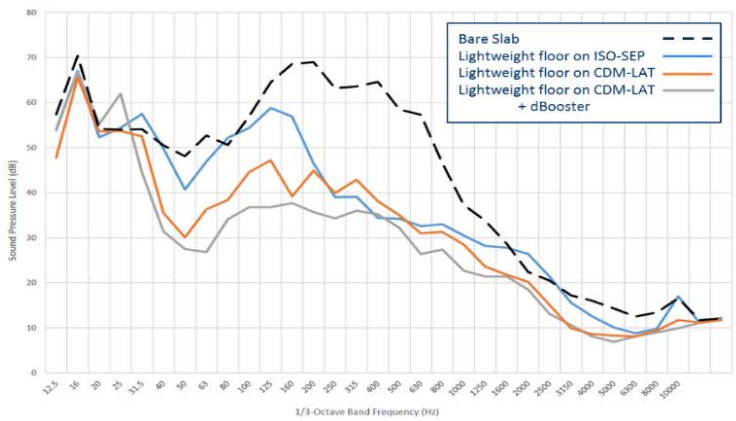


Fig. 5 –Sound pressure level measured in a bedroom in The Hill/Toronto (2016)[7].

The interest was awoken to further investigate these seemingly positive results. Additional in-house testing in CDM confirmed this result.

During Phase 1 Research[1], 2 types of CLD acoustic membranes were tested

- ✓ Heavy mass layer with 10 kg/m²
- ✓ Light weight high damping layer with 5 kg/m²

The results showed the effect of different CLD materials on panel vibration was similar, figure 6. As a result, only light weight high damping layers (type DAMP) were used in this study.

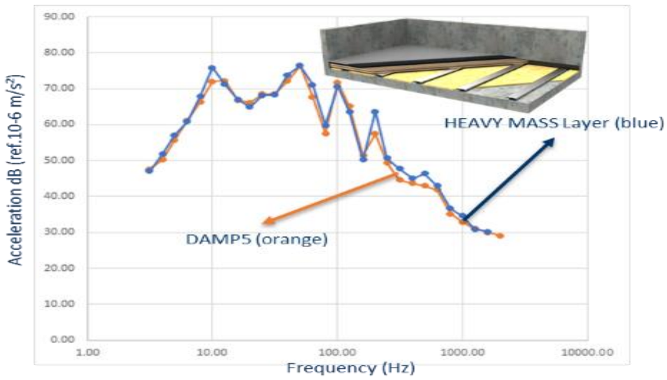


Fig. 6 – CLD effect comparison between 10 kg/m² heavy mass layer (blue line) and a 5 kg/m² LW high damping layer DAMP5 (orange line)

2 EXPERIMENTAL DROP WEIGHT TESTS

The measurement campaign was conducted at Riverbank Acoustical Laboratory (RAL) - Geneva, IL 60134-3302 in USA in 2017. For each floor assembly, a series of weights were dropped using a predetermined configuration of weight, drop height, and location on the specimen. Two weights were dropped from three heights at two locations (figure 7 and 8).

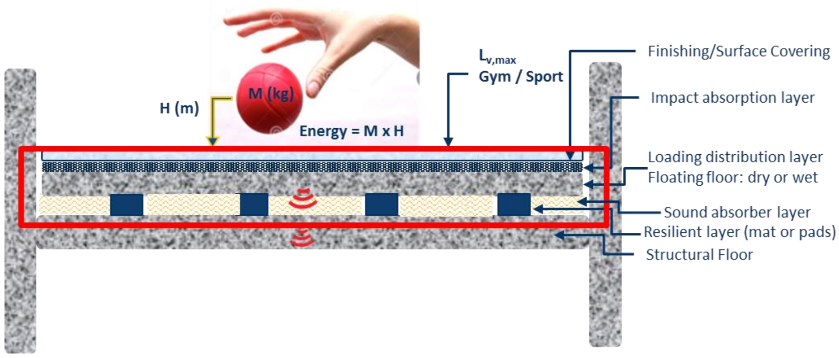


Fig. 7 – *Drop test configuration: conceptual cross section of the essential elements of floating floor setup for sport & gym applications.*

2.1 Impact Energy Level

The impact energy level E is the quintessential source generating the acoustic nuisance in neighbouring spaces: product of mass M in terms of force [N] and the drop height H [m].

Typical dumbbells weigh up to 25 kg are dropped from typical height up to 1 m, meaning energylevels up to 250 Nm. The test program in Phase 2 was conducted until energy levels of 25 Kg dropping from 1,5 (373 Nm). There seems to be a tendency to take 20 kg dropped from 1 as a standard for new normalization – this would conduct to a standardized energy level of 200Nm.

Fig. 8 – (a) typical dumbbells weigh *and, (b) drop weight test set up used in RAL*

Table 1 – applied energy levels throughout the Phase 2 research program in RAL.

Drop weight (Kg)	11,5	25,0	11,5	11,5	25,0	25,0
Drop height (m)	0,2	0,2	0,9	1,5	0,9	1,5
Energy levels (Nm)	**23**	**50**	**102**	**170**	**224**	**373**

2.2 Measurement Setup

Two microphone positions were used to measure the Peak A-Weighted Fast Response Sound Pressure Level (LA, F, Peak) at three positions by dropping the weight once, then moving one of the positions and dropping the weight again at the same location. Measurements were taken using a B&K Type 3160-A-042 frequency analyzer and B&K Pulse Labshop. The microphone was a B&K Type 4943-B-1 microphone. The LA, Peak, Fast for the three microphone positions and two drop positions were then averaged together for each weight-height configuration, giving 6 data points for each of the 6 weight-height configurations. The tested specimens are described in table 2. The orange highlighted ones are those discussed and presented in this paper. RAL used the recommendations supplied by Sato and Yoshimura[4]

Table 2 – The lightweight floating floor configuration

tested set-ups	Finishing		Load distribution system					Resilient support		
	rubber rollout 10mm	CDM-IMPACT 15/20mm	PW 18mm	DAMP 5/10/20	PW 18mm	DAMP 5/10/20	PW 18mm	Mat MTX	GYMLAT	dBOOSTERLAT
#1 CDM-GYM-SP, 25/7 - 98mm (3-27/32")	Y	20	Y	5	Y			25/7		
#2 CDM-GYM-HP-M30 - 103mm (4")	Y	20	Y	5	Y				M30	
#3 CDM-GYM-HP-L30 - 118mm (4,6")	Y	20	Y	20	Y				L30	
#4 CDM-GYM-XP-dB-L55 - 162mm (6,4")	Y	20	Y	10	Y	10	Y			L55
#5 CDM-GYM-HP-M50 - 98mm (4")	Y		Y		Y				M50	
#6 CDM-GYM-XP-L50 - 157mm (6,2")	Y	20	Y	10	Y	10	Y		L50	
#7 CDM-GYM-XP-L50 - 157mm (6,2")	Y	20	Y	10	Y	10	Y		L50	
#8 CDM-GYM-XP-dB-L75 - 182mm (7,2")	Y	20	Y	10	Y	10	Y			L75
#9 CDM-GYM-XP-dB-L75 172mm (6,8")	Y	20	Y	5	Y	5	Y			L75
#10 CDM-GYM-XP-dB-L60 167mm (6,6")	Y	20	Y	10	Y	10	Y			L60
#11 CDM-GYM-HP-dB-L40 - 113mm (4,4")	Y	20	Y	5	Y					L40
#12 CDM-GYM-HP-dB-SL-L40 108mm (4,3")	GT100	15	Y	5	Y					L40
#13 CDM-GYM-HP-L50 98mm (4")	Y		Y		Y				L50	
#14 CDM-GYM-HP-dB-L60 - 138mm (5,4")	Y	20	Y	10	Y					L60

3 MEASUREMENT RESULTS

Two different comparison studies are shown all related to the "dBooster"™ technology (fhase 2 research program). Results are presented in terms of insertion loss (the difference between the noise level measured in the receiving room below source room with (1) bare slab and (2) specimen):

- ✓ Top graph shows the overall average insertion loss as a function of energy impact level
- ✓ Bottom graphs show the insertion loss in function of 1/3rd oct bands (31.5-2kHz) for 3 different energy impact levels (23, 102 and 373 J)

The effect of "dBooster"™ (with and without #6 vs. #10)

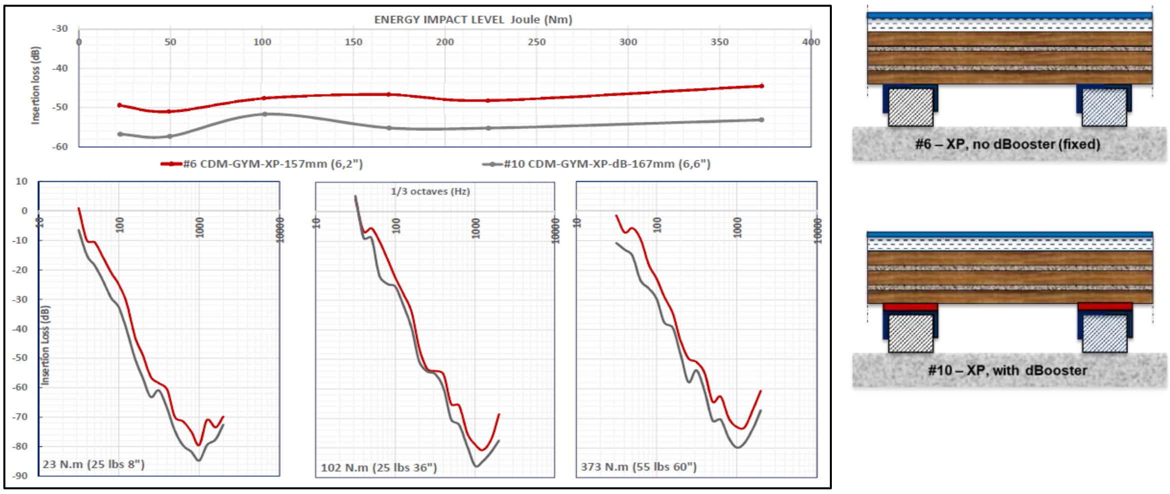


Fig. 9 – Comparison between insertion loss obtained for test setup #6 without "dBooster"™ and that of setup #10 with "dBooster"™.

It can be observed that for a 3-layer damped panel combination "dBooster"™ clearly improves the insertion loss by 5 to 10 dB and that the improvement remains consistently constant in function of energy impact levels and is consistent in the whole frequency spectrum

Effect of "dBooster"™ on the floor thickness (#6 vs. #14)

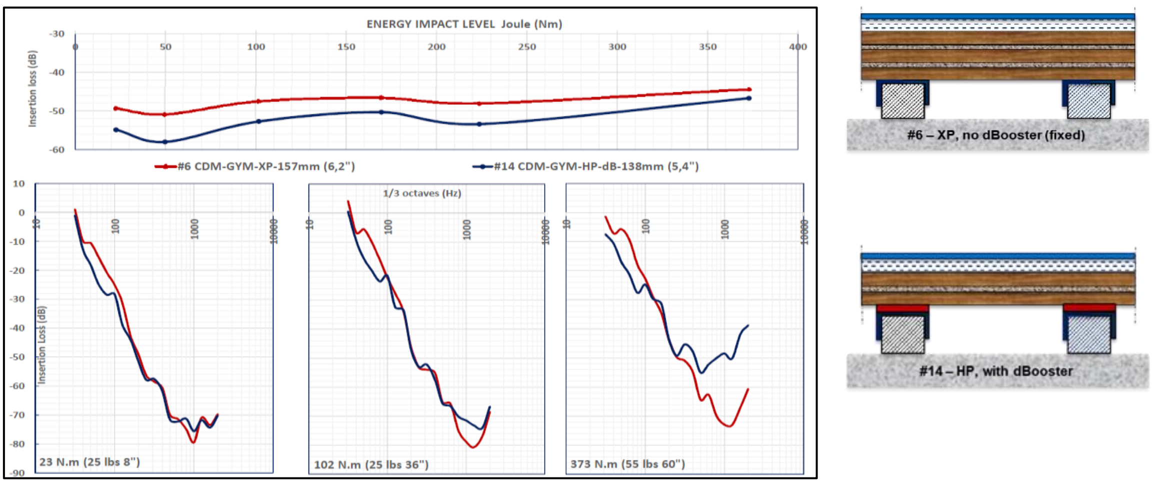


Fig. 10 – Comparison between insertion loss obtained for test setup #6 with 3layers of Plywood but without "dBooster"™ and that of setup #14 with 2 layers of Plywood with "dBooster"™

This particular comparison shows that "dBooster"™ can compensate the positive effect of an extra panel (included damping) in the floor combination, reducing thus the overall thickness of the set-up. However, this positive effect is less pronounced at high energy impact levels and frequencies above 800 Hz.

4 CONCLUSIONS

To improve the structure borne noise isolation efficiency of CDM lightweight floating floors, different panel configurations with and without "dBooster"™ technology were experimentally investigated as part of an ongoing in-house research program.

The following conclusions have been drawn:

- ✓ “dBooster”™ is an innovative technology allowing to improve the structure borne noise isolation performance of dry floating floors under heavy impacts.
- ✓ For a same dry floating floor set-up, the overall structure borne noise isolation improves by 5-10 dB when comparing the performance with and without “dBooster”™ .
- ✓ For the same lightweight panel combination “dBooster”™ implementation guarantees the consistent improvement over all tested energy impact levels. This makes the technology interesting to be implemented in multi-disciplinary fitness clubs floors with high isolation performance demands as a unique support technology for the whole surface.
- ✓ “dBooster”™ can compensate the positive effect of an extra panel (included damping) in the floor combination, reducing thus the overall thickness of the set-up.

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