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TIMBER EXOSKELETONS FOR BUILDING'S RETROFIT: ADVANTAGES, DESIGN CRITERIA, AND STRUCTURAL LAYOUTS

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Abstract: *The need for extensive and integrated renovation of the existing building stock is crucial due to its inherent seismic risk and significant generated environmental impacts. The approach to building retrofit should prioritize both safety and sustainability, promoting integrated interventions that can be conducted without interfering with the normal use of the structure. Additionally, adopting a Life Cycle Thinking approach will help improve the effective sustainability and minimize costs and impacts over the whole building's life cycle. With this approach, it is possible to define improved design criteria for seismic retrofit interventions that focus on damage control, to ensure the sustainability of buildings and the safety of the inhabitants even following medium to high intensity seismic events, but also on easy assembly/disassembly, reparability, management of tolerances, flexibility and reuse.*

Wood is one of the first building materials employed by man and still holds great potential in the construction sector today due to its mechanical and environmental properties and thanks to the adoption of dry construction techniques, which, combined with modern production technologies, have enabled to innovate the wood construction industry quite remarkably over the years. The employment of wooden-based materials, such as CLT panels, has made it possible to overcome the traditional limitations associated with the use of solid wood elements, such as dimensional limits, local defect, orthotropic behavior, and can also offer great potential for seismic retrofit of existing buildings. In fact, the study and application of lateral load resisting systems consisting of wood-based panels is gaining increasing importance both for new constructions and for the retrofit of existing buildings. As a result of these studies, it was possible to develop and test innovative structural systems and connections capable of developing high ductility and low damage, which can be easily disassembled and replaced.

In this work, the use of timber exoskeletons for retrofitting post-World War II buildings of no architectural value is investigated and the potential of using CLT panels in terms of adaptability, prefabrication, standardization of connections, integration with energy efficiency interventions and architectural upgrading are explored. A key aspect to consider concerns the differences between the use of timber-based structural solutions for existing buildings versus new buildings, which lies in the intensity of the seismic actions and in the displacement capacity of the building. In fact, considering the same envelope, an existing building with reinforced concrete or masonry structure may have a structural mass about three times higher than a new building with timber structure and a more limited displacement capacity, further reduced when considering damage to non-structural elements. For this reason, careful evaluation of the correct exoskeleton structural scheme and of the

connections is essential. Besides ensuring the required mechanical performances, other performance must be guaranteed, such as: easy assembly and easy management of the construction tolerances; reparability in case of damage after an earthquake, easy and selective dismantling at the end of life.

The retrofit of existing buildings with wooden exoskeletons also involves some limitations since these solutions are only applicable to regular buildings, where panels can be arranged continuously to ensure high performance. These limitations can often be overcome with the adoption of hybrid wood-steel systems.

Structural solutions for wood exoskeletons encompass two-dimensional systems, including simple walls or coupled walls, as well as three-dimensional systems or shells, which rely on the transfer of actions between orthogonal walls to enhance performance and reduce foundation stresses. In the latter case, the arrangement of panels can also follow two possible schemes: balloon type, with panels warped horizontally along the full extent of the façade, or platform type, with panels warped vertically along the full height of the façade. Each of the proposed schemes can be implemented with additional steel elements to form hybrid systems, or with post-tensioned cables to ensure re-centering behavior. Shifting from simple 2D to more complex shell structural schemes increase the overall performance of the exoskeletons in terms of stiffness and strength, while also introducing more connection systems that will need to be appropriately designed to ensure energy dissipation and avoid damage of the wooden panels. As a matter of fact, connections play a pivotal role from both a structural and a technological point of view: they transfer the seismic actions between the existing building, the exoskeleton and the foundation; they restrain the existing building infills or the masonry walls against overturning; they govern the energy dissipation and enable managing the construction tolerances and the re-centering behavior. Different connection systems will then be presented, based on the proposed structural schemes, and some of the technological solutions aligned with the LCT approach will be discussed.

Finally, two applications will be presented, namely a hybrid steel-CLT shell exoskeleton (Zanni 2021) and a CLT exoskeleton with coupled shear walls (Zanni 2023). Focus will be made on the preliminary LCT-based design approach, the different design schemes, the development of innovative connection systems, and the management of the construction process.

Figure 1. Case study 1: hybrid steel-CLT shell exoskeleton (Zanni 2021)

Figure 2. Case study 2: CLT exoskeleton with coupled shear walls (Zanni 2023)

Zanni J., Cademartori S., Marini A., Belleri A., Passoni C., Giuriani E., Riva P., Angi B., Franchini G., Brumana G. (2021). Integrated Deep Renovation of Existing Buildings with Prefabricated Shell Exoskeleton: The AdESA Case Study, Sustainability, 13 11287.

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