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Acoustic of lightweight timber buildings: A review

Marco Caniato[a,c,*], Federica Bettarello[b], Alessio Ferluga[a], Lucia Marsich[a], Chiara Schmid[a], Patrizio Fausti[c]

[a] Engineering and Architecture Department, University of Trieste, via Valerio 6/a, 34127 Trieste, Italy
[b] AcusticaMente Designers Team, via Garibaldi 13/b, 31015 Conegliano (TV), Italy
[c] Department of Engineering, University of Ferrara, via Saragat 1, Ferrara, Italy

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ABSTRACT

This paper presents a literature overview of the acoustic studies dedicated to lightweight wooden constructions. The reviewed articles contain prediction models, laboratory and field measurements, finite element or computational investigations as well as subjective survey describing the vibro-acoustic behaviour of a large range of wooden structures. The review analyses different type of timber constructions and investigates the acoustic research methodologies highlighting the following aspects: airborne sound insulation, impact noise reduction, flanking transmissions, human perceptions and pros and cons of the presented methods. Furthermore, an in-depth analysis of impact noise of bare floors focuses on how impact sound reduction could not be as efficient as in heavyweight constructions; the comparison between the different approaches on prediction of airborne sound insulation of multilayer timber partitions compared to traditional heavy building materials is shown. Finally a subjective method survey is provided, underlining the weakest point of timber buildings: low frequency sound insulation.

1. Introduction

Lightweight buildings are present worldwide and their market trend is growing, pushed by the Kyoto protocol [1]. They allow CO_2 storage since wood is widely used as it is renewable and environmental friendly raw material. Generally, these constructions are built within industry plants where very few waste and little energy consumption are possible and allowed. Furthermore, prefabrication often means high quality: educated workmanship is used and CE certifications are required and provided.

The production methods generally include CAD-CAM technologies, permitting new and complex architectural shape, concept and tendencies. The speed of assembly is an interesting point since it is possible to obtain multi-storey buildings containing prefabricated volumes. As a matter of fact, within two weeks, high constructions could be erected thanks to the previous in-depth design and high industrial production precision. In Fig. 1 an example of wall assembly is shown: from a) to c) the precast panel fits perfectly into the spaces of the flanking walls. Fig. 1d) highlights the great precision on the production. The walls (or floors) route start from the truck and finishes with long screw fixation upon the final position falling in its pre-designed location. This indicates the speed and the high precision of assembly typical of timber precast buildings; as a results, these properties attract many stakeholders like designers, builders and lay people.

Nevertheless, the technological diversity distinguishing wooden constructions (frame, CLT, etc.) makes homogenization of forecasting calculation methods more difficult concerning sound insulation parameters [2] compared to traditional massive buildings (concrete, masonry, etc).

In few years multi-storey timber constructions were erected e.g. in Europe [3], Japan [4], New Zeeland [5] and consequently many issues are grown. Over the last period many researchers have tried to handle with sound insulation and reduction topics but what they found is very difficult to understand at a first sight: timber structures are various. Every manufacturer, industrial plant or designer present different solutions using the same raw constructing materials and features: wood, wool, boards. Besides, multiple joints, screws, fastening and locking are possible and every precast wall, floor or roof present different types of junctions. In Fig. 2 it is possible to notice different kind of screw or fastening elements used in the same joints but in different buildings. This fact highlights the difficulty to standardize or predict the acoustic behaviour of joists since it is impossible to forecast how they will be fastened. The different fixing element properties like length, number of possible screws, shape etc. implies a diverse constrains and wall-floors junctions. These facts determine many possible vibrations propagation paths and flanking transmissions. For

* Corresponding author at: Engineering and Architecture Department, University of Trieste, via Valerio 6/a, 34127 Trieste, Italy.
E-mail address: mcaniato@units.it (M. Caniato).

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Fig. 1. Example of wall assembling in a multi-storey light weight timber building. From a) to c) the panel is let down using crane. In d) the high requested precision and accuracy is highlighted.

every wall or floor many different elements could be placed so the in situ behaviour could vary individually from one connection to another.

Furthermore, applying the same prediction methods or analysis used for heavy weight constructions it could be rather approximated. Bettarello et al. [6] show how different bare floors (heavy weight, beams and pots and lightweight ones) present dissimilar impact sound pressure level and the consequent floating floor sound reduction [7] could not assure the same results.

It is possible to find the same conclusion for vertical partitions too [8–10]. About these topics the authors demonstrate how sound insulation is affected by low frequencies and underline the difficulty to predict composite walls insulation [11]. In the same paper, many prediction methods applicable for sound insulation in timber structure are described. The study divides them in two different categories: i) energy combined with empirical knowledge and data approach and ii) deterministic, numerical and analytical approach. The overview con-

Fig. 2. different types of screws, joints and junctions used with precast timber panels. Pictures from different building constructions.