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TRANSPORTABLE ECO-FREINDLY CARDBOARD HOUSE – R&D WORKS ON IMPLEMENTATION OF CELLULOSE BASED MATERIALS IN ARCHITECTURE

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ABSTRACT

The project "Transportable Eco-freindly Cardboard House – R&D works on implementation of cellulose based materials in architecture" aims at conducting R&D works, which will result in the development of a new innovative product in the form of a structural system of houses with usable area between 18 to 60 sq m made of cellulose-based components. The house consists of prefabricated building components made of paper products. The structure is characterized by appropriate strength parameters allowing for independent assembly on the foundations or as a mobile house. The project is realised in interdyscyplinary team, that consist of specialist in the fields of architecture, structural engineering, chemical engineering acoustics and building physics.

Severl initial designs were prepared with different types of structural solution, spatial layut and possibilities to extend the house in the future. The research and development works are divided into five phases that embrace design, prototyping, stuctural tests, thermal insulation, acoustic insulation and impregnation methodes. The main building materials used for the construction are: paper tubes, corrugated cardboard, honeycomb

cardoard panels, full board and cellulose thermal insulation [1].

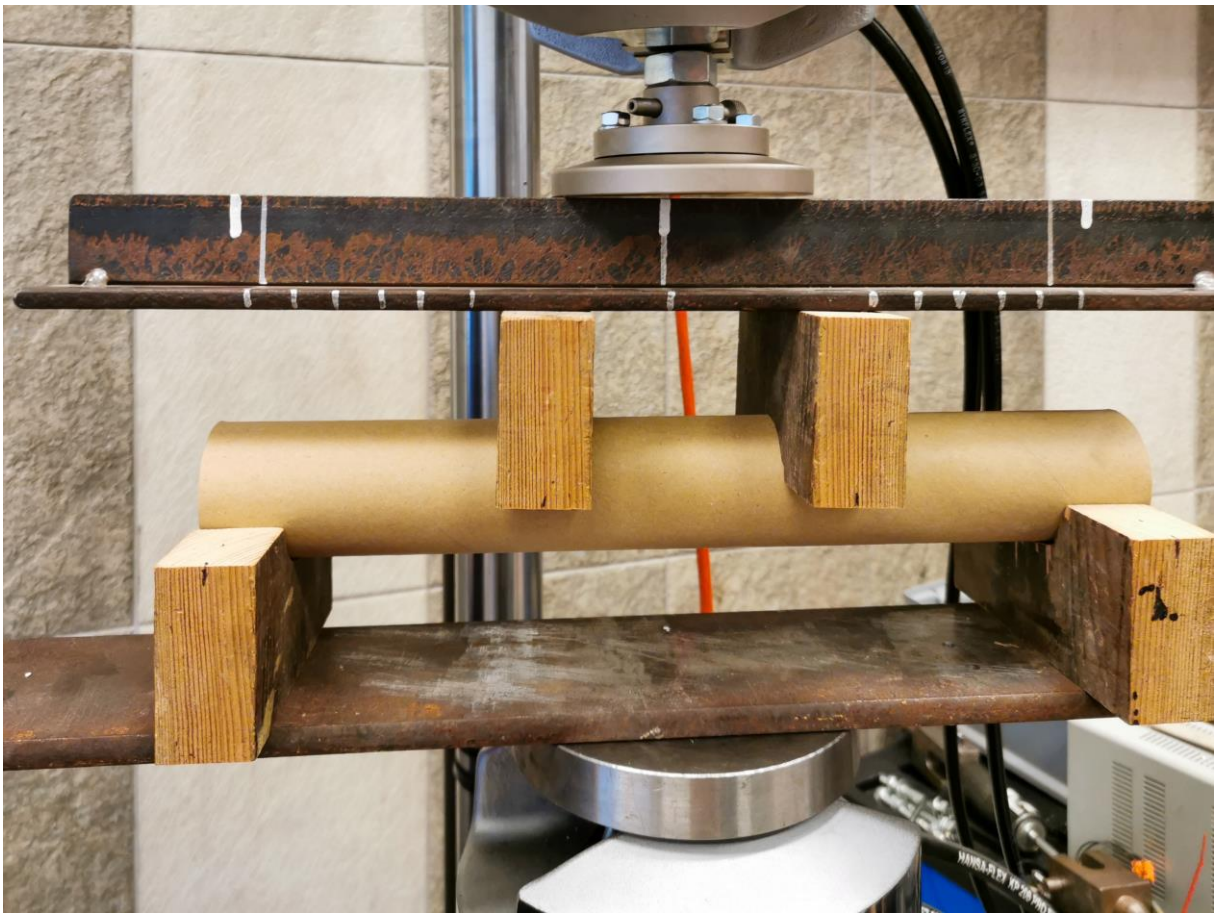

Fig. 1. Structural tests on paper tube

In structural scope of work, essential laboratory tests of the mechanical parameters of selected paper-based elements were performed. Products such as paper tubes (of different diameters and wall thickness), corrugated cardboard (of different flutes), and honeycomb panels (of different thickness), as well as composed layer samples (combined materials) were investigated and basic mechanical parameters, such as compressive, tensile, and flexural strengths, and the modulus of elasticity were determined. The obtained results are comparable to the results presented in the literature so far for similar materials and they indicate that the tested products can be applied as building components.

Based on the proposed geometric and material systems for three different design solutions, numerical analyzes of heat flow were carried out for non-uniform partitions using 2D models. Each partition was optimized in terms of meeting the requirements for the heat transfer coefficient (Uc) according to WT2021 (Polish requirements for thermal protection of partitions).

In the next step of thermal calculations for the 1 selected construction variant, calculations were made of the connection details: roof to wall, floor to wall and in the roof ridge. Calculations of the stationary heat flow confirmed that there were no problems with condensation of water vapor on the internal surface of the details (no exceeding of the dew point) [2].

The acoustical part focused on Sound Reduction Index (SRI) measurements for 7 semi-finished products conducted in a pair of reverberation chambers, following the PN-EN ISO 10140-2:2021 standard. Utilizing the INSUL software, an analysis was performed, integrating the measurement results with data on additional layers such as external covers and mounting types. This approach enabled the anticipation of the most effective solutions for achieving the projected apparent SRI with spectrum adaption term Ctr (R'A,2,R) for three key structures: the external wall (41 dB), the roof (41 dB), and the projected SRI for spectrum adaption term C (RA,1,R) (also reaching 41 dB). These findings provide valuable insights for facilitating the implementation of optimized acoustic design to enhance the sound insulation.

Based on the research results, a series of original envelope cores and outer layers was proposed and assessed in terms of environmental impact and performance. Afterwards, two paper-based full-performance building envelopes were designed and compared to literature-based envelopes made of paper and non-paper materials via Life Cycle Assessment and performance analysis.

It was concluded that aspects such as type of structure, amount of adhesive used, façade ventilation, recycling strategies and protection against destructive factors have a significant impact on paper-based envelopes' environmental burden. Furthermore, it was proven that replacing conventional envelopes with paper-based ones, especially in buildings with a limited lifespan, may reduce their embedded environmental impact, as well as the amount of waste generated, due to the high recycling potential of paper [3].

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