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Acoustic development of light weight building system

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ABSTRACT

In Sweden more than 15 % of all multi-storey residential buildings are built with light weight structure (the main part with wooden structural material). This is increasing due to several factors, for example governmental support, its highly industrialized production, etc. However, in order to consolidate the future position of light weight residential buildings compared to heavy weight buildings there is a need for future development of the acoustic evaluation methods and raised knowledge within the industry regarding vibrations and material characteristics. The most immediate needs are also important in order to actually fulfil the essential requirement "Protection against noise" of the European Construction Productive Directive (CPD). First of all it is absolutely necessary to establish well founded criteria for evaluation of impact sound insulation in order to make minimum requirements and various sound classes in classification schemes reasonably comparable to the corresponding requirements of heavy building structures. In this context it is important to consider the vibration behaviour due to household activities and its effect on the experienced low frequency impact sound. The light weight industry is also in need of quick implementation of new criteria in the International and European standards (ISO 717) in order to facilitate the trade of light weight building systems. The systems complexity, the difficulties to replace single products and the lack of calculation models make this issue even more urgent.

1. INTRODUCTION

The quantity of buildings using light weight structures for multi storey residential buildings is increasing and it is going fast. After years of development the commercial interest increases due to new fast modern industrialized building technique, Structural stability of light weight buildings and fire protection is solved, if not the buildings would not exist. No one wants the inhabitants to experience severe fire damage or damage due to break emanating from lack of strength. Nevertheless, still the sound insulation requirements are a remnant from the history and not adapted to current development of new systems.

Poor sound insulation is not a problem that is obvious to those who will buy an apartment immediately. They will become aware of it after they have moved into their new housing unit. In case the problem becomes severe and involves diffuse low frequencies and perhaps also

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includes disturbing vibrations it might cause long term effects on human beings. In case it is high frequency problems it might be irritating but often these problems will be solved quite easily even if the inhabitants have already moved in. Unfortunately light weight structures normally exhibit behavior involving diffuse low frequency problems and in case of failure it is very difficult to accomplish sufficient measures afterwards. Hence, in order to prevent an adverse development of the light weight building industry in general there is a need for quick action regarding target values and evaluation principles for sound insulation, and then in particular low frequency impact sound and vibrations caused by household activities.

2. BACKGROUND

Within Europe, Sweden is the only country which has adopted the low frequency spectrum adaptation term for impact sound (and for airborne sound) as a requirement in the national building regulations [1]. The reason for this was to adapt the requirement, at least to some extent, to new building technique for multi storey houses, with light weight structures. However, new research proves that the introduction of the low frequency spectrum adaptation term for impact sound is not harsh enough in order to prevent bad constructions to enter the market [3, 5]. It is necessary to rather quick create a new evaluation curve for impact sound and to introduce some sort of requirement regarding vibrations from household activities. The minimum impact sound requirement today in Sweden is:

$$L'_{n,w} \leq 56\,\mathrm{dB} \qquad (1)$$

$$L'_{n,w} + C_{I,50-2500} \leq 56\,\mathrm{dB} \qquad (2)$$

Both figures in eq. 1 and eq. 2 have to be fulfilled. For vibrations no strict minimum requirement exists, hence in case of annoying vibrations there is no building code taking care of this. Due to these facts there is a need for a reconsideration of current evaluation of impact sound but also to consider vibrations. This is of immediate interest since

- The experienced sound insulation is normally worse than the objective value exhibit, perhaps reinforced due to combined low frequency noise and vibrations
- The sound class for a light weight construction do not correspond to the sound class for a heavy weight construction even if the objective values are identical
- The light weight industry is rapidly increasing its market share. Hence, in case current objective measures retain, the risk of increased numbers of bad constructions entering the market grows

Perhaps a new evaluation curve is not necessary for all types of living accommodations. For some certain types of housing units current evaluation principles might work. However, there is certainly a need for raised knowledge regarding modern living habits in order to state well founded criteria in those cases. Hence the results might become different single numbers applicable to various multi storey residential building.

An example of what might happen even if the most severe low frequency single number according to current ISO 717 is applied is shown in figure 1. The two curves emanates from two very different constructions. One construction is a light construction with severe low frequency disturbance (complaints from the inhabitants) and one is a heavy homogeneous concrete construction, both taken from modern multifamily houses in Sweden. The construction behavior of these two extremes is completely different but still the types of dwellings are similar, expensive and modern family housing units. Naturally, considering the design of present building regulations, the evaluation in both these cases were accomplished according to current ISO 717 even if this standard still is entirely adjusted to heavy constructions. They both fulfill sound class A according to the Swedish sound classification standard SS 25267. The ISO results for the two examples are:

$$L'_{n,w} = 35\,\text{dB (wood)} \tag{3}$$

$$L'_{n,w} = 48\,\text{dB (concrete)} \tag{4}$$

$$L'_{n,w} + C_{I,50-2500} = 48\,\text{dB (both)} \tag{5}$$

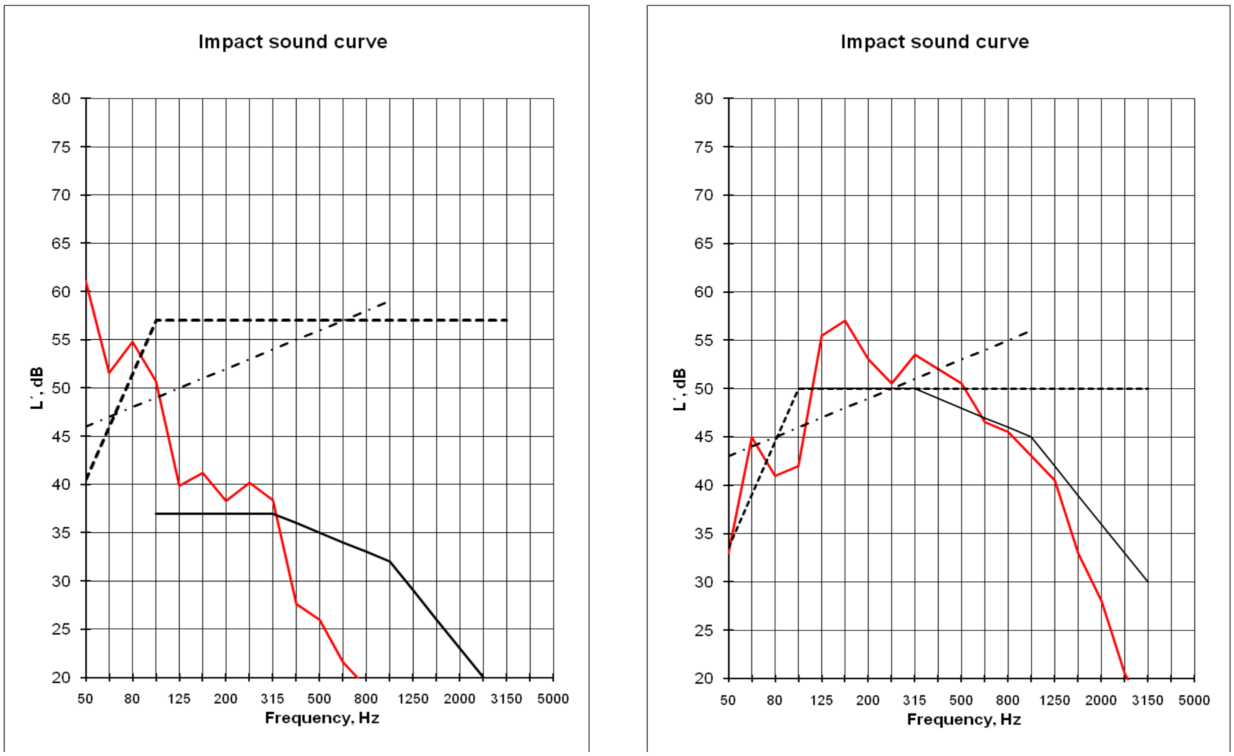

Figure 1: Examples from two real measurements. Left: Wooden structure with severe complaints fulfilling sound class A according to Swedish Sound classification standard. Right: Homogenous concrete structure fulfilling sound class A too but experienced almost "too quite".

Using current evaluation principle, an "end consumer" who knows nothing about acoustics catches the wooden house as 13 dB better than corresponding concrete house. However in reality (what is subjectively experienced) it is definitely the opposite! Studying low frequencies, the difference, in favor to concrete, is 28 dB at 50 Hz. In case using alternative reference curves and hence alternative single numbers, L_B, Bodlund 1985 [2] and L_{new}, Hagberg 2005 [3] the "end consumer" at least will be aware that the light weight structure is acoustically worse than the concrete structure not only subjectively but also objectively, see table 1. Instead of being 13 dB better it becomes 7 dB worse, which corresponds to a switch of 20 dB in terms of single numbers. Nevertheless, the light weight construction still will fulfill the similar potential minimum requirement which could be specified to [3]:

$$L_B \leq 62\,\text{dB} \tag{6}$$

$$L_{new} \leq 61\text{dB} \tag{7}$$

However, in case very low frequency disturbance occur not even these values are enough severe, but if they are used in addition to the ISO figures and if the measured curve is studied in parallel, they give at least some indication that there exist severe low frequency noise which has to be taken into account [4].

Table 1: *New single numbers might help to prevent the most degenerate offshoots of constructions in order to promote a healthy development of new light weight building systems.*

Measure	Wood [dB]	Concrete [dB]
$L'_{n,w}$	35	***48***
$L'_{n,w} + C_{I,50-2500}$	48	***48***
L_B	***56***	53
L_{new}	***57***	50

Of course, there exist some constructions in between these two extremes shown in figure 1. It is a floating scale from very light constructions to heavy homogeneous constructions. Today, if using ISO 717 and its low frequency spectrum adaptation term the single numbers and its adaptation to various structures is described very roughly in figure 2. $L_{n,w}$ does not work at all for light constructions (Zero on vertical scale) but is fully acceptable for heavy homogeneous constructions (One on vertical scale) whilst adding the low frequency spectrum adaptation term improves its adaptation to light constructions but also deteriorate for heavy constructions (high frequencies). If using the single number proposed in [3] it would come closer to the preferred value for any construction, but still not fully applicable to light constructions. Lower frequencies and vibrations determine the experienced value. However, it is important to take into consideration that the single numbers proposed in [2, 3] are valid only for what is historically called “normal dwellings”, and this is of course yet another shortcoming. In order to optimize the each type of residential building, i.e. to minimize production costs, regulations always have to be adapted to not only new constructions but also to new modern living habits in general and of course living habits during certain periods of life, i.e. risk for noise exposure due to type of accommodation.

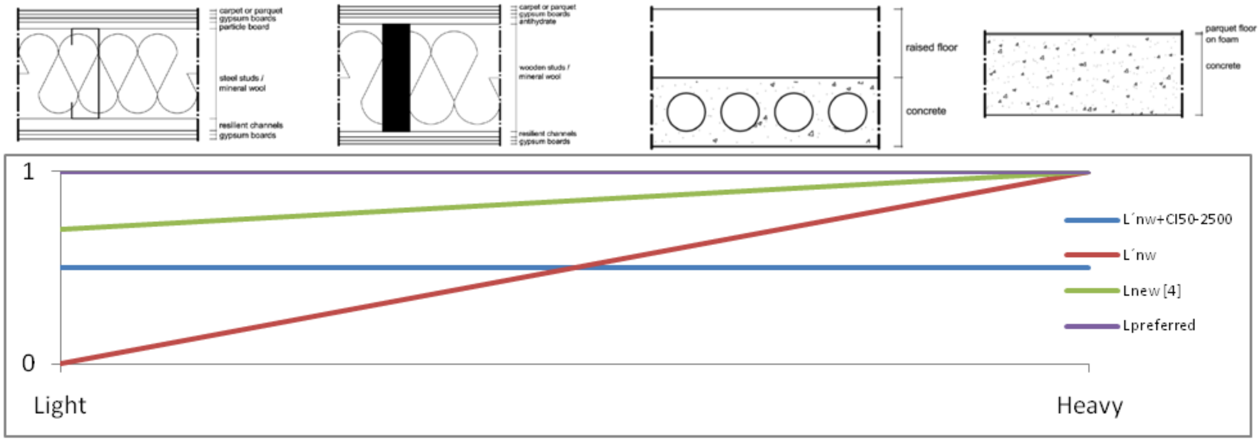

Figure 2: An attempt to describe the adaptation of different single numbers to different types of building constructions when applied to "normal dwellings", i.e. family multi storey residential buildings. On the vertical scale 0 represent bad adaptation and 1 represents good adaptation to the construction.

There are a number of advantages to continue the development of light weight structures. Its high degree of prefabrication and short building time on-site, together with an effective and "dry" building method is a positive future development for the building industry in general which historically uses old production method and has not been very interested in research development. Hence, this development might benefit the production economy and secure high quality regarding failure during erection, for example minimizing damp damages. Furthermore the material waste is less due to the element production in a plant, and production in a plant is good for the workers (decreased risk for bodily injury). Then of course if using wood, the raw material is taken from renewable resources, which is environmentally friendly. But don´t forget the acoustic behavior of a light weight structure – it is not at all similar to heavy weight structures!

To promote the use of light weight structures in future residential buildings, research is needed which in the extension will involve requirements adapted to various types of living accommodations. This will facilitate the development of competitive light weight systems also for multi storey houses which is not in need of the same requirements as the "normal dwellings" to which prior research has been directed.

3. DEVELOPMENT – NEEDS

The aim of the content in this paper is to show that there is an immediate need for review of evaluation principles for sound insulation in residential multi storey buildings. As new building structures are developed the design has to be directed towards new single numbers / evaluation principles regarding low frequencies and vibrations, naturally also considering potential high frequency disturbances. The primary development needs are summarized below in order of priority and this order is important to address correct means of control to the light weight industry to strengthen its power of competition in general but also to consolidate its position compared to the traditional heavy weight (concrete) industry. The most immediate parts below is also important for the society in order to secure the fulfilment of the essential requirement "Protection against noise" of the European Construction Productive Directive (CPD) for buildings with light weight structures.

1. Establish a well founded criteria for evaluation of impact sound insulation in order to make various sound classes A, B or C reasonably comparable to the sound classes of heavy building structures

- Take various types of living accommodations into consideration
- Connect to the needs of airborne sound insulation (optimizing)
- Take the source of energy into consideration (impact sound machine and other sources)

2. Connect the criteria to the experience of vibrations or establish separate criteria for vibrations – how will vibrations affect the valuation of sound (including structure borne sound from machines in houses with light weight structures)?

   - Is the human behaviour affected by the structural material?
   - Take common structure borne noise sources in residential houses into consideration (for instance washing machines including rotating units, bubble bath, etc)

3. Study long term effects regarding various methods for reduction of flanking transmission.

   - Consider the material characteristics of the interlayer to minimize flanking transmission and wind anchorages and their influence on sound insulation over time. This is important to minimize the risk of successively deteriorating sound insulation

4. Facilitate the trade / export with light weight building system in through increased harmonization of the regulations, which is favourable also for heavy structures (In the long term point 5 is also very important)

   - within the Nordic countries
   - within Europe
   - international

5. Develop calculation methods with well known security margin which might be applied on light weight structures. To achieve this it is needed

   - increased knowledge amongst light weight constructions and its anisotropic characteristics
   - knowledge amongst various joints and their behaviour, flanking transmission

4. DISCUSSION

The main reason for this order of priority is of course to address correct means of control in order to develop light weight structures (floors) which will become competitive with regard to impact sound / vibrations. Competitive both in general terms but also to consolidate its position compared to heavy building structures and also to minimize the risk of investment today which will become future problems for the society. The sound insulation in light weight structures is normally completely controlled by the sound levels in the lowest frequency bands while sound insulation in heavy structures not exhibit this “unbalance”. As long as the experienced sound insulation from a certain sound class <u>mostly</u> is worse for light weight structures despite it is objectively similar compared to heavy structures, this imply an obvious disadvantage for the light weight industry and a future risk for the society. Today, there is far too big scope for serious mistakes and shortage with current regulation and standards.

With correct means of control light weight structures might be developed in a manner meaning that the objective valuation accomplished, actually results in a light weight construction which is experienced subjectively equal to heavy structures. If not starting at this point the development might go too far in wrong direction, creating negative effects to light weight constructions. Even if a number of good examples exist today it is those buildings which are bad that might make the reputation gradually worse. Normally it is the industrial representatives who regularly really are working with the acoustic topics that express the need for revised evaluation principles. Perhaps since their solution becomes more expensive and complicated, compared to those who are taking “the easy way”, fulfilling the minimum requirement without any margin. Hence, if current evaluation principles remain unchanged the entire industry might suffer from bad reputation in future, created by those who are working close to limit.

Poor sound insulation at low frequencies creates both low frequency noise and vibrations, and then in particular (or almost solely), in buildings with light weight structures. When the noise is audible or the vibrations is possible to feel (when the hearing threshold is attained) a very small change is needed to experience increased disturbance. Normally 8-10 dB is used as a template to describe an experienced doubling or halving of the sound. This is not valid at very low frequencies, in those it might be enough with 3-4 dB to experience a doubling or halving of the sound. Besides this there are yet a number of factors influencing the sound levels at very low frequencies.

Vibrations are a very rare problem in heavy weight structures and normally not considered when studying normal housing activities. However, in a light weight structure they often occur, they are felt and they cause shaking of glass cabinets etc. A walking person or a jumping / playing child cause a combination of vibrations and low frequency noise, so do a bubble bath or washing machine. Some studies regarding vibrations and its subjective experience exist, however not the vibrations influence of the noise impact on the habitants at low frequencies, i.e. the combined influence of vibration and noise is an unknown area.

The modern light weight industry suffers from yet another disadvantage. Current building systems are normally comprehensive systems, compounded plane elements (walls, floor structures) or volumes piled together, well adapted to the legislation in country in point. It is not possible to simply replace single products since the systems are complex and the European standard EN 12354 is not applicable, and hence calculations are not possible to carry out with the same precision as for heavy weight structures. Hence, light weight building systems adapted to one country requires new adaptations to become competitive in another country and such adaptations cannot be made without extensive tests, perhaps in test buildings of different kinds. The threshold to enter new markets becomes huge. Therefore, the immediate need for more equal legislation / evaluation principles are more important to light weight industry.

5. SUMMARY

Right now there is an excellent opportunity to participate in the development of new standard evaluation principles. The evaluation standard ISO 717 is decided to become revised. Research within the proposed area would give rapid industrial benefits. In this context collaboration synergetic effects with the EU COST Action FP0702 for wooden buildings: *“Net-Acoustics for Timber based Lightweight Buildings end Elements (TBLB)”* might be expected. Furthermore, there exists yet another COST-action, aiming to harmonize the regulations in general *"Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions"*.

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