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WEAR RESISTANT PROTECTION OF WOODEN POLES IN ADVERSE ENVIRONMENTS

Thomas Lindblad[1], Knut Magnar Sandland[2], Andreas Treu[2]

ABSTRACT: Wood protection is needed for wood products in outdoor applications due to biodeterioration of this natural material. While bulk treatments of wood have their disadvantages related to impregnation and costs, coatings can protect wood products to large extent. However, harsh environments such as outdoor use classes 3-5 can lead to unfavourable levels of wood moisture content because of the permeable character of most coatings. Water-tight coatings could be an alternative for certain areas of use. This treatment has been identified as a promising approach for prolonging service life in adverse environments. However, installation in larger scale may need connections and fasteners which perforate the coating material. This study shows various solutions of bolt connections including sealants which can be used for installations without significant penetration of water into the wood core. The study also makes reference to a full-scale installation survey covering the same time period, as well as an ageing test of the same coating.

KEYWORDS: coating, outdoor applications, poles, sealant, wood protection

1 INTRODUCTION

Wood protection in adverse climates is obtained by bulk treatments using biocides or wood modification agents. Both approaches require penetrability of the wood substrate and can be challenging with regards to environmental concerns or price. Being independent of the refractory behaviour of some wood species and avoiding any form of impregnation treatment is therefore an asset. However, exposure of unprotected wood products in harsh environments such as outside use, the use in ground contact and sea water contact are particularly demanding. Outside use areas are defined by the incidence of rain and changes in temperature and relative humidity, which can lead to deterioration of unprotected products by fungi and insects. Exposure of wood products in ground contact is dominated by bacteria and fungi due to the constant moist surroundings. Products, which combine both use classes, such as telegraph poles, need therefore not only wood protection for above ground (use class 3), but also in-ground contact (use class 4). In addition, the marine environment (use class 5) represents a different challenge which can only be prevented when the attachment of shipworm larvae on the wood surface and the boring through the wood substrate can be avoided. In addition, gribble can attack the wood surface area, which leads to extensive damage as well [1].

The use of coatings is beneficial for products in outdoor use areas (use class 3-4) and could even prevent marine borer attack (class 5). Coatings help to drastically reduce the uptake of water by the underlying wood substrate, and when airtight it also limits the access of oxygen. This is widely used on wooden facades of many private houses in the Northern European countries. However, coatings for cladding are usually not fully watertight, but allow an exchange with the surrounding relative humidity. Measurements of wood moisture content underneath a wood coating prove the permeable character of some coating types [2,3].

Water-tight coatings could be an alternative for certain areas of use. One example is the full coverage of wooden poles with polyethylene (PE) via an extrusion process [4]. The use of several millimetres of PE on the wood surface leads to high resistance against wear of the coating and to protection against deterioration of the wood core. Given the shore D hardness of 62, it also neutralises the risks of marine borer attacks. WOPAS uses such PE extrusion technology to wood which can be of different shape, square, cylindrical, or tapered. The wood is first dried to a target moisture content of 14%. WOPAS standard PE thickness for marine piles and pole building poles is 6 mm, and for power poles 9 mm. The thicker dimension for power poles stems from the frequent use of climbing shoes causing 2-3 mm recess. However, the installation of these poles often makes it necessary to perforate the protective PE layer if bolts and other mounting parts need to be connected. Sealing of the joints need to make sure that water and oxygen ingress is prevented. However, the type of technical solution for the fastening and the sealing material needs to be investigated.

The aim of the study was to analyse different fastening and sealing solutions in both a short-term submersion test and a long-term outdoor weathering and to select the solution where water ingress could be strongly reduced or prevented. Furthermore, the specific objectives were to include recommended solutions, non-recommended solutions, deliberately damaged coating, references without penetration and references for full scale

[1] Thomas Lindblad, WOPAS, Norway,
thomas.lindblad@wopas.net
[2] Knut Magnar Sandland, Andreas Treu, Norwegian Institute of Bioeconomy Research (NIBIO), Norway,
knut.magnar.sandland@nibio.no, andreas.treu@nibio.no

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installations covering the same time period, as well as an ageing test of the PE.

2 MATERIAL AND METHODS

2.1 BOLTS AND FASTENERS

Starting in May 2019, different connection solutions (see table 1 and example in figure 1) were analysed using water submersion test at the NIBIO laboratory for 1600 hours. The samples were stored between submersion cycles in the freezer and in room climate. Thereafter, the test pieces were exposed to outdoor climate for 700 days (figure 3). Measurements were done twice per year. The weight change during submersion and exposure were measured gravimetrically using a 0.1 g readability scale. (Mettler ToledoPG5002-S DeltaRange), except for test series 21-25 where a 0.5 g readability scale was used (KERN DE 6K0,5N).

Table 1: *Connection material used for the test.*

Connection type	Name
8 pcs stainless steel building board screws, 4,9 mm x 35 mm, incl. gasket	Screws with sealant
20 mm pin bolt with curved washer and mastic. Pre-drilled 20 mm diameter	Bolt with insulation putty
10 mm French bolt, circular washer and mastic. Pre-drilled 7 mm diameter	French bolt
20 mm pin bolt with curved washer. Pre-drilled 20 mm, EPDM gasket	Pin bolt EPDM
Plastic removed from the poles in small flakes	Partly removed plastic
No connections used	Reference

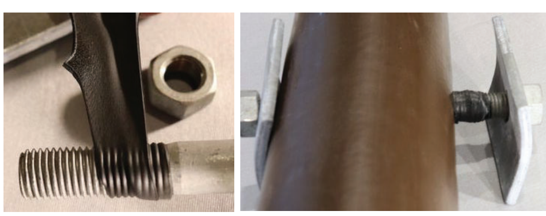

Figure 1: *20 mm pin bolt with curved washer and mastic*.

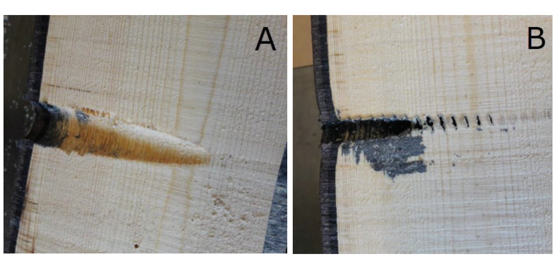

Figure 2: *After the first test period was finalized 15 July 2019, one sample of each series was split. Pictures show: Longitudinal cut from A) 20 mm pin bolt with curved washer and mastic and B) 10 mm French bolt, circular washer and mastic after two months of outdoor weathering.*

Figure 3: *Exposure to outdoor climate.*

2.2 FULL-SCALE INSTALLATION

A 40 kV overhead line with 108 WOPAS poles was installed early 2019 and finalised in May the same year (see figure 4). The fitters used WOPAS recommended fasteners, i.e. pin bolts with curved washer and mastic, French bolts with mastic and building board screws with gasket. The installation was surveyed in June 2022 by a third-party wooden pole expert, representatives from the grid owner and WOPAS. The time frame between installation and survey equals the time frame for the accounted laboratory tests in 2.1.

Of the 108 poles a selection of eight poles was installed in different environments, such as arable land, forest, swamp, rocky ground and gravel. Several methods were used for the survey, such as classical hammer sound surveying, non-destructive electronical moisture meter by Tramex and drilling resistance measurement by use of an IML Resi F400-SX. Drilling was either made just above the ground or close to penetrating fittings, as shown in figure 5. The drilling resistance measurement method enabled recording and print outs, as shown in figure 11. Neither the drilling resistance measurements, nor the survey in general, showed sign of deterioration of the poles.

Figure 4: *Fitters from Linde Energi using French bolts with mastic to prevent sliding and rotation of cross arm fitting.*

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Figure 5 *Drilling measurement using a resistograph, close to pin bolt with curved washer and mastic.*

2.3 AGING TEST

Critical to the sealing function is the integrity of the PE over time. Test laboratory CESI of Milan, Italy, on behalf of power grid owner Enel Grids has conducted a test programme of 8 repeating steps during 2022. In addition to mechanical tests like impact protection[5] (IK), bending fatigue and flame test, an ageing test was made to simulate outdoor daily cycle. The testing was made by placing a pole in an insulated steel tube filled with water, figure 7. The water temperature was controlled and varied between 20 and 80 °C (figure 6). The cycle consisted of 8 hours of heating and 16 hours of cooling. The thermal conditions of the cycle were described as consistent with climatic extremes to constitute an acceleration factor of the real stresses to which the pole is subject to in operation. The test was conducted for 1000 hours. The pole, sealed at the ends, is placed in a cylindrical chamber where water is circulated. The water was coloured to enable a subsequent verification of water ingress. At the end of 1000 hours the pole was extracted from the steel tube and inspected for cracks to the PE and welded end caps. The pole was then tested with a bending test to compare any deviation to other non-aged WOPAS poles. The PE layer was thereafter separated from the wood, and the moisture content of the wood was measured, as well as visual inspection tracing any coloured water penetration.

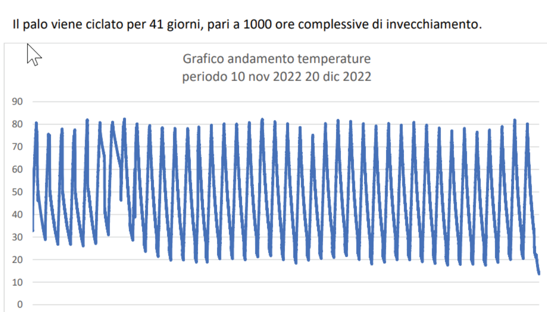

Figure 6: *Temperature variation during 1000 hours of water aging test.*

Figure 7: S*teel tube containing a WOPAS pole for age testing.*

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3 RESULTS

3.1 THE INFLUENCE OF BOLTS AND FASTENERS ON WATER UPTAKE

Minor weight changes during submersion and outside exposure were observed (figure 1 and figure 2). The water penetration through the used connections was therefore almost insignificant for all solutions except the use of bolts with insulation butty, which even showed mass loss during the exposure. This could have been caused by the different scale, which was used for these samples or by degradation of the washer. Reference poles with partly removed plastic coating showed higher water uptake during water submersion and outside exposure. The test proved the good performance of the sealants and underlines therefore the importance of the sealing material and the care during installation.

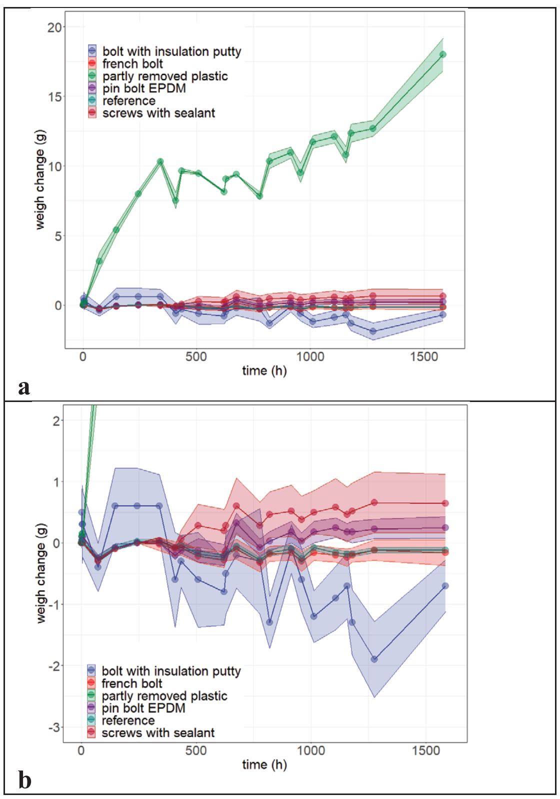

Figure 8: *Weight change due to water uptake during submersion test for more than 2 months. a) note the scale from 0-20, b) note the scale from -2 – 1. The colour-shaded areas show the standard deviation (N=5).*

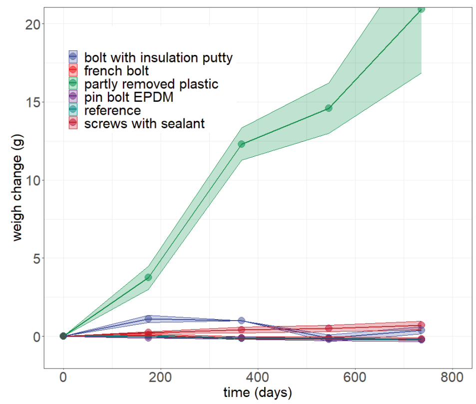

Figure 9 *Weight change due to water uptake during more than two years of outside exposure. The colour-shaded areas show the standard deviation (N=5).*

3.2 SURVEY OF FULL-SCALE INSTALLATION

The visual inspection showed no deviations. The construction was described as very well built by third party Vattenfall Eldistribution. The moisture measurements demonstrated no elevated values of wood moisture content. In addition, the resistograph showed no unusual values, which could indicate deterioration of wood components. See below the photograph of resistograph printouts, figure 11.

The hammer control noted two anomalous sounds, one behind a mark caused by the installation of the poles using excavator grab john (hydraulic pin grab on the back side of the bucket) and another at a random place. Both locations were examined with moisture measurement and resistograph, but without anomalous values. One hypothesis discussed was that the pressure from excavator grab john caused some kind of local sound change, and natural cracks that occur in the wood may have caused abnormal sounds as well.

Figure 10: *Anomalous sound from hammer was followed up using resistograph, in turn showing normal values.*

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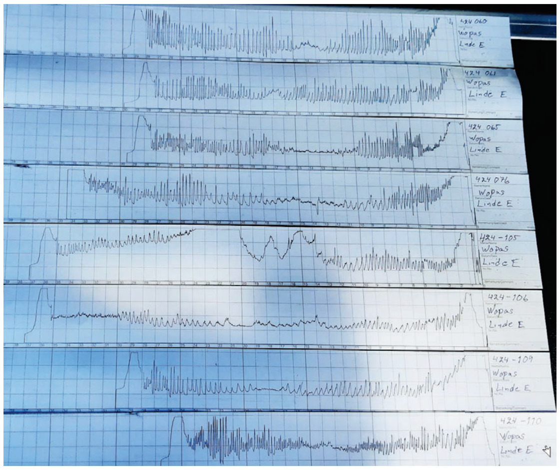

Figure 11: *Paper print-outs of drilling measurement using a resistograph*

3.3 THE RESISTANCE OF THE COATING TO HEAT AND WATER

After the aging test, the pole was tested for bending, impact (IK) and the PE was removed to measure the moisture level and for visual inspection of any coloured fluid. Even after the bending test, no damages were found on the PE, and no water ingress could be noted. The moisture level was observed at two positions, as shown in figure 12, and the moisture level was 10,5-10,7%.

It has been pointed out by CESI and Enel Grids that the specification and aging method have been defined by them for their test, and cannot be extrapolated.

Furthermore, it was described that the PE was well attached to the wood and is able to fill even the natural cracks. In this way the PE is not free to move, which was also verified during the torsion test.

The PE-welded end caps were considered the weakest point before the test. However, it demonstrated to be adequately robust for the intended use as power pole, both in terms of aging and impact. In fact, the impact protection rating corresponded to IK10 according to norm IEC 62262, or 20 Joule (weight of 5 kg from a height of 400 mm).

Figure 12: *Moisture content observation after the aging test*

4 CONCLUSIONS

Several connections through polyethylene coated poles were analysed during water submersion and long-term outdoor exposure. Sealant and careful installation play a crucial role for the long-term performance of installed poles in service. Various solutions of bolt connections including sealants can be used in large-scale installations. In addition, the performance in service as poles for electrical power lines shows promising results so far.

The characteristics and lifetime of polyethylene of PE100 quality is witnessed from water infrastructure, automotive, sea farming and other adverse environments. The combination with wood represents an interesting use, without the need for using biocides or wood modification agents.

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