Short Report

31.12.2020

Title

Development of innovative fire retardants using textile crosslinking chemicals for wood building products in exterior use

Reason / initial situation

The fire behavior of wood requires preventive, protective measures in construction applications. Currently, available flame retardant systems are partly based on hazardous substances and are not resistant to weathering, so leaching occurs in outdoor applications. This poses health risks as well as a limitation for permanent flame protection in outdoor applications, which raises a need for research.

Research objectives

This research project aims to improve the fire behavior of wood in an outdoor constructional application through products already established in the textile industry. The issue of health risks is addressed with chemicals that are free of halogens and borates. Leaching prevention is to be achieved by crosslinking the chemicals with the wood to make an outdoor application possible.

The research plan followed a consecutive structure and was divided into five work packages. The first work package served to identify promising chemicals. General questions of impregnability were also considered. Process parameters were determined to impregnate chemicals into the used pine sapwood (*Pinus sylvestris L.*). These parameters ensure a good and predictable chemical absorption (weight percent gain WPG) by a specific variation of the pressure conditions between vacuum and high pressure. The solid content of chemicals of 15 % in the impregnation solution was found to be a good measure, resulting in a WPG of about 20 - 25 %. According to EN 84 (accelerated ageing cycle), the washout showed that chemical combinations with a crosslinking component remained in the wood to a higher degree, whereas the non-crosslinked chemicals were washed out.

The second work package dealt with fire tests on a laboratory scale. In orientating fire tests with a simple test setup and the standardized small burner box (DIN EN ISO 11925-2), the fire protection effect of the different chemicals could be shown qualitatively and quasiquantitatively. Experiments in a cone - / mass loss calorimeter were carried out on references, impregnated test specimens as well as test specimens washed out according to EN 84. A significant delay of the ignition time was found for all chemicals (combinations) used - in many cases, no flame formation occurred within the 30-minute heat radiation of 50 kW/m². However, after washout, it was found that for all non-crosslinked chemicals, there was no reduction in ignition time compared to the reference. Only one variant with a crosslinker continued to significantly delay the ignition time while at the same time reducing the amount of heat released.

Work package 3 dealt with secondary material properties that are (can be) influenced by the impregnated chemicals. Analyses of the mechanical properties according to DIN 52186 and DIN 52189 often showed a reduction of the impact bending strength, whereas static parameters such as the

bending stress or the modulus of elasticity were less influenced. In general, the values were only slightly changed by impregnation, so usage in many application areas is still possible. In accordance with EN 113-2, the durability of impregnated wood against wood degrading fungi was tested. For this purpose, two crosslinked and two non-cross-linked chemicals and virulences/references were incubated with a white rot fungus (*Trametes versicolor*) and two brown rots (*Coniophora puteana, Rhodonia placenta*). All tested fire protection chemicals increase the wood's resistance, with only one exception to the brown rot *Coniophora puteana*.

Upscaling from small test specimens for laboratory tests to working dimensions was realized in work package 4. A complete impregnation with the chemical solutions as well as the faultless drying and curing of the active components in impregnated solid wood test specimens must be ensured. Such a parameter set could be determined for both upscale processes.

For the fire tests in serviceable dimensions, which were carried out in work package 5, the boards previously impregnated and dried with the washout resistant fire protection chemical combination were machined: Planed, sawn to length, and provided with tongue and groove to build wall claddings. Flame treatment showed that the treated wall coverings did not ignite in contrast to the references.

Conclusion

The aim of the project was to use halogen- and borate-free fire protection chemicals to provide increased and washout resistant fire protection in wood products by testing the effect of textile crosslinkers in wood. In the course of the research project, it could be shown over different size scales from small laboratory scale up to working dimensions that the chemicals used are suitable to impregnate wood and achieve a fire protection effect maintained to a large extent even after an accelerated aging cycle.

Basic information

Short title: FiRetWood

Scientist: Philipp Sauerbier

Project lead: Prof. Dr. Holger Militz

Total cost: 205.848,78 €

Federal subsidy: 143.848,78 €

Project duration: 24 months

Pictures / figures

Figure 1: 1-Einstellbarer_WPG.png
Exemplary plot of the WPG after impregnation with different solid contents of a fire protection chemical in the impregnation solution. The linear relationship via the regression line can be clearly seen, which can be used to adjust the WPG.

Figure 2: 2-Pries_et_al.png
Results of the fire protection test according to Pries et al. (2013). Comparison between reference measurements (black) and two different 1-component flame retardant chemicals. In comparison, red has a very good fire protection effect; the variant shown in green shows a lesser effect.

Figure 3: 3-MLC_Bsp_ohne_Vernetzer
Averaged mass loss calorimeter measurements. Plotted is the heat release rate (HRR) of the untreated references (black), impregnated with 15% solids content of a 1-component fire protection chemical in the impregnation solution (red), and the impregnated test specimens after washout (EN 84) (blue). The strong reduction of the HRR after impregnation is clearly visible - no ignition of the test specimen occurs. However, it can also be seen that the heat release rate after washout approaches the reference. There is no delay in the ignition time and only the amount of heat released is reduced.

Figure 4: 4-MLC_Bsp_mit_Vernetzer
Averaged mass loss calorimeter measurements. Plotted is the heat release rate (HRR) of the untreated references (black), impregnated with 15% solids content of a fire protection chemical with additional textile crosslinker in the impregnation solution (red), and the impregnated test specimens after washing out (EN 84) (blue). The strong reduction of the HRR after impregnation is clearly visible - no ignition of the test specimen occurs. Even after washing out, the test specimens are inflamed only after a long delay and significantly reduced HRR.

Figure 5: 5-MLC_Vgl_nach_Auswaschung
Averaged mass loss calorimeter measurements after washout (EN84) of an untreated reference (black) and seven different fire protection chemicals (gray). Test specimens treated with fire protection chemicals and additional textile crosslinker (green) show a significantly improved fire protection effect than the other fire protection chemicals.

Figure 6: 6-Beflammung_Gebrauchsabmessung
Corner flaming of a built wooden cladding. Left: untreated pine; right: test specimen impregnated with a fire protection chemical and an additional textile crosslinker. During the test, it was already apparent that the impregnated wood does not contribute to flames' formation. After the experiment, the differences in charring are visible.