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Simulation of flanking transmission in super-light structures for airborne and impact sound.

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Super-light structures are an invention based on combining lightweight concrete with normal concrete for better structural performance and lighter structures. The overall principle is based on load carrying arches of a normal concrete stabilised and protected from fire by a light-aggregate concrete.
Previously the airborne and impact sound insulation has been measured for a super-light deck element in a laboratory. This paper presents a flanking transmission analysis based on the measured results and are carried out for the Super-light deck elements by means of the acoustical software Bastian. In the flanking transmission analysis the influence of a large array of different flanking walls, structural connection details, room size and floor constructions, all typical or desirable for common multi-storey residential constructions, have been investigated. The results form a basis for guidelines on how to design buildings with super-light deck elements while achieving a good acoustical environment in the building, fulfilling various acoustical requirements from the building regulations.

1   INTRODUCTION

Super-light structures as a principle were invented in 2007 by the co-author Kristian Hertz[1-3]. The overall concept of super-light structures is to utilize desirable parameters of different

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materials, for super-light structures these materials are a stiff normal/strong load-carrying concrete with a compressive strength of at least 50 MPa and a lightweight aggregate concrete to optimize the material consumption and weight of building elements, the idea behind super-light structures emerged from considerations on their statics, namely the properties of arches.

The super-light slab elements are shown on figure 1 and 2 as a sketch and during production. It is built up by blocks of lightweight aggregate concrete with a density of 600 kg/m³ combined with prestressed normal concrete having a density of 2400 kg/m³, the super-light deck elements are described in further details by Hertz[4]. For the current investigation of flanking transmission of super-light deck elements measurements made on a modified deck element are used[5]. Due to the geometry of the used laboratory with an opening of 3.33x3.0 m and limitations at the production facility have a deck element without pre-stressed wires been used. No cracks were observed in the concrete so therefore full stiffness was present and the absence of pre-stressed wires had no noteworthy influence on the results of the deck element.

The aim of the present work is to investigate and estimate the super-light deck elements performance in-situ. This is carried out by a parametric study of 168 different configurations; simulating current building methods applied in pre-fabricated elements constructions in Denmark as of spring 2012 along with light-weight solutions with good acoustical properties as e.g. double gypsum walls. Due to the large array of different configurations the acoustical software Bastian[6] has been used for the simulations.

The simulations shows that the standard configuration most often used gives single number ratings of 54 dB in airborne sound transmission loss and 50 dB in impact sound transmission loss. The variation of the results in airborne sound transmission loss is dominated by the flanking walls here, as expected, lightweight partitions excel in reducing the sound transmission. For impact sound it is, also as expected, the floor structure which dominates the performance.

2 SIMULATIONS

2.1 Bastian

Pedersen[7] describes how in-situ measurements should be modified in Bastian to obtain simulations with increased precision. However, for laboratory measurements no modification should be carried out. All flanking elements have been measured in-situ and modified accordingly, all floor coverings have been measured in a laboratory on a standard reinforced concrete element with a height of 140mm.

2.2 Input Parameters

The room used for this analysis is shown on figure 3 where the room is build up with four flanking walls, one façade, one external partition and two internal partitions this results in one T-joint and 3 cross-joints.

The airborne and impact sound transmission loss was previously measured[5] and are used as input data. In Table 1 the different floorings, flanking walls, room sizes and connections in use are listed. Some of the connections are not compatible with some of the wall configurations, these combinations are omitted from the analysis. The four floorings have been measured in laboratories to have ΔR = [3, 3, 3, 9] dB and ΔL = [24, 21, 26, 23] dB respectively.

A standard set of input data is defined by column 1 which is the most common used in prefabricated constructions in Denmark right now. Due to recent changes in the requirements of acoustics, namely the airborne and impact transmission loss between dwellings this is dimension

wise a rather new configuration. The emphasis on this study will lie on this standard set along with different choices of floorings since it is debated that an optimization on the flooring systems should help accommodate the new acoustic building regulations.

2.3 Results

Figure 4 shows the airborne and impact sound transmission loss of the standard setup, the single number ratings are measured to 54 dB and 50 dB for airborne and impact sound respectively, the slope of the airborne sound transmission loss is almost constant and follows the rule dictated by the mass law in the for building acoustics important frequency range 100-3200Hz.

On figure 5 are the contribution for each of the flanking paths shown. Here it is revealed that the internal partitions accounts for most of the flanking transmission while the external partition and façade element have an almost neglectable contribution the total sound transmission. Each of the transmission paths contributes the following, direct: 58% façade: 7% internal partitions 14% and 19% and the external partition 2%, these results are close to the general rule of thumb that for heavy building elements flanking transmission accounts for approximately 50% of the total transmission. For the impact sound transmission the corresponding contributions are 74% direct, 4% façade, 9% and 11% internal partitions and 2% external partition, the flanking transmission accounts for less meaning that the floor is more important for determining the single number rating.

On figure 6 the influence of the different floors in use are shown for both the airborne and impact sound transmission. The results for the airborne sound transmission are [53.4, 54.6, 54.6, 54.6, 55.0] dB = [No floor, floor 1, floor 2, floor 3 and floor4] for impact sound the numbers are [78.2, 49.9, 54.6, 48.6, 52.0] dB = [No floor, floor 1, floor 2, floor 3 and floor4], yielding ΔR = [1.2, 1.2, 1.2, 1.6] dB and ΔL = [28.3, 23.6, 29.6, 26.2] dB. The combination of flooring and super-light slab element underperforms compared to the ratings of the individual floors in use which were 3 dB and 9 dB, one of the reasons for this deviation could be that the floorings are measured on the standard 140mm concrete slab which has slightly different properties than the super-light element. The opposite is the case for the impact sound transmission where the performance is better than anticipated, this can be ascribed to the performance of the super-light element at higher frequency in impact sound insulation, where a decrease in performance compared to other concrete slabs are observed and therefore the naked super-light slab element have a relatively higher single number rating for impact sound, after applying a floor the determining frequency range is shifted and the poorer performance at the higher frequency range no longer have influence on the single number rating.

Figure 7 shows histograms of the single number rating of all the simulations. Each bar corresponds to the amount of simulations which yielded this specific single number rating. It is clear that the standard setup of the room is one of the poorest configurations, adding light-weight partitions or resilient layers greatly improve the single number rating and they are the factors that cause the greatest variation in the single number rating. The histogram of the impact sound transmission loss shows that the single number rating is somewhat more evenly distributed, also the spread are more dominated by the type of floor in use as flanking transmission constitute less of the total transmission.

Figure 8 and 9 validates the previous statement that lightweight partitions and resilient layer greatly improves the airborne sound transmission single number rating of the super-light deck element. Nine different cases have been shown, but the tendency is the same for all cases. Here it

is build up around the standard case, while varying one of the other parameters. Changing from a monolithic concrete wall to a double wall of gypsum yields approximately an improvement of 4 dB in airborne sound transmission loss, while the impact sound transmission is only improved by 1-2 dB. For the resilient layer the numbers for airborne sound transmission loss is 3 dB and for impact sound transmission 1 dB. It can be seen that one result deviates from the previously observed, this is the case when the difference in a monolithic wall and double gypsum wall is compared to the standard configuration with resilient layers added. They cannot both be added to further increase the single number ratings.

3   CONCLUSIONS

The current study of the performance of super-light deck elements in-situ under various conditions shows that the previous assumption that in-situ correction along with addition of floor counteracts the flanking transmission in airborne sound. The deck element had had its single number rating measured to 55 dB. For the most common setup in residential construction in Denmark the contributions of flanking and flooring yields 54.6 dB (54 dB rounded), this value can be greatly increased by just changing one of the monolithic walls with double construction or introducing resilient layers at connections. The combination of flooring and super-light deck element does not yield the expected results in airborne sound transmission loss, it would be favourable to measure the floor constructions on super-light deck elements to further increase the precision of this study.

For the sound transmission in impact the combination of super-light slab elements and flooring is better than expected, on the standard setup the floor gives an improvement of 28 dB, which is 4 dB better compared to similar concrete floors. For the impact sound transmission the flooring is singlehandedly the most important factor for achieving good sound quality, flanking transmission is of less importance here.

4   ACKNOWLEDGEMENTS

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Table 1 – Different parameters used in simulations

Parameter	1	2	3	4
Floorings	Knudsen kilen with layer of filt.[9,10]	Knudsen kilen.[8,10]	Harpun lydbrik.[11]	22mm chipboard on 30mm rockwool 100kg/m³.[6]
Wall - Facade	150mm concrete with insulation and bricks of 200 kg/m².[6]	150mm concrete, gypsum cladding with insulation and bricks of 200 kg/m².[6]	13mm gypsum, 145mm rockwool, 9mm gypsum, 28mm air, 28mm wooden panal.[6]	N/A
Wall - Partition	200mm concrete.[6]	270mm double gypsum wall with separated steel connectors 3 13mm gypsum on each side and 190mm rockwool[6]	N/A	N/A

Wall – Internal Partition	100mm lightweight aggregate concrete 1350 kg/m^3.[6]	120 double gypsum wall with separated steel connectors 2 13mm gypsum on each side and 30mm rockwool [6]	N/A	N/A
Room size	5x4x2.5m	8x5x3m	N/A	N/A
Connections	Without resilient layer. [6]	With resilient layer of E=3GPa and t=12mm. [12]	N/A	N/A
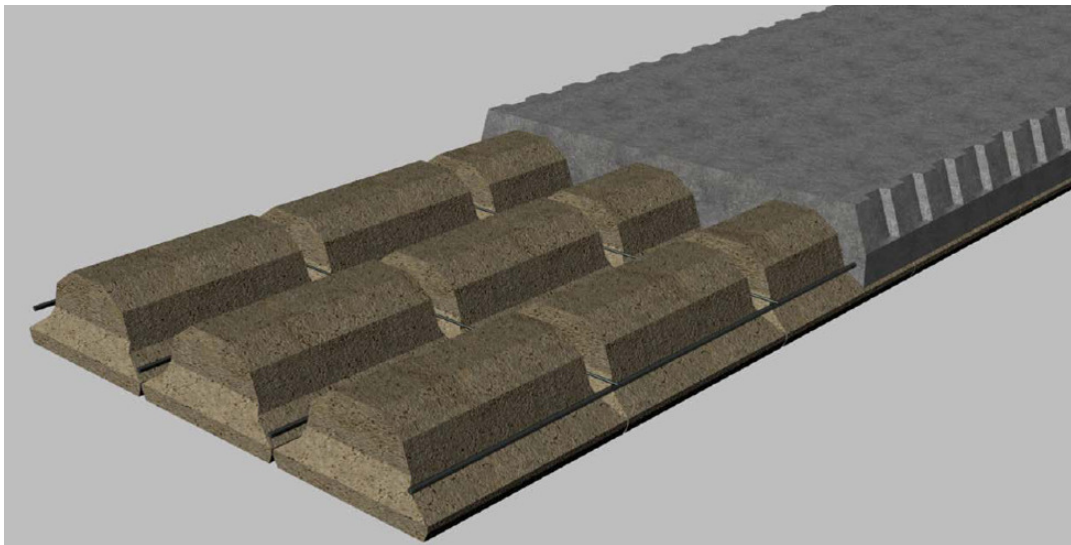
Fig. 1 – Conceptual design of a 1.2 meter wide super-light slab element.

Fig. 2 – Production of a super-light slab element.
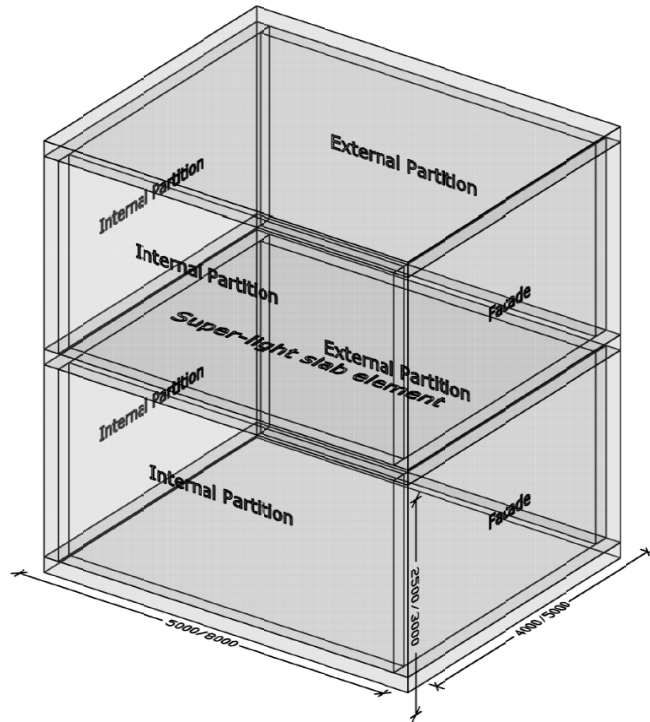
Fig. 3 – View of the room used for analysis and naming of the flanking partitions.
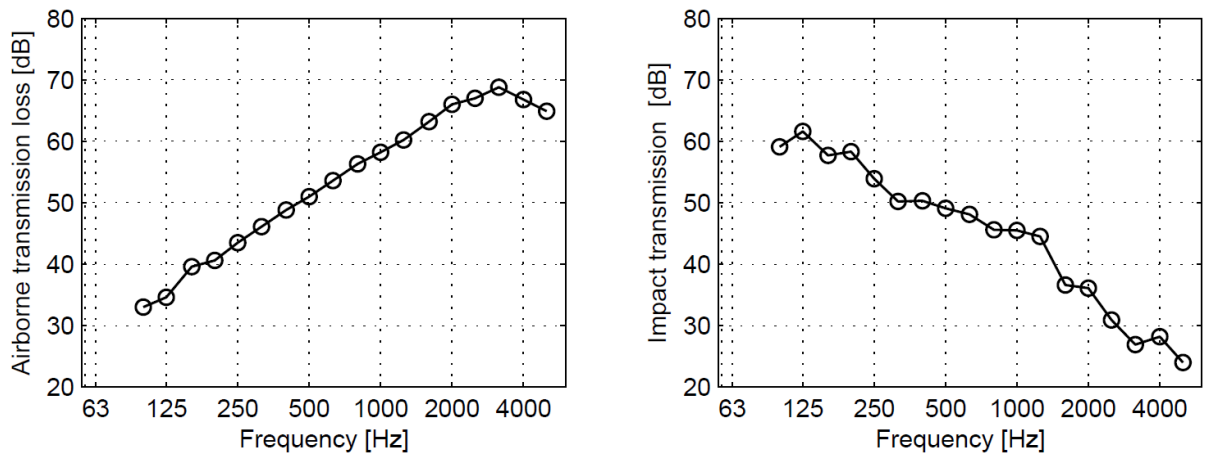
Fig. 4 – The airborne sound transmission loss for standard setup is visable on the left plot and impact sound transmission loss for the standard setup is shown on the right plot.
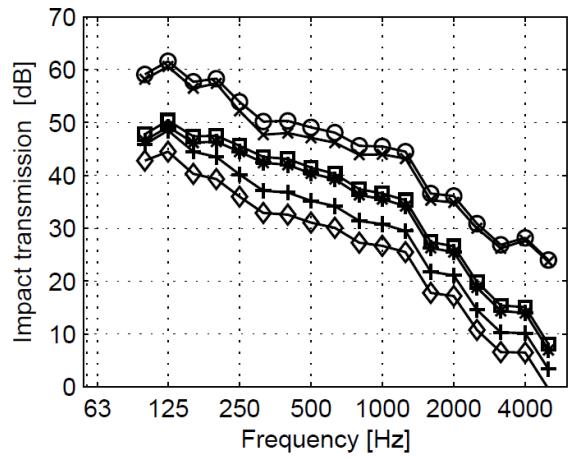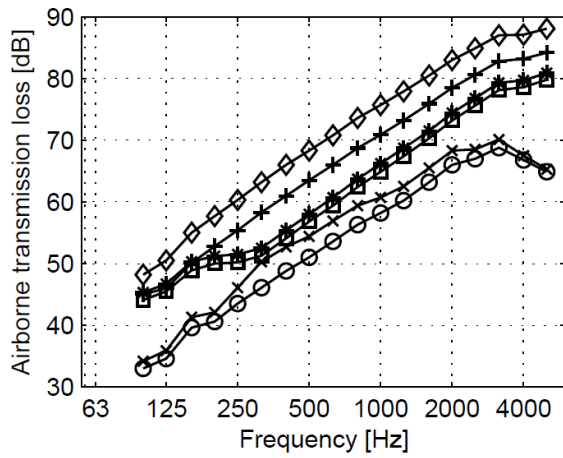
*Fig. 5 – The individual flanking paths for the airborne sound transmission loss for standard setup is visable on the left plot and the individual flanking paths for the impact sound transmission loss for the standard setup is shown on the right plot. o: Total, ×: Direct, +: Facade, *: Internal Partition, □: Internal Partition ◊: External Partition.*
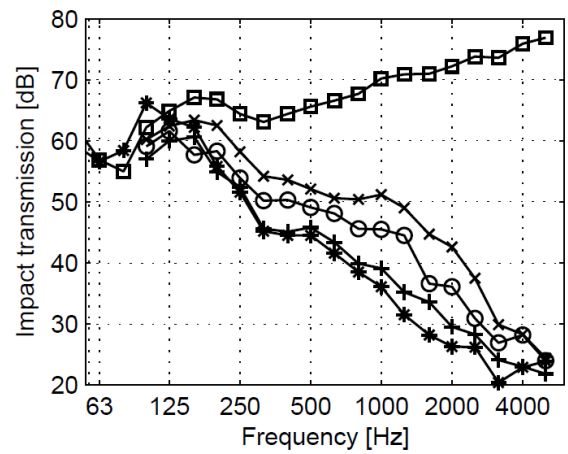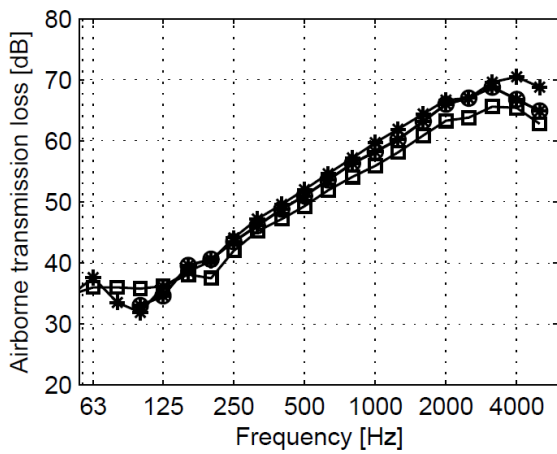

*Fig. 6 – The airborne sound transmission loss on the left and the impact sound transmission loss on the right is shown with and without the contribution from the flooring. o: Floor 1, ×: Floor 2, +: Floor 3, *: Floor 4, □: No floor*
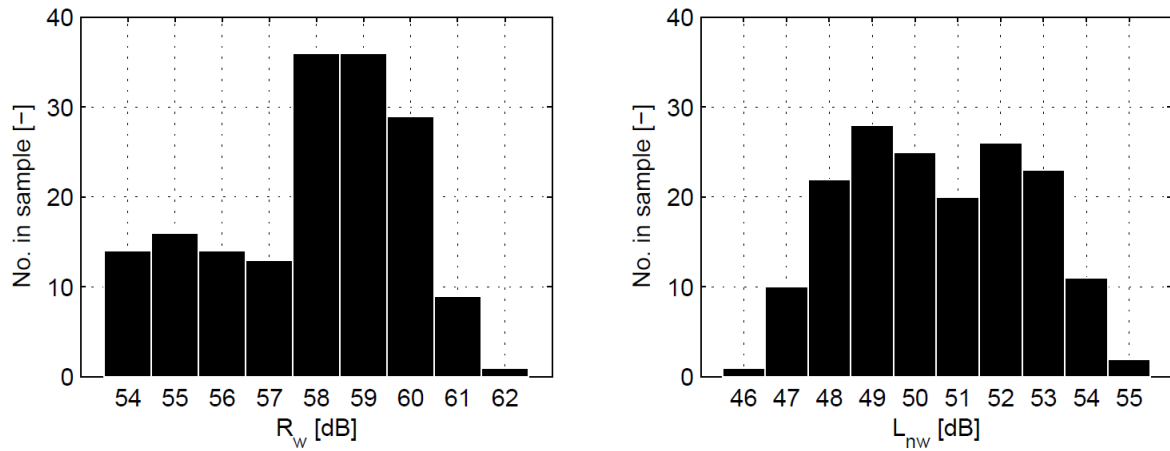
Fig. 7 – Histogram of all the parametric simulations, on the left single number ratings for airborne transmission and on the right single number ratings for impact sound transmission.
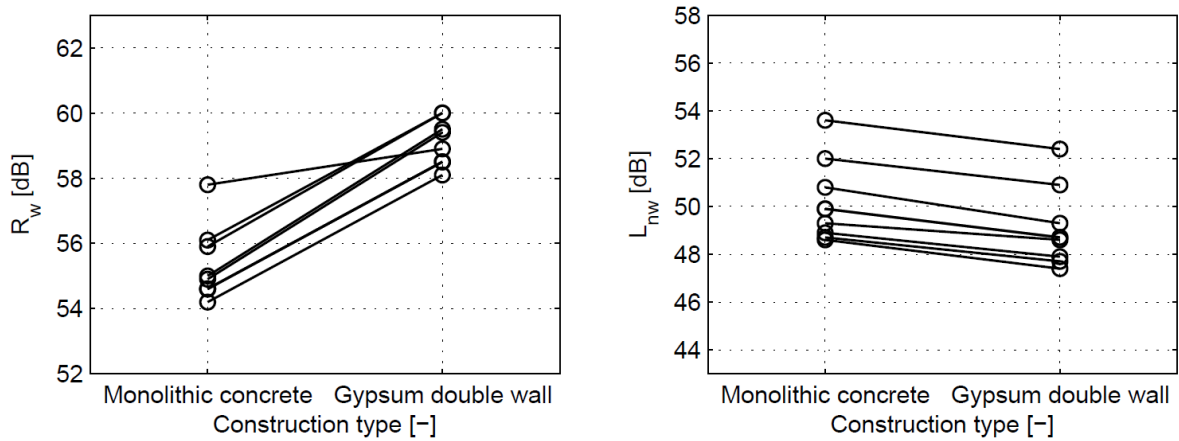

Fig. 8 – Overview of the influence of the choice of external partitions, here the standard configuration is depicted while only one of the parameters are changed, e.g. standard configuration with floor 2 instead of floor 1 etc.
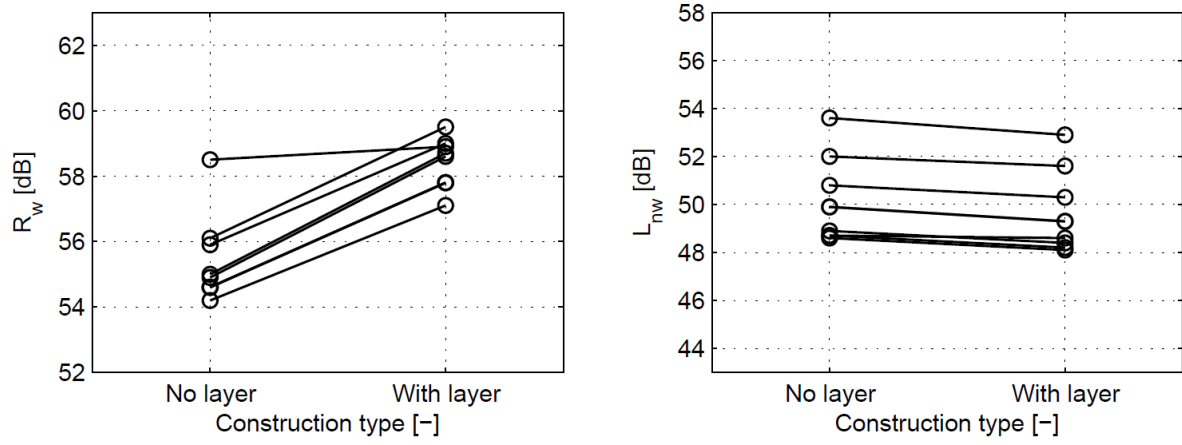
Fig. 9 – Overview of the influence of the use of elastic layers, here the standard configuration is depicted while only one of the parameters are changed, e.g. standard configuration with floor 2 instead of floor 1 etc.