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SOUND INSULATION PROPERTIES OF WALLS EQUIPPED WITH ENERGY STORAGE DEVICES

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ABSTRACT

The integration of electrical energy storage in buildings is a transformative solution for enhancing the efficiency and reliability of the power grid. By installing battery systems, households can store excess energy generated from renewable sources, such as solar panels, during periods of low demand. This stored energy can then be utilized during peak hours, reducing the strain on the grid and mitigating the risk of outages. Energy storage also promotes better utilization of renewable resources by addressing their intermittent nature, ensuring a more stable supply of green energy. A wall equipped with energy storage systems is proposed, to be installed in the external envelope; beyond structural and thermal properties analyses, not described in this research, the acoustic properties of the solution are evaluated, in comparison with an equivalent traditional light-weight wall. In more detail, the airborne sound insulation of these walls has been measured in coupled reverberating rooms, showing a certain improvement respect to light-weight walls, especially at low frequencies. A large space for improvement emerges also as one of the main results.

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1. INTRODUCTION

Building walls serve structural, insulating, and protective functions, with solutions ranging from traditional masonry to prefabricated panels, dry construction systems, wood, and aerated concrete. Traditional masonry, known for its robustness and durability, is complemented by faster and more sustainable technologies such as wood, valued for its energy efficiency and sustainability. A comparison between masonry and wood highlights the ecological and seismic advantages of wood, despite higher costs and maintenance requirements. The choice fell on wooden construction due to its adaptability to various dimensions and ease of customization for integrating electrical storage.

Prefabricated wooden walls can utilize X-Lam or frame systems as load-bearing elements. The X-Lam system, made of cross-laminated solid wood panels, offers high structural strength. The frame system, lightweight yet strong, consists of wooden studs and insulation materials. Due to its configuration, the frame structure proves more suitable for integrating electrical storage modules.

Energy storage systems are essential for balancing energy production and demand, promoting the use of renewable sources, and supporting electric mobility. Commercially available devices rely on lead-acid or, more recently, lithium-ion batteries. Lithium batteries offer advantages such as high energy density, long lifespan, and integrated management systems, but they come with higher costs and disposal challenges. A rapidly developing technology is supercapacitors, based on electrochemical double-layer principles, which provide benefits in charge/discharge cycles and versatility, though currently limited by high costs and lower specific energy.

The supercapacitor production and application sector has been expanding rapidly in recent years, particularly due to technological advancements driven by the automotive industry's interest. This has led to significant technological improvements, and increased commercialization is expected to drive down costs.

The prefabricated wall analyzed in this research has been designed using a load-bearing frame structure, with an internal stratigraphy based on the most common commercial configurations (Figure 1) to ensure broad market representation. The wooden studs are spaced at 62.5 cm intervals to accommodate the developing supercapacitor modules.

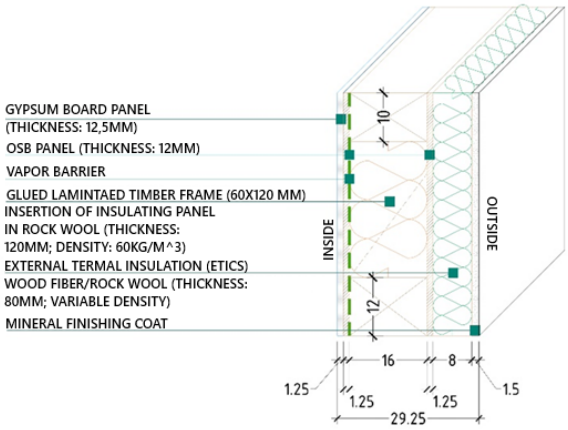

Figure 1. Typical stratigraphy of the prefabricated wooden wall.

The integration of the prefabricated wall's characteristics with the need for a modular supercapacitor system led to the development of an interlocking and lamellar system, featuring high-potential modules.

The proposed solution employs 48V supercapacitor modules with a capacity of 1050 Wh each (Figure 2). These modules are stackable up to 15 units, enabling quick and easy installation of the storage system (Figure 3). The technical specifications are listed in Table 1. Additionally, thanks to the modularity of the final design, the system can cover a wide range of applications and energy needs.

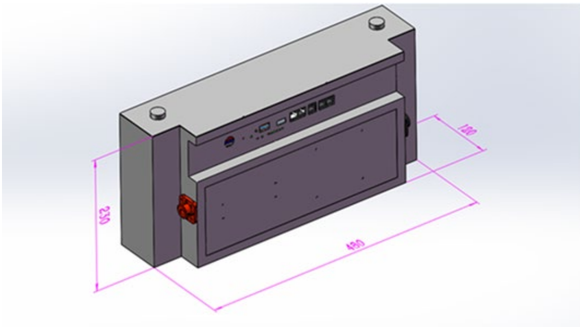

Figure 2. Draw of the storage systems.

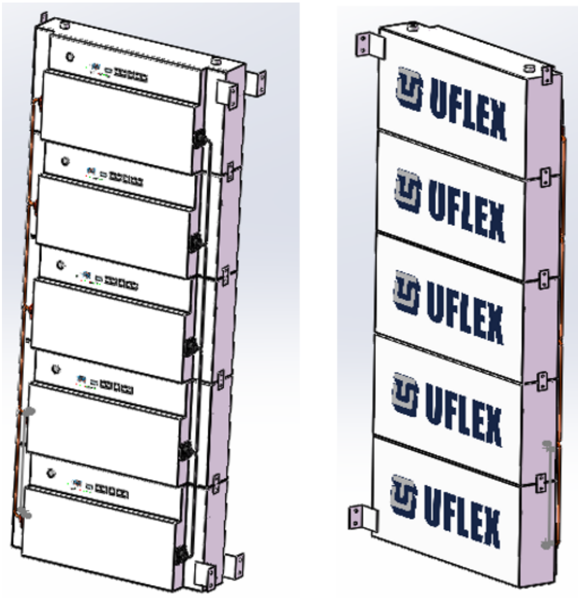

Figure 3. Storage system modules.

Characteristic	Parameter
Nominal Energy	1050 Wh (@10A)
Max Charging Voltage	58.8 VDC
Min Charging Voltage	42 VDC
Charging Current	Standard: 10A, Max: 20A
Discharging Current	Standard: 10A, Max: 20A
Operating Temperature	Charge: 0 °C ~ +60 °C Discharge: -20 °C ~ +55 °C
Life Cycles	20,000 cycles (@10A)
Storage Temperature	-20 °C ~ +45 °C
Parallel Connection	Up to 15 units
Dimensions (W x D x H)	48 x 12 x 23 cm
Weight	12 kg
IP Rating	IP30

Table 1. Supercapacitor module specifications.

The wiring system is designed to avoid occupying additional space within the wall, with the module's shape allowing cables to pass along the edges without exceeding the module's maximum footprint (Figure 4).

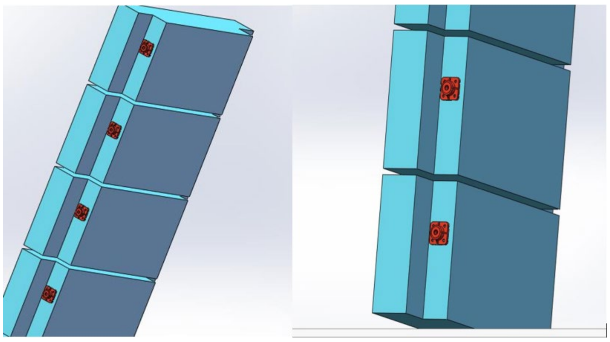

Figure 4. Electrical connection details.

2. DESCRIPTION OF THE REVERBATING ROOMS AND SAMPLE HOUSING PARTITION

The reverberating rooms of Perugia University are characterized by a test opening of the partition between the chambers, with a surface area of 10.5 m^2. Since samples of these dimensions were not available, the opening had to be adapted, reducing the sample area and trying to get as close as possible to the real assembly conditions. For this reason, it was decided to install a masonry wall, which. in the central part, was equipped with a hole where the sample being tested was installed.
It should be emphasized that the partition for housing the samples must have soundproofing properties sufficiently higher than those of the tested sample; for this reason, high mass materials were chosen.
The partition wall between the reverberation chambers was built with 2 rows of Lecablocco Fonoisolante ® elements measuring 20 cm x 20 cm x 25 cm, laid so that the length corresponds to the longest dimension, for a total thickness of 40 cm. The wall was plastered on both sides.
A value of the sound insulation index R_w equal to approximately 60 dB was estimated for this wall, significantly higher than that presumed for the samples under examination.

3. MEASUREMENTS RESULTS

Figure 5 shows the stratigraphy of the walls used for the comparison with the wall equipped with the storage system.

Figure 5. Stratigraphy of the tested walls.

Beyond an external thick coating of wood wall and cement, there is a space that hosts wood wool (or storage devices), to end with a thin inner layer of wood wall, closed with a final layer of plaster.
In figure 6, the traditional wall filled of wood wool is shown during the installation in the reverberating rooms.

Figure 6. View of the traditional sample with rock wool, before internal finishing.

Figure 7 shows the wall with the storage systems, again during the installation in the reverberating rooms.

Figure 7. View of the sample with storage devices, before internal finishing.

Figures 8 and 9 display the traditional sample during the tests both in the emitting and receiving room.

Figure 8. Sample from the emitting room.

Figure 9. Sample from the receiving room.

In figure 10, the trend of the sound insulation power with frequency is reported for both the traditional sample and the sample with the storage system.

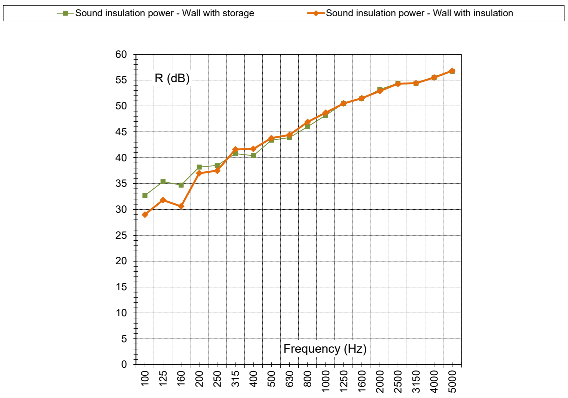

Figure 10. Comparison of the trend of the Sound insulation power R in one-third octave bands between 100 and 5000 Hz for the sample with storage systems and the traditional sample.

It is evident how the addition of mass generates an improvement in the acoustic insulation performance, especially at low frequencies, although the single-number index for airborne sound insulation R_w shows a rather limited growth, moving from 47 to 48 dB.
This circumstance is probably due to the presence of acoustic bridges that interrupt the continuity of the modules of the storage systems.
A more accurate design of the stratigraphy could lead to a more significant improvement in the sound insulation characteristics of the wall with storage systems.

4. ACKNOWLEDGMENTS

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