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MFB - Wooden building system with high sound insulation

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ABSTRACT

A new wooden structure based building system with high sound insulation aimed for multi storey residential buildings with a maximum height equal to eight storeys has been developed by the Swedish company Masonite Beams AB (a member of Byggma ASA). The building system is compounded by Masonite light weight beams and a certain stiff board lamella slab which is mounted; 1. on top of the floor structure; 2. as a bearing element in the walls. In order to secure the final sound insulation properties, and to shorten the time for erection on site, the degree of prefabrication is high. The elements are delivered as plane floor and wall elements which will involve all technical installations. Hence, all elements are assembled on site and the floor elements are connected to the bearing walls through vibration isolated joints. Maximum floor span of the elements will be equal to 10 m, allowing great freedom of action regarding individual dwelling design. The building system fulfil sound class A according to the Swedish sound classification standard, SS 25267 which imply impact sound level less than or equal to $L'_{n,w}+ C_{I,50\text{-}2500}$ and $L'_{n,w}$ 48 dB and airborne sound insulation greater than or equal to $R'_{w} + C_{50\text{-}3150}$ 61 dB. The sound insulation of the system is verified in one two storey test building in Rundvik in Sweden and in a recently finalized four storey residential building in Stockholm, Sweden. This paper presents the technical principles of the system and its sound insulation properties.

1 INTRODUCTION

Building technique using lightweight structures and in particular, wooden structures, is interesting for any country with large areas covered with forest (like the Nordic countries) not least since the forest is renewable. Hence, if this opportunity is used carefully and with respect to the environment it is a source of building material that is always available.

The development of high rise multi storey residential buildings has rapidly increased in intensity over the last five to ten years in Sweden and other Nordic countries. To large extent the development is impelled by the industry itself. A number of systems have entered the market, most of them based on prefabricated volumes which will be piled together on site. Even though the experienced sound insulation in light weight multi storey buildings differ from those with heavy structures despite their objective measures are similar (unfortunately, the subjectively evaluated sound insulation is normally worse in a lightweight building, particularly with regard to impact sound) volume element systems exhibit acceptable or good acoustical properties. Furthermore, their technical characteristics are predictable and hence, they will serve their purpose to a great extent. Even though the systems are beneficial in many cases, there are disadvantages as

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- their finite ability to offer flexible plan solutions
- their degree of prefabrication lead to a size that interrupt the traffic flow during transport from the manufacturer to the site

Current system, MFB (Masonite Flexible Building system), differ from other systems since it is based on plane wall and floor elements joined together on site through a particular joint preventing sound transmission from the floor to the connected walls. The objective of the system development is to create a flexible building system for high rise residential buildings (approximately 8 storeys) with high degree of prefabrication but still, take the impact sound insulation into consideration in particular in order to compete with heavy structure buildings.

Furthermore, the system will also be flexible with regard to production alternatives since the system elements might be manufactured either at certified manufacturers or at plants established on-site for a particular building. If produced at certified manufacturers the elements will be easy to convey on trucks or train since they are flat and the width is limited. In the case where a plant is established on-site the building products (beams, gypsum boards, flexible hangers, mineral wool etc) are delivered to the site and then the elements are both produced and mounted on site by the contractor. In this paper examples will be given from both lines of production action, one site in Stockholm, Sweden and one site in Gothenburg, Sweden.

2 SYSTEM DESCRIPTION

2.1 Basic prefabricated system

The basis of the system consist of two main elements

- load bearing exterior wall elements
- floor structure elements joined to the load bearing walls through a momentum free joint

The load bearing part in the exterior (façade) wall is a stiff board lamella slab with small cuttings on top to be used for the floor structure joints. To prevent flanking transmission between different storeys, through the wall board lamella, and to create a space for installations the board lamella is covered with a layer facing the inside of the dwellings, see Figure 1. The layer is acoustically divided from the board lamella via Gyproc acoustic profiles and a framework of wooden beams covered with at least two layers of gypsum boards, see Figure 2. When the system is fully developed the aim is to deliver the wall elements equipped with all installations in the layer facing the apartment. The wall elements will be conveyed standing to an upright position on a truck or a train to prevent damage of the resilient installation layer.

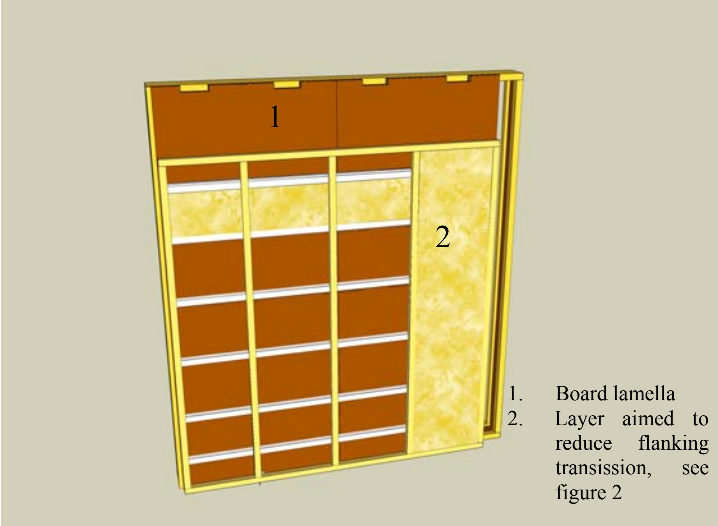

Figure 1: Principle for the load bearing part of the exterior wall including an interior flanking transmission sound reducing layer.

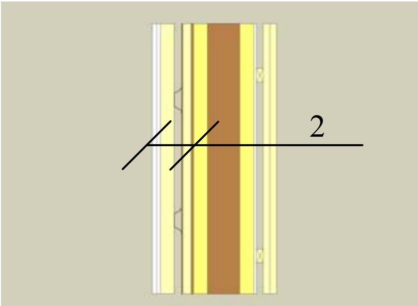

Figure 2: The load bearing exterior wall. The layers indicated with the number 2 is from right to left; 2 layers of 13 mm gypsum board; 45 × 45 mm^2 wooden beams and mineral wool; Gyproc resilient acoustic profile (AP); board lamella.

The floor structure elements are built up around I – shaped beams from Masonite AB, HI 350 or HI 300, depending on the floor span. Below the beams a suspended ceiling is mounted and above the beams the board lamella is mounted. The board lamella is tightly fixed to the beams both with glue and screws in order to create an interaction between the parts involved in the structure. Hence, the floor structure becomes really stiff and has an ability to distribute the load effectively over the surface to the edges. The floor covering is applied to the board lamella surface either directly or using an intermediate layer of floor gypsum board. The normal system floor span is between 6 m and 10 m. The sound transmission through the floor structure is partly reduced by

1. the suspended ceiling
2. the floor covering applied to the board lamella surface

The suspended ceiling is integrated to the element by the manufacturer using a particular resilient hanger from Christian Berner AB enabling the flat elements to be transported piled above each other from the element production plant to the building site, hence minimizing the work on site. When the floor element is mounted on site the ceiling will “fall down” and the soft acoustical material Sylomer will start to work as an acoustical “obstacle”. The design principle for the floor structure is given in Figure 3.

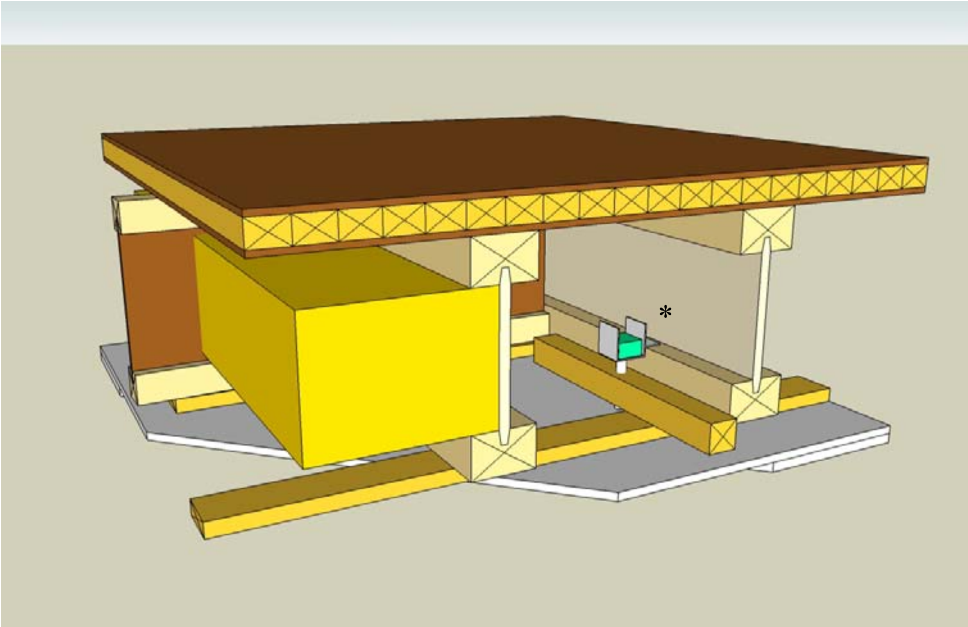

Figure 3: The design principle of the floor structure. An example of the resilient hanger is indicated with *. When the element is conveyed the hanger is automatically out of order and the ceiling is able to carry transport load through the wooden beams.

The floor elements will be connected to the load bearing exterior wall elements through a resilient and momentum free joint. The joint comprises one steel plate shaped as a hanger and the dynamic damper Sylodyn ©. The joint hanger is mounted on each side of the floor element, see Figure 4. The horizontal loading is taken care of through the steel plate.

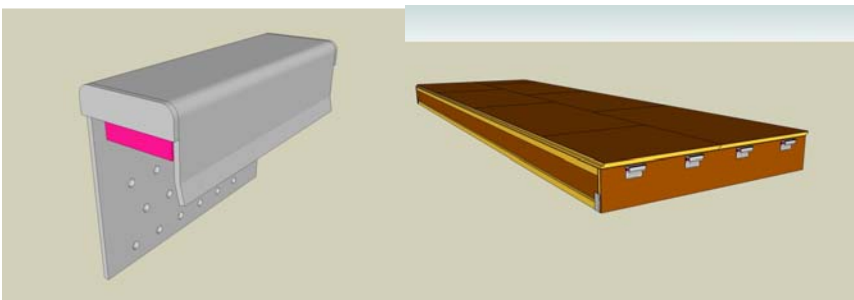

Figure 4: The steel hanger and their application to the floor structure.

The system parts will be compounded on site in very short time after its delivery to the building site. However, for a fast and effective erection it requires carefully performed casting of the foundation, it has to be even and levelled according to the conditions specified from the manufacturer. If not, the system parts might be difficult to fit together and small errors in the lower part will tend to increase for upper storeys. The principle for composition is given in Figure 5 and Figure 6.

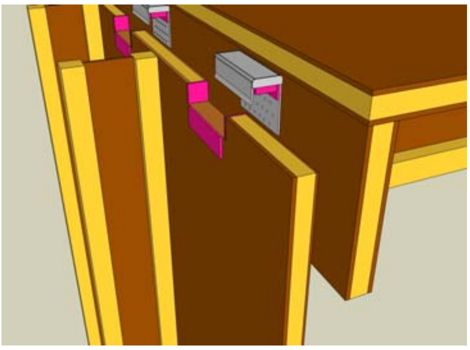

Figure 5: The floor structure application to the load bearing walls.

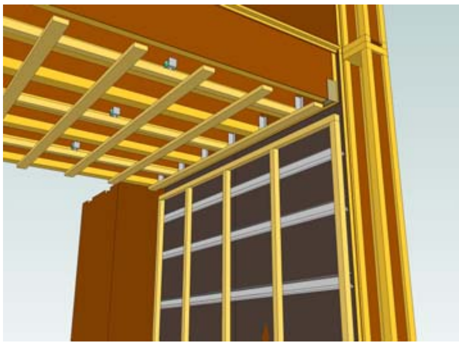

Figure 6: The floor structure from below and its connection to the load bearing walls including the sound reducing ceiling and wall covering.

The system might also be delivered with load bearing separating walls between dwellings, however it is not preferable since the separating wall will become complicated and its airborne sound insulation will be limited and not reach as high sound insulation as the system might exhibit through other parts.

2.2 Manufacturing on site

In some particular projects with certain prerequisites, a common fully prefabricated system is not preferable. For example in large cities, it becomes more and more common to find attractive plots of land. A typical and modern condensation of a housing area might be where an existing foundation is used, for instance if a parking house will be complemented with a number of dwellings above. In those particular cases it is necessary to use a lightweight system in order to minimize the added load to the existing foundation. Normally, these types of buildings also need adaptation on site to some extent. Besides these particular cases, some contractors prefer to establish their own production plant due to their internal quality aspects etc. Too meet these requirements from the clients, MFB is flexible also with regard to this aspect.

In a project in Gothenburg in Sweden a building using MFB **floor** elements is currently being put together. The floor elements are produced in a production plant established on site solely for this complicated project. In this project the board lamella is replaced with a 22 mm particle board + 2 layers of gypsum board. Also the ceiling hangers are replaced with more simple ones, which is possible since the elements are produced on site. The replacement of the board lamella where judged as fully possible as the floor span in this project is short, there is one steel beam support in the middle of the building. Hence, using on site manufacturing might involve options to some cost saving measures when it comes to building parts included in the elements.

3 RESULTS

The results from measurements and design will be presented from three projects

- A test building in Rundvik in Sweden. A two storey building with a floor span equal to 10 m. The system is identical to the basic prefabricated system, however installations excluded.
- A four storey building in Stockholm, Sweden, recently completed. Also in this case the system is identical to the basic prefabricated system, apart from some additional details regarding the floor covering above the board lamella. The details are described below, in connection to the measurements results
- A three storey building in Gothenburg, Sweden, partly completed during this paper preparation. The building is on site manufactured and it is solely the floor structure elements as are typical MFB elements. A detail description is given in connection to the measurement results.

In all measurement results presented below the results are presented according to edition 3 of the Swedish standard SS 25267, i.e. the receiving room volume is limited to 31 m^3 whit respect to impact sound level, $L'_{n,w}$ and the relation *V/S* is limited to 3,1 with respect to sound insulation, R'_w. Hence most of the single number values, $L'_{n,w}$ and R'_w, equals $L'_{nT,w}$ and $D_{nT,w}$.

3.1 Test building in Rundvik, Sweden

The building consists of two storeys divided by three floor elements, i.e. 10 m floor span and a width equal to 2,4 × 3 m. However, approximately 0,1 m disappears due to the layer aimed to reduce flanking transmission, see figure 1. This means a floor area equal to 70 m^2. The height of the room is 2.4 m and the receiving room volume becomes 169 m^3. This is not a normal receiving room volume of a room in housing units and therefore the receiving room was divided into two smaller rooms during measurements, where the smaller room volume was 68 m^3 (area ≈ 7,1 × 4 m^2). The impact sound level measurement results presented in Table 1 below emanates from the smaller room.

Three different floor coverings were used

1. Floor structure - rough surface
2. Floor structure equipped with 2 mm Airolen© + 14 mm parquet
3. Floor structure equipped with 13 mm gypsum board + 2 mm Airolen© + 14 mm parquet

Table 1: This table contains impact sound results emanating from the test building in Rundvik, Sweden. The results are evaluated according to SS 25267:2004 (edition 3). The indication [1] in the table below, include the following explanation to the sound classification system: Presupposed that that the mean value from all measurements within one hosing unit will fulfil the requirement, minor deviations (maximum 2 dB) are accepted for single measurements. Thus, this might become a sound class A building with regard to impact sound. With one layer of gypsum board below the floor covering (no 3) class A will be fulfilled even if this condition is excluded.

Floor	Impact sound level SS 25267, edition 3 [dB]		Limit [dB]	Paper – ID
	L'_{nw}	$L'_{nw}+C_{I,50\text{-}2500}$	A / B ≤	
1	61	56	-	IN08_01
2	48	49 [1]	48 / 52	IN08_02
3	47	48	"	IN08_03

In table 2, vertical airborne sound insulation is presented for two cases

1. The installation layer applied to the wall board lamella without Gyproc © sound reducing beam
2. The installation layer applied to the wall board lamella with Gyproc © sound reducing beam according to Figure 1 and 2.

Table 2: This table contains airborne sound results (vertical) from the test building in Rundvik, Sweden. The results are evaluated according to SS 25267:2004 (edition 3).

Case	Airborne sound insulation SS 25267, edition 3 [dB]	Limit [dB]
	$R'_w+C_{50\text{-}3150}$	A / B ≥
1	54	61 / 57
2	62	-

Please note that the test building is an idealized case since the building does not include any installations. Furthermore, the building is not equipped with window openings or any other irregularities that might affect the sound insulation of the building. Nevertheless, this initial test showed that it is possible to create a multi-storey building with long floor span and high sound insulation properties.

3.2 Four storey MFB building in Stockholm, Sweden

During 2007 the first complete MFB building, located outside Stockholm in Sweden, was produced. The building comprised four storeys and the requirements of the sound insulation were to fulfil sound class B according to SS 25267:2004 (edition 3), hence fulfilling L'_{nw} and $L'_{nw}+C_{I,50\text{-}2500}$ less than 52 dB ($V_{r,max}$ 31 m^2) and $R'_w+C_{50\text{-}3150}$ larger than 57 dB. In order to secure the results the floor was applied with an extra layer of 13 mm gypsum board according to floor no 3 in Table 1. The measurements were performed during the building process partly without using any floor covering but also with a temporarily mounted parquet layer, approximately 6 m^2 that was moved as the tapping machine position was changed. The results are shown in Table 3 and Table 4.

Three different floor coverings were used

1. From 2nd floor to 1st floor, living room – living room (V = 109 m^3, limited to 31 m^3), parquet on Airolen © 3 mm applied to the floor
2. From 2nd floor to 1st floor, living room – living room (V = 109 m^3, limited to 31 m^3), measured directly on gypsum board
3. From 3rd floor to 2nd floor, living room – living room (V = 109 m^3, limited to 31 m^3), measured directly on gypsum board

Table 3: This table contains impact sound results from the first complete MFB building in Stockholm, Sweden (comprising 4 storeys). The results are evaluated according to SS 25267:2004 (edition 3).

Floor	Impact sound level SS 25267, edition 3 [dB]		Limit [dB]	Paper – ID
	L'_{nw}	$L'_{nw}+C_{I,50\text{-}2500}$	B ≤	
1	46	49	52	IN08_SO_01
2	48	50	"	IN08_SO_02
3	52	52	"	IN08_SO_03

3.3 Three storey building (MFB floor structure) manufactured on-site in Gothenburg, Sweden

During 2006 – 2008 an additional concept was developed in close cooperation with one of the largest building contractors in Sweden. Due to the complex project conditions with an existing foundation of a current parking house the building weight has to be limited in order to be able to build enough high building to create an economical interesting project. Furthermore, the current parking house was very well fitted to use as a temporarily production plant for flat wall and floor elements. These conditions are suitable to the MFB system and hence the first on – site production plant was established. In this particular project the MFB system is limited to the floor structure, since the walls are produced using ordinary wooden beams. Even the floor structure is changed to some extent since the board lamella is replced with 22 mm particle board and two layers (2 × 13 mm) of gypsum boards. The outer walls are load bearing, however the floor structures is not connected to the walls as in the ordinary MFB system, see Figure 7. Sylomer © damping material is applied between the intermediate walls and the floor structure beams. In some cases an additional load bearing steel beam is mounted in the middle of the building when necessary in order to reduce the floor span.

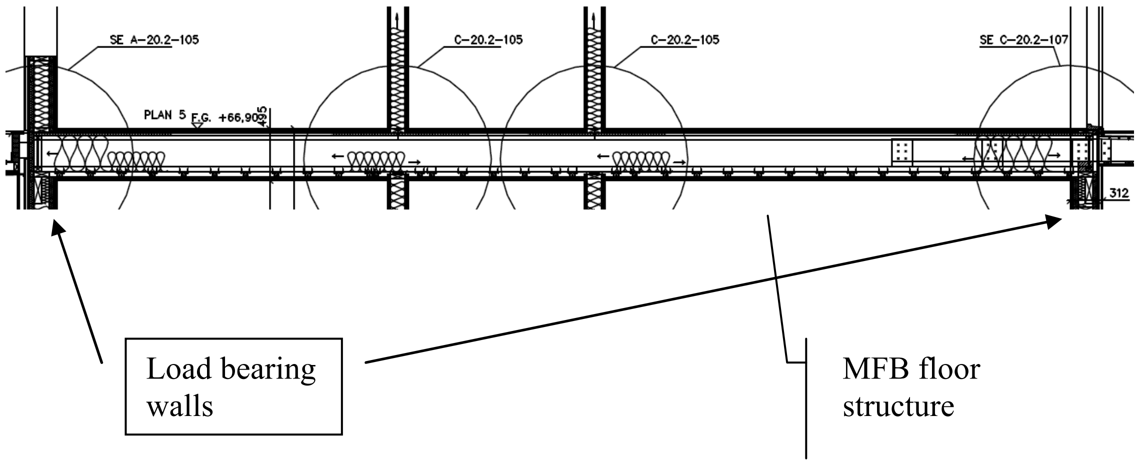

Figure 7: The intermediate floor structure and its connection to the walls for the project manufactured on – site.

All measurements presented in this paper are performed before applying the floor covering. Therefore the results shown in Table 4 prove to have opposite figures compared to normal appearance for wooden structures (normally $L'_{nw}+C_{I,50\text{-}2500} > L'_{nw}$). When the floor covering is applied to the structure the L'_{nw} value should become lower and hence almost fulfilling sound class B. This is an expected effect since the reference curve is exceeded in the high frequencies and the floor covering impact sound improvement will lower the impact sound levels in those frequencies, see Figure 8.

Table 4: This table contains impact sound results from the building in Gothenburg, Sweden, manufactured on site. The results are evaluated according to SS 25267:2004 (edition 3).

Vertical measurements between	Impact sound level SS 25267, edition 3 [dB]		Limit [dB]	Paper - ID
	L'_{nw}	$L'_{nw}+C_{I,50\text{-}2500}$	B ≤	
734 – 717 living room	54	52	52	IN08_KAV_01
733 – 716 living room	56	53	"	IN08_KAV_02

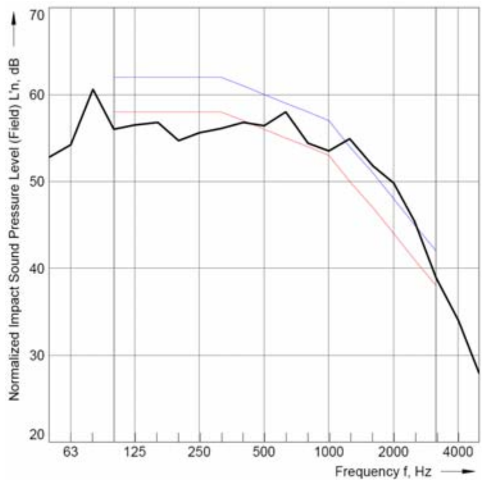

Figure 8: Measured impact sound level in the living room in apartment no 716 from the living room in apartment no 733. When the floor covering is applied the high frequency levels is expected to become lower and hence reduce the $L'_{n,w}$ value.

In Table 5, vertical airborne sound insulation between the living rooms in the two dwellings is presented. In both cases the sound insulation exceeds the minimum requirement according to SS 25267:2004 (edition 3), satisfactory. Also the horizontal sound insulation was measured and proved to fulfil sound class B. However, since that partition is not involved in the MFB system it is excluded in this paper.

Table 5: This table contains airborne sound results (vertical) from the project in Gothenburg, Sweden, manufactured on site. The results are evaluated according to SS 25267:2004 (edition 3).

Vertical measurements between	Airborne sound insulation SS 25267, edition 3 [dB]	Limit [dB]
	$R'_{w}+C_{50\text{-}3150}$	B ≥
734 – 717 living room	60	57
733 – 716 living room	59	-

4 ANALYSIS AND DISCUSSION

The results presented in this paper prove that it is possible to produce and erect a wooden structure building which exhibit satisfactory sound insulation properties. Nevertheless, there is still a lot of work remaining until the low frequency properties are equal to those appearing in heavy structure multi storey residential buildings. Nevertheless, MFB is a system with considerably good low frequency characteristics, but still, if noise from neighbours appear it is most probable that the noise is low frequency heavy impact noise emanating from human footsteps or jumping children in the apartment just above. If calculating a new single number [01, 02] punishing poor low frequency to larger extent than ISO figures do, and compare it to an expected limit for sound class B according to a probable future classification for light weight structures, it is still below the limit for sound class B, see Figure 9.

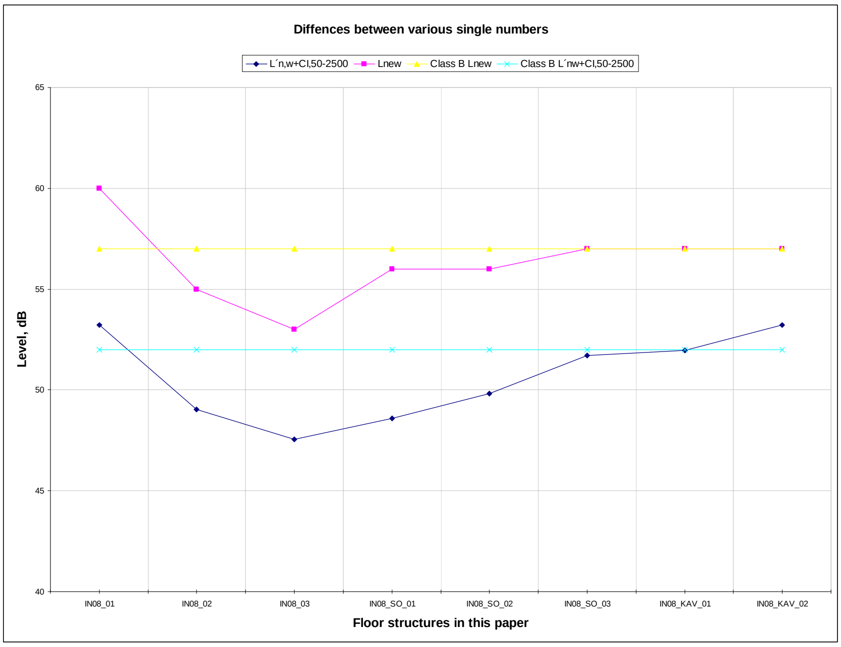

Figure 9: Calculated single numbers according to ISO ($L'_{nw}+C_{I,50\text{-}2500}$) and according to ref 01 (L_{new}) and compare these levels to a limit level expected from results in ref 01 it is obvious that the MFB system is competitive even when low frequencies are taken into account.

I certainly hope that the research within light weight building technique will become more intensive in the near future. It is important in order to make those buildings acoustically competitive to more traditional buildings. First of all, requirements and prediction models for flanking transmission and floor vibration have to be developed a lot. In Sweden, the first step to inspire an increased research activity was taken in a collaboration project (participants from all Swedish research institutes, the wooden industry, leading consultants) during 2007, finalized in May 2008. The project resulted in a report [3] compiling current research status within light weight building technique. The results were also presented in BNAM 2008 [4]. Due to limited time and financial support the report results primarily focuses on the status in Sweden and other Nordic countries. Nevertheless, it could serve as a basis for a future global analysis of the research needs within light weight building technique.

5 REFERENCES

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