Enhancement of durability through impregnation of amino-functionalized silica xerogels added with copper and boron

The aim of the project was to develop a technological process that increases the natural durability of wood, coming from forests of Trentino (Italy) for outdoor applications not in contact with the ground.

In order to satisfy the criterion of sustainability in the field of construction, a chemical modification by sol-gel process with organo-silicon compounds, added with copper and boric acid separately was proposed. The use of boric acid as a biocide is allowed if under the limit of 5.5% w/w as indicated by EU Regulation 790/2009; on the other hand, copper remains the primary biocide component used today to protect wood used in ground contact or fully exposed to the weather. The two alkoxysilanes tetraethyl orthosilicate (TEOS) and 3-aminopropyltriethoxysilane (APTES) were used as precursors. Hydrolysis and co-condensation processes were allowed to take place in situ, inside the wood. The presence of amino groups in siloxane materials can both improve wood biological resistance and enable fixation of copper cations through coordinative interactions. Boric acid was supposed to interact with the silica xerogel in two ways: by condensation with silanol groups, giving rise to Si-O-B linkages (formation of borosilicates); by formation of ionic interactions with the amino groups.

Wood blocks of Scots pine sapwood were used in the laboratory essays in order to highlight the effect of wood modification on the enhancement of wood durability.

SEM-EDX investigations, FT-IR and atomic absorption were adopted to demonstrate that the wood modification took place after impregnation. Solid-state NMR was used to assess the degree of condensation of the siloxanes in the wood.

The boron/copper fixation capacity was tested through the leaching procedure described in the European Standard EN 84:1997. Fungal decay resistance of modified wood was assessed with durability tests according to the standard EN 113:1996. Treatments were also tested against subterranean termites and the dry-wood borer *Hylotrupes bajulus*, in accordance with standard procedures.

Results from different investigations showed that the functionalized xerogel deeply interpenetrated in the wood texture and that was also able to draw copper into wood, even after leaching. Solid-state NMR investigations detected a high degree of condensation for wood specimens treated with the TEOS/APTES combinations and for the treating xerogel. The standard test showed good effectiveness of boron-based treatment against the two brown rot fungi Coniophora puteana and Poria placenta and the white rot fungus Trametes versicolor.

A good protection of the copper-based sol-gel modification was conferred to wood against *Coniophora puteana* and *Trametes versicolor*, but no protection was offered against the copper-tolerant fungus *Poria placenta*. This drawback might be overcome by the addition of other co-biocides.

Although the sol-gel treatments added with boron and copper act in different ways, both of them are efficacy against subterranean termites. The boron-based treatment conferred durability also against larvae of H. bajulus.

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