Description of the research project CIMEDE for the industrial construction of evolutionary, sustainable and economic houses

Fabienne Duthoit
CEDIA, University of Liège, Belgium.

Jean-Jacques Embrechts

Department of Electrical Engineering and Computer Science, Acoustic lab, University of Liège, Belgium

Summary
CIMEDE is a research project supported by the Region of Wallonia (Belgium). It stands for CIMEDE "Construction Industrielle de Maisons Evolutives, Durables et Economiques – industrial construction of evolutionary, sustainable and economic houses". Since the materials envisaged for this project are timber and gypsum fiber board, it was necessary to design a constructive principle of lightweight timber frame constructions which meets the industrial, sustainable, evolutionary and economic requirements and also the requirements of the Belgian acoustic standard NBN S01-400-1. First of all, an inventory of constructive elements that are currently used in this type of construction (floors, walls and facades) is presented with their acoustic performances. Then, the laboratory measurements of some samples of floors, facades, interior walls and partition walls are described and discussed. On the basis of the measurement results, several solutions that best meet all criteria were retained and a mock-up was buildt with these constructive elements. Measurement results on this mock-up are also presented. The final solution for the floor, the partition wall, the interior wall and the facade which meets the acoustic requirements is finally described

1. Introduction

CIMEDE is a research project supported by the Region of Wallonia (Belgium) which started in 2009. It stands for CIMEDE "Construction Industrielle de Maisons Evolutives, Durables et Economiques – industrial construction of scalable, sustainable and economic houses". CIMEDE continues to evolve to improve each of the criteria. The main industrial partner and coordinator of this project is "L'Atelier de l'Avenir", located in Grâce-Hollogne (Liège, Belgium). This company is specialized in the re-using of wood waste, manufacturing and repairing wooden pallets and crates and it has a woodworking shop. The other industrial partners are WUST, a general contractor, Knauf, a manufacturer of gypsum, Mery BOIS, a woodworking shop and the architectural bureau Grondal. The scientific partnership includes the BBRI (Belgian Building Research Institute) and four research teams of the university of Liège (EnergySud, energy and sustainable development, LUCID, architecture, Structural Engineering and fire technology laboratory and CEDIA specialized in acoustics).

2. Objectives

The main objective is to design a scalable principle of construction which meets the CIMEDE requirements. According to CIMEDE definition, the main requirements are:

- industrial construction : easy prefabrication, as complete as possible,
- scalable : easily removable and reusable,
- sustainable : the main materials used are timber frames and gypsum fiber boards,
- economic: weight optimization, space optimization, easy in situ assembly.

In addition to these objectives, it's obviously necessary to meet requirements of stability, fire and acoustic insulation (through the Belgian acoustic standard NBN S01-400-1). This paper describes the acoustic part of CIMEDE.

3. Main requirements of the Belgian standard NBN S01-400-1 [1]

The standard NBN S01-400-1 defines the acoustic requirements for residential buildings. The main requirements are the following:

- $D_{nT,w} \geq 54$ dB between 2 flats (normal comfort) or 58 dB (superior comfort)
- $D_{nT,w} \geq 58$ dB between 2 new houses (normal comfort) or 62 dB (superior comfort)
- $D_{nT,w} \geq 35$ dB between a bedroom or an office and another room in the same housing (normal comfort) or 43 dB (superior comfort)
- $L'_{nT,w} \leq 54$ dB between 2 housings (normal comfort) or 50 dB (superior comfort)
- $L'_{nT,w} \leq 58$ dB between a bedroom or an office and another room in the same housing (superior comfort)
- $D_{Atr} \geq$ min. 26 dB (normal comfort) or min. 30 dB (superior comfort), depending of outdoor noise.

The objective of CIMEDE is to meet the requirements imposed by the *normal* comfort.

4. Floor design

According to the standard NBN S01-400-1, the acoustic requirements for the floor are the following (normal comfort):

- $D_{nT,w} \geq 54$ dB between 2 flats,
- $D_{nT,w} \geq 35$ dB between a bedroom or an office and another room in the same housing,
- $L'_{nT,w} \leq 54$ dB between 2 housings.

To meet these requirements with timber frame and gypsum fiber board constructions, the usual construction system consists in covering the wooden structure with a floating floor and to hang under the floor an independent suspended ceiling (figure 1).

However, the suspended ceiling is not suitable for industrialisation, as it is envisaged in CIMEDE. To combine prefabrication and acoustic requirements, it is rather proposed to design a basic element of complete floor, easily transportable, that alone would meet the acoustic isolation requirements between rooms of the same housing. Then, a floating floor covering this basic element will be designed to meet the acoustic isolation requirements between housings.

The basic element is shown in figure 2.

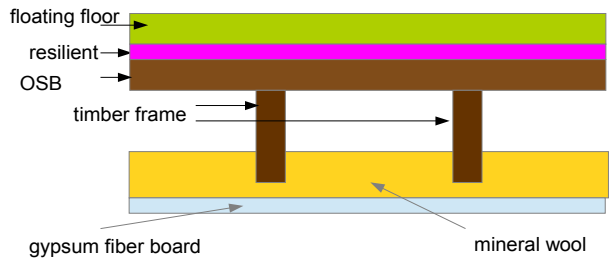

Figure 1. Usual floor construction to meet the NBN S01-400-1 requirements

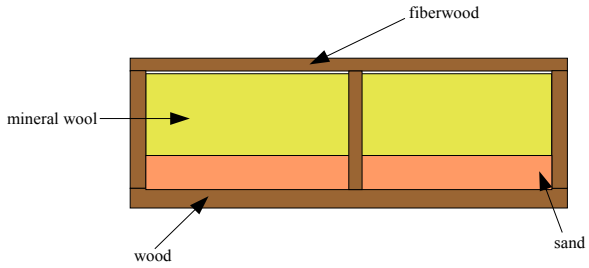

Figure 2. Basic floor in CIMEDE

A mock-up realized with all CIMEDE elements was built in situ. Measurements of airborne and structure-borne sound insulation were realized on the basic floor element.
The measurement results are the following: $D_{nT,w}$ = 40 dB and $L'_{nT,w}$ = 76 dB. The basic floor element therefore meets the requirement imposed between a bedroom or an office and another room in the same housing (normal comfort), but it would be necessary to add a floating floor in order to meet the requirement imposed between 2 flats (normal comfort).

Two kinds of floating floors are considered in CIMEDE: dry and wet floating floors (figures 3 and 4).
The measurement results with a dry floating floor are $D_{nT,w}$ = 56 dB and $L'_{nT,w}$ = 52 dB and the measurement result with a cement floating floor is $D_{nT,w}$ = 57 dB.

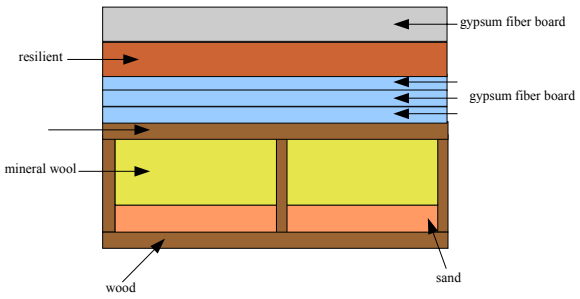

Figure 3. Floor structure with a dry floating floor

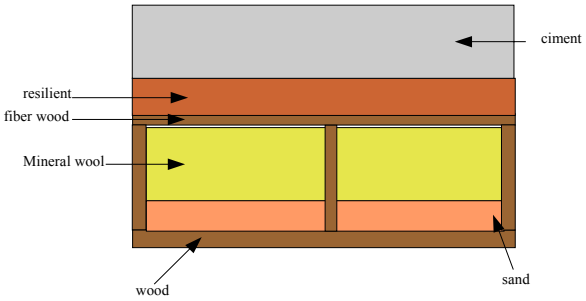

Figure 4. Floor structure with a wet floating floor

5. Partition walls design

According to the standard NBN S01-400-1, the acoustic requirements for the partition wall are the following (normal comfort):

- $D_{nT,w} \geq 54$ dB between 2 flats,
- $D_{nT,w} \geq 58$ dB between 2 new houses.

The classical solution using metal studs has been rejected, because it is not compatible with the objectives of industrialization, prefabrication and sustainable development. In order to combine prefabrication, ease of transport and the possibility to integrate technical elements (inside the wall) already in the workshop, it is proposed to design a complete wall element (OSB + timber frame filled with mineral wool + OSB) and to double this basic element.
The basic wall element is shown in figure 5. The laboratory measurement result for a sample of dimensions (1.5 m*2.1 m) is R_w = 43 dB.
By doubling the basic wall element (figure 6), the laboratory measurement result for a sample of dimensions (1.5 m*2.1 m) is R_w = 61 dB.

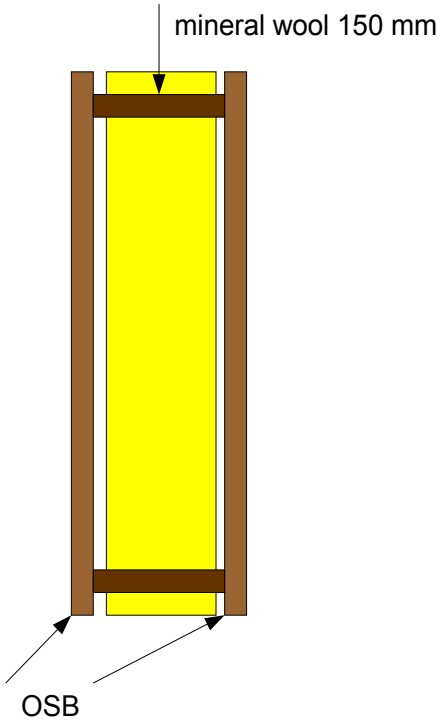

Figure 5. Basic wall element

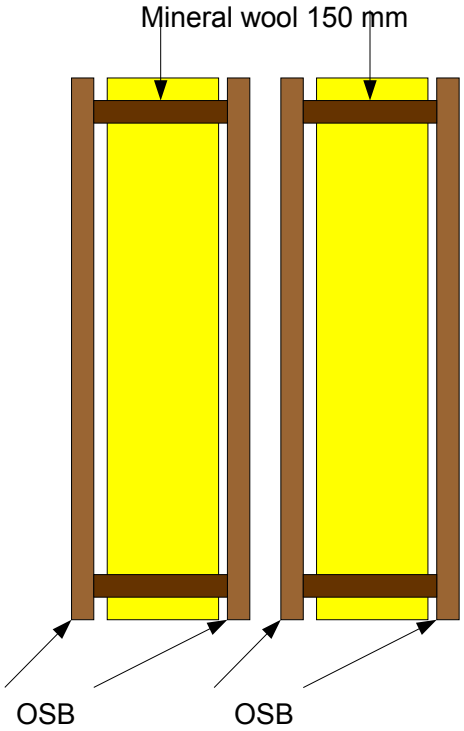

Figure 6. Double partition using two basic elements

Since the measurements have been realized in laboratory with a small sample size, these performances are probably not sufficient to meet $D_{nT,w} \geq 54$ dB or 58 dB in situ. To improve the acoustic isolation and meet the acoustic requirements, a gypsum fiber board is added on each wall (figure 7).

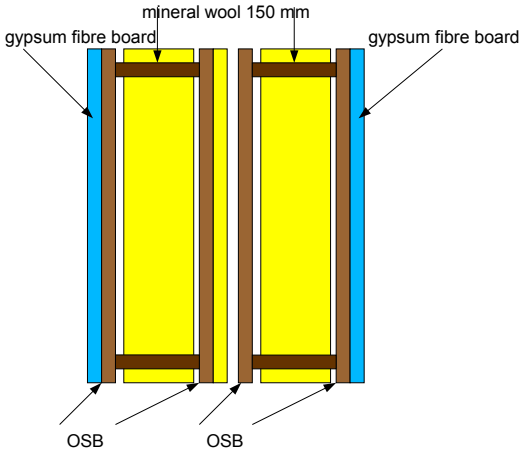

Figure 7. CIMEDE partition wall

The laboratory measurement result for a sample of dimensions (1.5 m*2.1 m) is R_w = 73 dB and meets the acoustic requirements.

6. Facades design

According to the standard NBN S01-400-1, the requirement for the facades is the following :

- $D_{Atr} \geq$ min. 26 dB (normal comfort), depending of outdoor noise.

For example, if the outdoor noise level is 75 dBA, D_{Atr} should be ≥ 44 dB.
To meet this requirement with an inserted window of R_{Atr} = 43 dB, the sound reduction index of a facade element R_{Atr} should be ≥ 49 dB (computed with the standardized road traffic noise spectrum).
As for the partition wall, the classical solution using metal studs or resilient studs is rejected since it not compatible with the objectives of industrialization, prefabrication and sustainable development. For the same reasons as described above, it is proposed to design a complete wall element (OSB + timber frame filled with mineral wool + OSB) and to add gypsum fibre board to meet the acoustic requirement. The cavity of the first sample was 300 mm (figure 8).

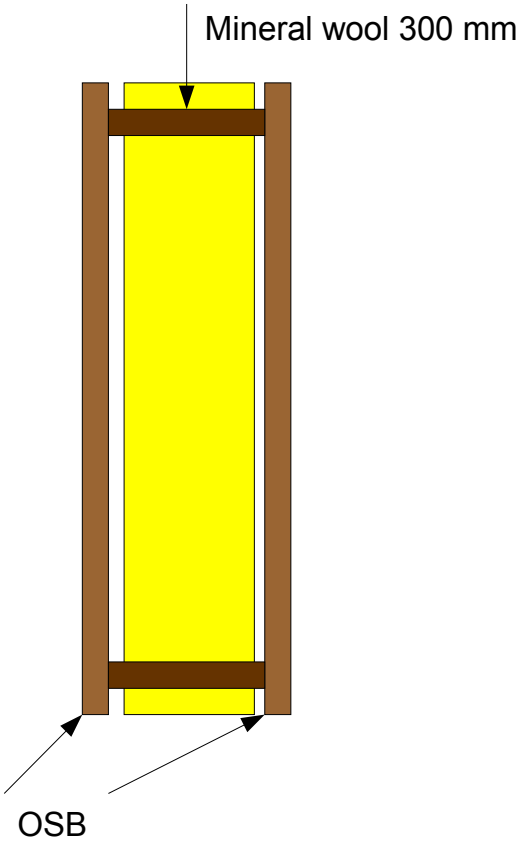

Figure 8. Basic facade element

The laboratory measurement result for a sample of dimensions (1.5 m*2.1 m) is R_{Atr} = 35 dB.

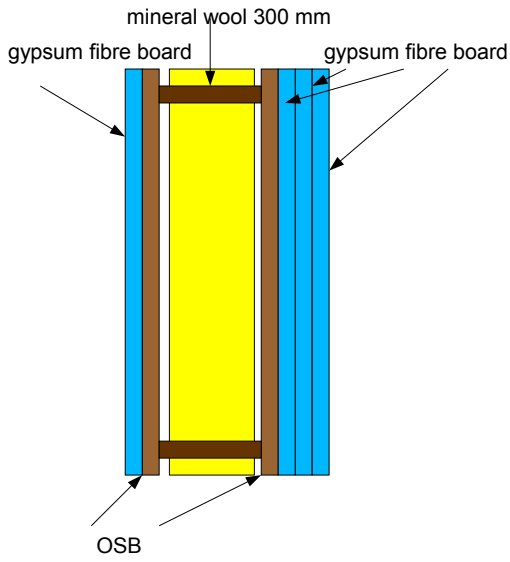

Figure 9 . Complete facade element

To meet the acoustic requirements for an outdoor noise level of 75 dBA, 4 gypsum fibre boards must be added to the basic element, as shown in figure 9. The laboratory measurement result for such a sample of dimensions (1.5 m*2.1 m) is R_{Atr} = 52 dB.

Another suggestion was to use a thinner basic facade element, as shown in figure 10 (economic interest), and to design the lining-partition used for decoration and hiding techniques to meet the acoustic requirements (figure 11).
The laboratory measurement result for such a sample *without* lining partition is R_{Atr} = 41 dB and the laboratory measurement result for the sample *with* lining partition is R_{Atr} = 49 dB, which meets the acoustic requirement for an outdoor noise level of 75 dBA.

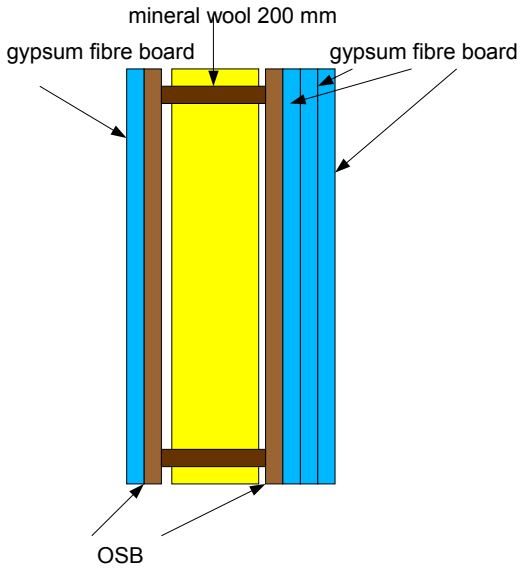

Figure 10. Thinner facade element

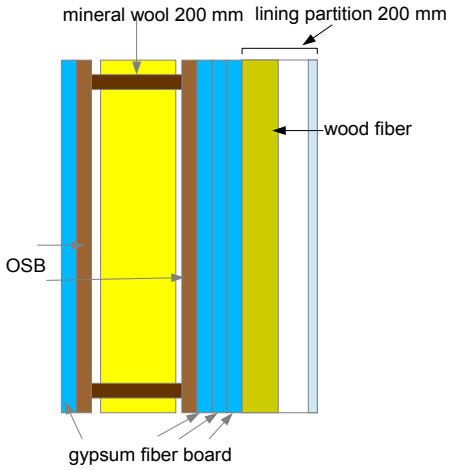

Figure 11. Thinner facade element and lining partition

7. Interior wall design

According to the standard NBN S01-400-1, the acoustic requirement for an interior wall is the following :

- $D_{nT,w} \geq 35$ dB between a bedroom or an office and another room in the same housing (normal comfort).

Tests have been realized in situ on the mock-up. The interior wall is easily mounted and removable with a rail upper and lower as shown in figure 12. The airborne sound isolation of a timber frame partition with mineral wool in the cavity (gypsum fiber board 12.5 mm + timber frame 40 mm + gypsum fiber board 12.5 mm) is $D_{nT,w} = 38$ dB, which meets the requirement.

Figure 12. Mounting of interior wall (picture by courtesy of Atelier de l'Avenir)

8. Examples of achievements

Sinds 2012, "Les Ateliers Dumonceau" have realized buildings following the constructive principle CIMEDE. Examples of realizations are shown in figures 13 to 15.

Figure 13. New offices of Atelier de l'Avenir – outside (picture by courtesy of Atelier de l'Avenir)

Figure 14. New offices of Atelier de l'Avenir – inside (picture by courtesy of Atelier de l'Avenir)

Figure 15. Arche - a residential facility for adults with disabilities (picture by courtesy of Atelier de l'Avenir)

9. Conclusions

The objective of the research project CIMEDE was to design a principle of construction which meets a set of requirements (maximum prefabrication, fast and easy to assemble, scalability, sustainability, economic, acoustic requirements,…). Concerning the acoustic requirements, laboratory and in-situ measurements have shown that the different elements (floor, walls, facades) fulfil the normal comfort objectives imposed by the Belgian standard NBN S01-400-1.

Acknowledgement

The research project CIMEDE is supported by the regional Government of Wallonia (Belgium), DGO 6, by the Convention number 7179.

References

[1] NBN S01-400-1 : Critères acoustiques pour les immeubles d'habitation, 2008.