Monitoring the performance of Accoya in different applications

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ABSTRACT

More than 10 years ago, industrial production of acetylated radiate pine started under the trade name Accoya in the Netherlands. This early industrial production of Accoya was used in different building applications above ground as well as in ground and water contact. Over this past 10 years a tremendous amount of real life experiences with Accoya in commercial; applications has been obtained. In order to learn more about the long term performance of the acetylated radiate pine in these applications, projects were visited and the quality of the acetylated radiate pine was inspected. Only projects older than 5 years, without or with limited maintenance were selected. In total 16 projects were inspected including acetylated wooden doors, windows, window frames, claddings, bridges and sheet pilings. This paper summarizes the results of the inspections in terms of functionality, maintenance frequency, coating quality, moisture content, smell, decay and corrosion. Furthermore the results are discussed in relation to the special technological properties of Accoya.

INTRODUCTION

The process of acetylation improves the wood quality by a reaction of acetic anhydride with the cell wall. The wood is fully impregnate and in the reaction that takes place one molecule acetic acid is attached to the cell wall and the other one is released in the cell lumen. Because of this reaction the cell wall swells, the wood density and resistance against microbiological degradation increases and the equilibrium moisture content and shrinkage behaviour decreases. The degree of improvement of these properties and the removal of the remaining acetic acid, depends on the intensity and quality of the process of acetylation (Hill 2006, Tjeerdsma and Bongers 2009, Bongers *et al.* 2013).

Accsys in Arnhem produces acetylated timber under the brand name Accoya and their timber is used in joinery and a variety of outdoor building constructions. Their timber is highly dimension stable and has a high resistance against fungal decay. In order to avoid corrosion with metal parts or any emission of acetic acid, the industrial processing is optimised in order to remove as much as possible of the remaining acetic acid.

Although the industrial production of Accoya started in 2007, pilot projects were established even earlier and especially during the first production years their process was further improved, resulting in a more homogeneous treatment, a more homogeneous moisture content of the treated timber and a low concentration of residual acetic acid of below 1%.

In order to monitor the performance of Accoya in different applications, several projects were investigate and special attentions was given to the those properties which were affected by the process of acetylation.

SELECTION OF THE PROJECTS

In cooperation with Accsys, the Dutch joinery industry, the Dutch paint producers and on the basis of the internal SHR database, a selection of projects was made and visited (Table 1). In the majority of the projects, the modified timber was used as painted joinery (windows, window frames, doors, door frames) and no maintenance was performed during the years of use. Two projects consisted of unpainted timber (joinery claddings). Furthermore, there were two large flooring projects and several projects with outdoor constructions (a bridge and canal linings with pile planking).

Table 1: information of the projects inspected, unless otherwise given the projects are newly built and without maintenance

Building year	location	Construction type	Use	Ownership
2000	Flevoland	Sheet piling	Pile planking	Government
2007	Den Haag	Family houses	joinery	Private
2007	Den Haag	Family houses	joinery[b]	Housing association
2007	Voorthuizen	Canal wall protection	Pile planking	Government
2008	Amsterdam	Flat, 5 stocks,	joinery[a]	Housing association
2008	Wageningen	Office building	Window frames[b]	University
2008	Wageningen	Office building	claddings[b]	University
2008	Sneek	Bridge	bridge	Government
2009	Amsterdam	8 historical apartments	joinery[a]	Housing association
2010	Amsterdam	Restaurant	joinery[a]	Private
2012	Wageningen	58 family houses	joinery[a]	Housing association
2012	Den Bosch	65 Family houses	joinery[a]	Housing association
2012	Amsterdam	Flat, 16 stocks	Unpainted joinery	
2012	Wageningen	124 family houses	joinery[a]	Housing association
2012	Oss	shelter	joinery[a]	Housing association
2014	Almere	Single house	joinery	Private
2015	Assen	Outdoor Cycle track	Floor	Government
2016	Apeldoorn	Indoor Cycle track	floor	Government

[a] renovation projects [b] projects with periodic maintenance applied

METHODE

In the period March 2017 to May 2018, all project except the cycle tracks were visit and visually inspected with attention for functionality, cracks, corrosion, fungi (blue stain, decay), smell, adhesion (dirt, algae, mosses, fungi), distortion, glued quality (corner joints, finger joints / lamellae, marking), paint quality (loss of adhesion, blistering, discoloration) and crystallisation. If relevant moisture content measurements were done using a capacitive moisture meter (Brookhuys, FMW, wood density 550 kg/m^3). The found status of the timber products was discussed with reflection towards design, orientation and use. Both cycle tracks were visited in the building phase and special attention was given to cracks and release of odour .

RESULTS AND DISCUSSION

In this section the results of the inspections are discussed as general trends over all the projects. Several main trends can be distinguish in the use of Accoya timber related to: increased dimension stability; residual acetic acid; glue-ability, crack formation; changed moisture behaviour; decay.

The impact of strongly reduced shrinkage and swelling on the material and product behaviour

Shrinkage and swelling of the wood as a result of changing surrounding humidifies is strongly reduced by the acetylation treatment. The impact of this dimension stability was noticeable in all projects by the well-functioning and non-deformed windows and doors. The quality of the 6 to 10 years old paint layers in the projects was still good and meeting the requirements, therefor showing a painted surface without cracks or blistering. Because different paint products with diverse properties were used, a wide range of paint surface degradation was recorded with respect to gloss and chalking.
The high dimension stability prohibits the timber to react in its usual way. Untreated wood shows a higher shrinking and swelling of latewood compared to the early wood. This results in a visible print of the timber pattern in the paint layer. As this effect is absent in dimension stable Accoya, the wood surface stays extremely flat and gives the timber often a more plastic alike appearance.
On both long sides, shutters are included for opening of the track to enable large equipment to enter the centre of the court, in the 250 m indoor cycle track (Figure 1). In summer the seams at both ends of the shutter are about 10 mm and in the winter they are 7 mm smaller (Figure 2). Calculated with respect to the length of the track, this means a longitudinal shrinkage of about 0.01% , which is ten time less compared to non-treated wood. The moisture content of the modified wood under these indoor track conditions varies in the summer and winter period between 3 and 8%.

Figure 1: Cycle track with right an opening while the shutter is removed.

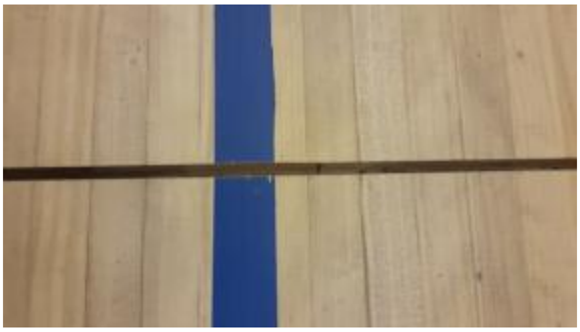

Figure 2: Interface of the shutter and the cycle track, showing the size of the seams in the winter.

Residual acetic acid in the timber

Inspection of some of the oldest projects, revealed some emission of acetic acid. Just by removing the paint layer or drilling a hole, the typical smell was detectible. In the more recent projects no clear acetic acid smell was recorded. During the construction of the new indoor cycle track more than 90 m³ non-coated acetylated timber was used under indoor conditions with limited ventilation. In the first days directly after installation, only a light acetic acid odour was observed by a limited number of persons of the test team, despite this huge amount of acetylated timber used under indoor conditions. The analyses showed that the residual acetic acid in the wood was between 0,1 and 0,3%.

In some of the projects (Den Haag 2007, Sneek 2008, Wageningen 2012 and Almere 2014) heavy corrosion was seen. In all of these projects, the corrosion was related to extreme water load and the use of non-corrosion resistant metals. In Den Haag the joinery was stored unprotected for a longer period. In the bridge the water uptake in the outer layers of the wooden beams is high, resulting in free water around the metal connection parts (Figure 3). The high corrosion in the sheet doors, which open to the outside, in the 2012 Wageningen project was caused by use and construction. Frequently the sheets doors stood open for a longer time and the connection between the metal locks and the wooden part acted as a funnel causing water storages around the metal door clasp (Figure 4). In case of joinery in the Almere project, problems with condensation, causes water storage around the metal locks (Figure 5).

In all other projects the water load was to a much lower extend and although often non-corrosion resistant metals were used, no corrosion was seen, not even in the unpainted joinery.

Based on our findings we concluded that heavy water load is the main feature for causing metal corrosion in acetylated joinery timber rather than a general material characteristic of Accoya itself.

Figure 3: Bridge and its metals components. Behind a removed wooden plug water accumulated appeared causing corrosion on the metal parts.

Figure 4: Sheet door which stood frequently open causing water accumulation in the lock resulting in corrosion on the metal parts.

Figure: 5 Window with high and long term condensation causing corrosion on the metal parts.

Effect of residual acetic acid on paint layers was found insignificant. During none of the projects visit, de-adhesion of paint layers was seen in relation to residual acetic acid. Crystallization as a reaction of residual acetic with environmental substrates could take place and was rarely found in and through paint layers and only in connection with high water loads e.g. open joinery connection (Figure 6 and 7). So based on these findings it can be concluded that residual acetic acid does not have an negative effect on the quality of the paint layers except in situations with a high water load and moisture transport through the timber. In these high water load situations already low remaining acetic acid concentration (e.g. < 0.3%) can have an effect on paint performance.

Figure 6: Joinery with small humps near the corner.

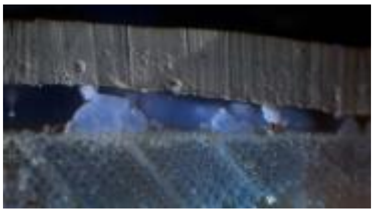

Figure 7: Microscopic image of crystallization between the flow coat and top coating layer.

Glue lines of laminated timber

In none of the projects visited, structural delamination or open corners connections were found. This shows the high potential of producing durable glued connections and well performing laminated beams with acetylated wood.

Cracks

Cracks caused by or during the acetylation treatment were not seen in any of the projects. For both cycle tracks some of the delivered timber beams during the building phase, included drying cracks resulting in shallow thin peels. The number of these cracks did not increase in time, after the timber was included under tension in a curved position (Figure 8).

In joinery no cracks were seen other than those related to the production (e.g. timber was split because of the use of too high force or the use of too narrow connecting parts).

Development of new cracks during the use phase were only seen in the bridge (Sneek 2008) and only in the larger beams (e.g. the king post). In general the cracks were shallow (< 15 mm deep) but in the middle of the two central columns deeper cracks

until 25 mm over several centimetres appeared (Figure 9). Mechanical evaluations showed that none of these cracks had a negative impact on the stability of the bridge, however they enable free water to penetrate deeper into the wood with the risk of water accumulation in the construction.
The cause of the presence of these deeper cracks is not clear and needs further research, but relationships are suggested with the extreme large timber dimensions and heavy exposure.

Figure 8: Beam in cycle track Assen with a removed shallow peel which was a resulted of a drying crack.

Figure 9: postcentral column with cracks.

Moisture content

Because of the acetylation treatment the timber has a low equilibrium moisture content. In exterior joinery without exceptional local water load caused by open connections or internal water condensation, the recorded moisture content normally was between 2.5 and 4.5%. However the moisture content can be much higher near local moisture load caused by damage, resulting in wet conditions of the acetylated wood for longer periods. The acetylated wooden cell wall is more hydrophobic leading to a disturb transport or diffusion of water inside the wood. This disturbed transport of water causes a slow release of moisture and water accumulation in wood, leading to slower drying characteristic of acetylated wood compared to untreated wood. Although, long term high moisture content did not result in decay or substantial swelling, it can give some unwanted side effects. In claddings (Wageningen 2008) with a high water load because of unsealed upper cross surfaces, resulted in mould and moss growth on the paint layer (Figure 10).

Figure 10: Moss and fungal growth on paint layer of wet timber.

Window frames which were not handled properly in the building phase (Wageningen 2008) caused deep penetration through the end grain of free water into the cell lumen of the timber. During the first several years, these high moisture contents, combined with solar exposure caused severe de-adhesion of the paint. Only after several attempts to repainted the window frames, a stable situation was reached in 2017 (Figure 11).

Figure 11: Window frame with high moisture content causing paint damage.

The moisture measurements done in the bridge (Sneek 2008) showed that free water uptake also can take place through the longitudinal surfaces of the timber. After almost 10 years the thin paint layer of the wooden elements of the bridge has lost its water protecting function. The sealing of the timber connections were still functioning properly (Figure 12). It is suggested that the high moisture contents in the outer layer of the beams (e.g. < 20%) are a result of free water uptake mainly by the tangential surface and slow drying of wet acetylated wood.

Figure 12: bridge with degraded paint layer.

In case of joinery it is concluded that the fast water uptake, through the end grain surfaces, leading to free water in the wood, should be avoided and special methods or maintenance instructions should developed in order to remove free water in acetylated timber building products.

Unpainted exterior joinery

Inspection of a 6 year old project with un-coated joinery and cladding revealed a clean and grey impression of the wood surface (Amsterdam 2012, Figure 13). Caused by UV radiation over a period of 6 years, the fibres on the exposed wood surface of the joinery were only degraded in an outside layer with a thickness of several cell layers deep. However depending on the degree of exposure, the surface was darker because of dirt adhesion and mould growth. On locations were the wood was exposed for longer time to high relative humidity, additional moss and algae growth and more extensive mould discoloration was seen (Figure 14). Local differences in discoloration were on some places quite extensive resulting from grooves in the joinery itself or expended materials like bricklayers(Figure 15). Furthermore in some cases the blocks between the finger joints react differently on exterior exposure (Figure 13). It is unclear if small moisture content differences or if the timber quality itself is causing this effect.

Figure 13: Unpainted joinery, clean, partly homogeneous discoloured, party heterogeneous e.g. door.

Figure 14: Unpainted joinery with lichen on moisture areas.

Figure 15: differences in discolorations and mould growth.

After six years in use it is remarkable that the indoor surface of the joinery is unaffected by exposure and use (Figure 15, 16, 18). The inspected surface of the indoor surface of the timber was clean and whitish. Only on a limited number of locations and always near connections brawn discolorations were seen (Figure 17). It is suggested that this discoloration is caused by water transfer from outside inwards.

Opening and closing of the doors and windows as well as the wind and water tightness of the joinery was never a problems. Only in the wet season the consulted residents mentioned that the inside of the turning elements were sometimes somewhat humid. It was not possible to verify this because the inspection was done after a dry period of several days and the moisture content of all the joinery was between 3,5 and 4.5%. No signals of corroding locks were found anywhere in the building, despite the fact that the joinery was unprotected against direct water exposure and assumed water transfer through the wood.

Figure 16: Clean inside timber surface with some brown discolorations.

Figure 17: Clean and homogeneous discoloration (greying).

Figure 18: Clean joinery and non-corroded locks.

Decay

In none of the projects, clear signs of decay were observed . Even under extreme conditions like in the application of sheet piling (Flevoland 2000 and Voorthuizen 2010), after 10 to 15 years of exposure, no significant decay appeared and the planks were still hard and coherent. Only in one instance some fruit bodies of *Schizophyllum commune* and *Gloeophyllum trabeum* were founded near the larger cracks in the bridge (Sneek 2008). The cause of this individual case is not fully understood and further research is needed. One of the preliminary assumptions is that the exceptional cracks in the postcentral column, cause specific conditions for fungal infection. The uptake of water deep in the construction and the deep cracks might cause a homogeneous surrounding and optimal conditions for fungal growth in deeper timber layers.

CONCLUSIONS

Based on all the results of the project visits we concluded that the use of acetylated wood increase the lifetime of timber products and decrease the intensity of maintenance. However special attention is needed to avoid fast water uptake as well in outdoor as in indoor (condensation) conditions and to develop techniques that can accelerate the removal of accumulated water in the wood.

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