ETH Zurich Career Seed Grants: Final Report

Project code: SP-SC 03-15

Title of project: Green Sleepers: Eco-Friendly Mineralized Railway Sleepers from Domestic Beech Wood

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Project duration (from - to): 1.7.2016 – 30.6.2017

A) Scientific part

(please dedicate 2 pages maximum to the scientific part; point 1 and 2 will be published on a dedicated website)

1. Achievements and advances made during the course of the research project

The common tar oil impregnation of beech is a crucial environmental obstacle for wooden railway sleepers application. This implicates that currently concrete is the most commonly used material for the sleeper production although these sleepers are by far not ideal in terms of environmental aspects and technological requirements. Therefore, this project investigated in the development of more eco-friendly beech wood sleepers by application of a newly developed technology of wood mineralization. The following tests were carried out:

- Alternative treatments to tar oil impregnation of beech wood, including treatments with barium sulphate (wood mineralization), pine tar, paraffin wax and a combination of the modifications.
- Mass gain measurements after the treatments
- Measurement of swelling properties after the treatments (DIN 52184).
- Artificial weathering tests by UV irradiation/water spray cycles (DIN EN 927-6).
- Fungal decay testing (EMPA, St. Gallen, internal testing standard).

The above described treatments were successfully carried out at sample sizes from 3 x 4 x 10 cm^3 to 5 x 5 x 25 cm^3 with full infiltration of the centre of the specimens (Figure 1).

Figure 1: Specimens with a size of 5 x 5 x 25 cm^3 . Top: native beech sample; middle: Paraffin wax treated sample; bottom: pine tar treated sample.

The following mass gains were measured after the treatments:

- Barium sulphate: 20-25%
- Pine tar: 30-45%
- Paraffin wax: 45-65%

Water adsorption and swelling were measured on unmodified beech and after all individual and combined treatments. The mineralization by $BaSO_4$ and its combination with further treatments had the most severe effect on the swelling, whereby the combination of $BaSO_4$ and pine tar resulted in the lowest swelling values. However samples treated with wax or pine tar without additional mineralization reduced swelling rather marginally compared to the reference sample. Water adsorption shows similar tendencies with the lowest adsorption measured for the combination of $BaSO_4$ and pine tar.
This results in an anti-swelling efficiency (ASE) higher than 55% and a water repellence efficiency of more than 80% for the best combination ($BaSO_4$/pine tar). For comparison: Egner (1937) reported an ASE of 43% for a modification with petroleum tar and an ASE of 10% for paraffin wax and Hill (2006) referred to an ASE of 60% for acetylation.

The artificial weathering over 4 weeks (192 cycles with UV radiation (2.5 h) and water spraying (0.5 h)) induced mass losses from 3.4% (native beech), 4.2% (beech treated with BaSO4 and paraffin wax) and 5.9% (beech treated with BaSO4 and pine tar). None of the treatments could preserve the samples from whitening and therefore there was no UV-protection effect.

The fungal decay was tested over 24 weeks on five types of wood modifications ($BaSO_4$, pine tar, paraffin wax, $BaSO_4$ + pine tar, $BaSO_4$ + wax) and on native samples. Two fungal species were applied, a white rot: *Trametes versicolor* (EMPA 159) and a brown rot: *Fometopsis pinicola* (EMPA 567). After an exposure time of 24 weeks, the mass loss of the samples was measured.
The results indicate a protection effect for some the tested treatments. The mineralization as well as the pine tar treatment and its combination protect very well against fungal decay (white rot and brown rot) with a mass loss < 2%. In contrast the treatment with paraffin wax (even with a previous mineralization) did not result in an effective protection against fungal degradation.

The achievements and advances can be summarised as follows:
An alternative treatment for railway sleepers could be successfully tested at medium sample size. Although artificial weathering indicated no specific UV protection, a reduction in swelling and water adsorption as well as a better protection against fungal decay could be measured. The best treatment combination is $BaSO_4$/pine tar with an anti-swelling efficiency (ASE) of above 55% and a strong wood protection against fungal decay (white and brown rot). This treatment should be further investigated in terms of upscaling potential and long-term durability.

Literature:
Egner, K. (1937): Neuere Erkenntnisse über die Vergütung der Holzeigenschaften. Mitteilungen Fachaussch. Holzfragen, Berlin, vol. 18
Hill, C.A.S (2006): Wood modification: Chemical, thermal and other processes. John Wiley & Sons, Chichester

2. List of research outputs

(Publications (published; in press/accepted; submitted; in preparation), patents, presentations at international conferences and other)
The research results have not been published so far, but an extended internal report has been prepared, which can be taken as a basis for contacting potentially interested industry partners and for publication.

3. Reasons for not achieving the original goals

The original goals could be achieved in terms of the applicability and efficiency of the treatments. A further up-scaling was not possible due to time constraints (artificial weathering tests and fungal treatments with long durations). Prior to a successful implementation of the green sleepers, further investigations need to be carried out. The impregnation of sleepers of real size needs to be tested and the resulting long-term protection needs to be determined. Also, additional tests concerning fungal decay (including outdoor exposure and ground contact) should be carried out to prove the long term durability of the sleepers.