

ISM+D Institute of Structural Mechanics and Design Institut für Statik und Konstruktion





Paper is a new material for the construction sector, for which no defined and This can be realized by closing temporary gaps between buildings and expanding standardized techniques for the use of a building material exist to date. Paper is a costefficient building material and, therefore, promotes affordable construction. Furthermore, temporary paper constructions contribute to coping with demographic change using circular temporary building constructions.

buildings by creating temporary living and working spaces. The influence of humidity and temperature is particularly important to determine the durability of paper constructions.





Floor component opening (left), position of the measurement sensors (right). TUDa 2023.



Test to determine the fire behaviour of a wall element. TUDa 2023.



Load test of the roof cross-section. TUDa 2023

BACKGROUND

The project "Emergency Shelters Made of Paper" funded by ZukunftBau involved the development of a prototype paper shell with integrated measuring sensors. The roof, floor and walls were fully made of paper while the open gable walls were closed by polystyrene. The prototype was tested over a time period of six months under real weather conditions. In February of 2022, the prototype was severely damaged by a fire, making further monitoring impossible. A subsequent utilization concept was developed for the components that survived the fire with the aim of completing the project with the knowledge gained despite the unfortunate circumstances.

MONITORING OF TEMPERATURE AND HUMIDITY

As part of the monitoring process, sensors for measuring temperature and humidity were integrated into various areas of the cross-section of the paper shell. The tests which were carried out over a timeframe of six months evaluating the humidity revealed that the diffusion density of the paper cover was insufficient. Nevertheless, moisture transport through the building envelope could be observed. The critical threshold values for moisture were not exceeded. At the beginning of 2022, a measurement cycle of around one week was carried out to evaluate the insulation effect. This resulted in reference points for optimizing the experimental setup.

The infrared lamp used for heating caused distortions in the recorded measurements which affected the sensors inside the wall. Due to the fire, no further measurement cycles could be recorded. The gained knowledge can therefore only be interpreted as initial indications of the behavior of a paper envelope under environmental influences.

FIRE AND SUBSEQUENT USE

Results after analyzing the remaining elements following the fire suggest that the cause of the fire was a battery explosion. The energy which was released caused the paper elements of the floor to catch fire. The fire spread along the gap clearance of the floor elements due to the prevailing chimney effect. The fire as well as the necessary extinguishing measures lead to the destruction of the installed measurement technology, the floor segments, a paper wall element, and the polystyrene gable walls. Twelve segments from the wall and roof could be reused for further experiments as part of a reuse concept to maximize the knowledge gain. The research included the analysis of the structural properties, fire behavior, heat transfer coefficient, deconstruction and recycling, and moisture absorption. Bending tests on individual strip elements and a buckling test were made as part of the structural design experiments.

Additionally, a structure was tested in which an entire cross-section was analyzed. The test results showed that the roof construction is the weakest point of the structure. The fire behavior of the construction was tested with a gas flame at 900 °C. The results reveal that constant flaming over 45 minutes was required to ignite a hole in the construction. The moisture tests showed that only the first layers of paper were affected by moisture under the usual dynamic pressure on facades. No critical value of 14% material moisture was exceeded. Moreover, the construction had an additional outer layer of polyethylene-sealed shingles as a rain barrier. The use of paper layers behind curtain-type, rear-ventilated facades can be assessed as positive in terms of rain resistance.

FUNDING PROGRAM

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PROJECT PERIOD

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