Effect of ponding on the wood quality of Scots pine

René K.W.M. Klaassen

SHR Timber Research, postbox 497, 6700 PA Wageningen, r.klaassen@shr.nl

Abstract

Ponding is reintroduced in the Netherlands as a treatment to improve the quality timber. This paper shows the effect of ponding on the properties (density, moisture content, strength, resistance against wood degrading fungi and blue stain, dimension stability, permeability) of Scotch pine.
Most properties determined show up as not affected by ponding. Internal stress is less obvious in ponded pine compared to non-treated pine. But this improvement is regarded to be more related to the time of storage than to the process of ponding. The permeability of ponded pine is higher than that of non-treated pine, resulting in a higher life time under weathering conditions because the wood is easier to dry, water accumulation is prevented and the appearance of cracks is less frequent.
Because of its stability, ponded pine can be used in a wide variety of indoor uses. As a non-durable timber, its outdoor use is restricted.

INTRODUCTION

In the old days, when time was not yet synonymous for money, at least in the Netherlands, timber was often ponded before sawing. This means that it was put under water for several months. Ponding was supposed to result in better wood properties, like higher durability, more dimension stability and better working properties. Earlier work on ponding and related subjects (e.g. wet storage, bacterial decay) was done by Adolf et al. (1972). Benthem & Massop (1999), De Groot & Scheld (1972), Dunleavy & Mc Quire (1970), Gibbs & Weber (1996), Gough (1996), Ellwood & Ecklund (1958), Holmgren (1961), Jutte (1971), Knuth & McCoy. (1962), Liese (1984), Liese & Karstedt (1971), Liese & Karnop (1968), Liese & Peek (1984), Liese et al. (1995), Lutz et al. (1966), Peralta et al. (1993), Perry et al. (1993), Platzer (1971), Platzer & Stackelberg (1969), Powell & Eaton (1996), Schmidt & Liese (1994), Singh et al. (1996, 1998a+b), Suolahti & Wallen (1958), Syme & Saucier (1995) and Unligil (1969).
Currently, a Dutch sawmill is applying ponding of Scots pine which is used in reconstruction work of monumental buildings. In the Netherlands Scots pine (*Pinus sylvestris*) is the most common forest species and because of its fast growth, stems contain a high amount of sapwood. Ponding is believed to substantially increase the quality of Scots pine sapwood in a way that it might even be suitable for outdoor uses like cladding, doors, and window frames. If so, a major part of the Dutch timber stock could be used in this important market segment. To evaluate the effect of ponding on the wood quality of Scots pine, several properties of ponded and non-ponded Scots pine wood were investigated.

MATERIAL AND METHOD

Study material was collected from the Twickel estate. Five Scots pine stems which were submerged in water for 12 months (considered as a normal period for ponding) were used for determining properties of strength, durability (against blue stain and wood degrading fungi), dimensional stability, electrical resistance (as parameter for a moisture content meter) and density. Six non-ponded Scots pine stems were used as reference.
To get more information on the temporal dynamics of the ponding process about 100 Scots pine stems of 4 m length were harvested at the end of February and directly submerged in water. On eight reference stems the moisture content and density gradients across the diameter and the stem length were determine. After 3, 6, 9, 12 en 15 months respectively, ten stems were taken out of the water and were analyzed on the same way as the reference stems.
Furthermore, a project was monitored during four years where preserved ponded Scots pine was used as claddings (Summer house Braamakker design in 1940 by the Dutch architect Rietveld).

RESULTS AND DISCUSSION

Strength properties (table 1), electrical resistance and the resistance against wood degrading organisms of Scots pine heartwood and sapwood were not directly affected by ponding (see table 2 - 3 and figure 1).

Table 1: strength properties of failure free samples and 20 x 20 x 400 mm in size, 12% in moisture content, 4 point bending test.

	N	**MOE (N/mm^2) mean (std)**	**MOR (N/mm^2) mean (std)**
Sapwood ponded	10	10.545 (2.747)	82,7 (10,3)
Sapwood	12	9.878 (2.913)	70,1(15,8)
Heartwood ponded	10	8.111 (1.754)	85,4 (16,3)
Heartwood	12	7.682 (1.936)	76,2 (20)

It is however remarkable that in the graveyard soil test, ponded heartwood is relatively fast degraded (figure 1) which is not confirmed by the results of the laboratory soil tests (table 2).

Table 2: resistance against decay in soil, test according the ENV 807

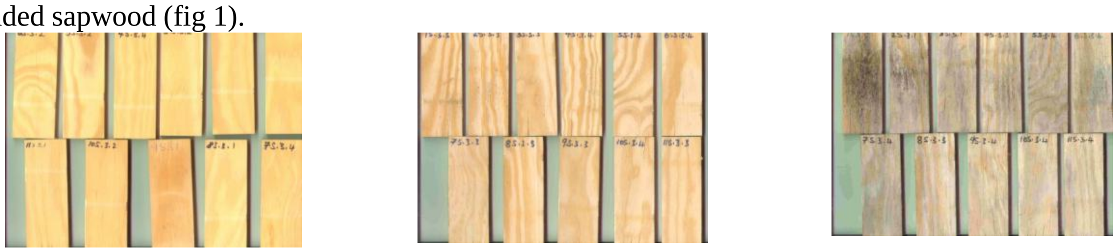
	sapwood		**heartwood**	
Time	**Mass loss [g] mean (std)**			
[weeks]	**Non ponded**	**ponded**	**Non ponded**	**ponded**
4	9 (3)	11 (1)	6 (2)	7 (3)
8	19 (2)	20 (2)	14 (3)	17 (2)
22	36 (21)	26 (18)	22 (17)	21 (13)
27	52 (11)	56 (6)	25 (12)	14 (4)
58	66 (3)	69 (3)	49 (13)	44 (14)
	Moisture content [%] mean (std)			
0	12	12	12	12
4	44 (6)	37 (2)	40 97)	39 (7)
8	49 (5)	52 (22)	46 (7)	43 (7)
22	78 (13)	71 (18)	68 (9)	63 (10)
27	109 (17)	117 (49)	113 (39)	96 (25)
58	126 (37)	156 (44)	152 (39)	148 (35)

Blue stain resistance shows no differences between ponded and non-ponded pine sapwood in the test according EN 152 (no data are given).

Table 3: resistance against fungal decay (test according EN 113).

	Mean mass lost [%]							
Fungi species	***Coniophora***		***Gloeophyllum***		***Coriolus***		***Poria***	
	Gem.	**Std.**	**Gem.**	**Std.**	**Gem.**	**Std.**	**Gem.**	**Std.**
Sapwood ponded	33,8	3,8	24,8	10,7	4,0	1,7	19,9	2,1
Sapwood	34,1	6,2	34,0	7,1	13,3	1,4	14,9	3,1
Heartwood ponded	6,2	9,6	0,0	0,7	0,2	0,7	11,9	5,0
Heartwood	8,5	12,2	6,3	10,8	2,3	4,2	10,5	4,7
Referents	44,8	9,7	36,2	7,3	12,4	3,0	16,9	2,3
Virulent controls	42,2	4,3	34,4	2,4	12,5	1,2	20,1	3,3

Whereas the field test showed an initial increase in resistance against blue stain of the ponded sapwood but at the end of the test period the ponded sapwood showed up as equal susceptible as non-ponded sapwood (fig 1).



start weathering exposure | 8 weeks, first blue stain signs | 12 weeks, increasing blue stain

Fig 1 Blue stain field test (April – July, south east exposure, 45°), ten pine sapwood samples (110 x 40 x 10 mm); visual results show first signs of blue stains after 8 weeks mainly on the non-ponded samples, after 12 weeks clear blue stain on all samples.

Further research on this topic was not carried out because the stems were harvested at the end of the winter and it turned out that most starch was already changed into soluble sugar and detection of the amount of carbohydrates was not possible anymore (Powell et al 2000).

Table 4: Longitudinal water uptake: samples (20 x 20 x 400 mm) standing with their cross surfaces in water.

	Water uptake [g/4 cm^2]							
	Non ponded				ponded			
Time	**sapwood (N=12)**		**Heartwood (N=12)**		**sapwood (N=10)**		**heartwood (N=10)**	
[days]	**mean**	**Std.**	**mean**	**Std.**	**mean**	**Std.**	**Mean**	**Std.**
0,04	3,5	1,0	0,8	0,4	12	7,5	0,7	0,3
0,29	5,7	1,2	1,7	0,8	19	12,3	1,7	0,6
1	8,8	1,4	3,1	1,3	25	14,2	3,2	0,9
2	11,4	1,5	4,4	1,9	29	14,9	4,3	1,3
3	13,3	1,5	5,2	2,2	31	15,4	5,3	1,5
7	16,9	1,9	7,0	2,9	36	16,5	7,7	2,2
14	22,3	1,9	8,3	3,4	42	15,2	8,9	2,6
21	27,8	3,1	9,0	4,2	46	13,7	9,1	2,5
35	27,5	4,2	8,9	4,7	39	12,0	8,7	2,5

Water-permeability of the sapwood of ponded Scots pine increased, as well for water up take (table 4), as for the water release (table 5). No effect in water permeability was seen in the heartwood.

Table 5: Water release of samples tested on water uptake (table 4) drying conditions were 65% RH and 23°C.

	Water release (g)							
	Non ponded				ponded			
Time	**sapwood (N=12)**		**Heartwood (N=12)**		**sapwood (N=10)**		**heartwood (N=10)**	
[days]	mean	Std.	mean	Std.	mean	Std.	Mean	Std.
0,04	1,1	0,2	0,5	0,1	2,1	0,4	0,8	0,2
0,29	5,4	0,9	1,8	0,6	10,4	2,6	2,3	0,5
1	16,2	2,6	4,1	2,1	27,5	7,9	4,5	1,3
2	22,9	3,8	5,8	3,3	33,7	10,4	5,8	1,8
3	24,7	4,3	6,6	3,9	35,7	11,3	6,3	2,0
7	25,9	4,3	7,4	4,3	37,2	11,7	7,2	2,3
14	26,0	4,3	7,6	4,3	37,4	11,7	7,4	2,3
21	26,1	4,3	7,7	4,4	37,5	11,7	7,6	2,4

Figure 2 shows that the increased permeability by ponding only takes place in the sapwood and that it is a process that proceeds gradually in time. It is assumed that this process continues also after a ponding period of 15 months.

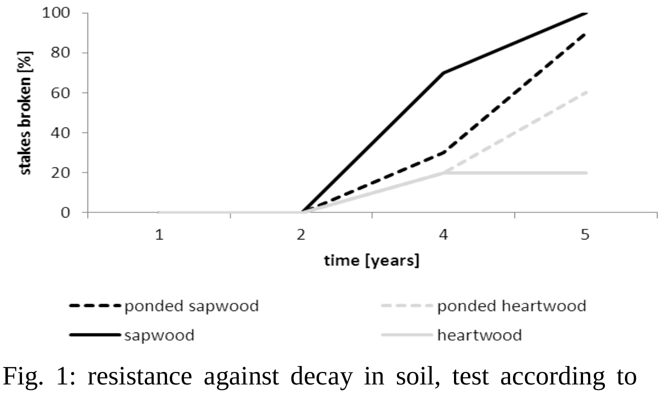


Fig. 1: resistance against decay in soil, test according to EN 252. Ponded and non ponded sapwood and heartwood are tested, 10 samples each (40 samples in total).

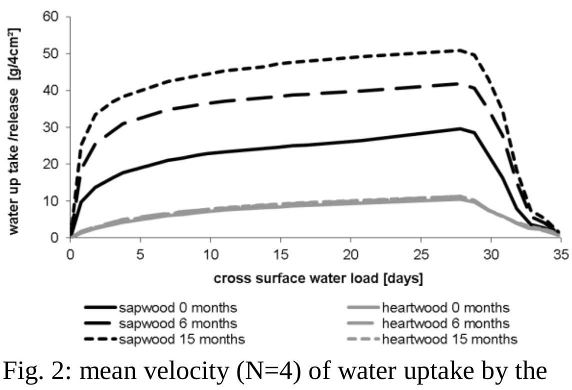


Fig. 2: mean velocity (N=4) of water uptake by the cross surface and mean water release in time for sapwood and heartwood for the different ponded periods

Earlier studies showed already that bacterial activity results in local degradation of the pit membrane in sapwood leading to a higher permeability which favors water transport through the wood (Dunleavey & McQuire 1970, Knuth & McCoy 1962; Lutz et al. 1966; Liese et al. 1995; Liese &

Karnop 1968; Holmgren 1961; Suolathi & Wallen 1958; Ille 1957; Unligil 1969). Local degradation of the pit membrane also causes dark areas in ponded Scots pine sapwood painted with a pigmented transparent coating. These darker areas reflect permeable areas where more pigments are absorbed by the wood (figure 3).

Fig 3 Local increased permeability results in dark spots by semitransparent coatings

Although ponded Scots pine (heartwood and sapwood) shows no differences in shrink and swelling properties (table 6 and 7), it appeared to be more stable after machining (table 8 and figure 4).

Table 6: Shrinkage determine at samples (40 x 40 x 10 mm), starting at 97% RH.

Mean shrinkage (% of dimension at RH 97%), N=15 (5 stems)												
RH	**Moisture content [%]**				**radial [%]**				**tangential [%]**			
[%]	**sapwood**		**heartwood**		**sapwood**		**heartwood**		**sapwood**		**heartwood**	
	ponded	**non**	**ponded**	**non**	**ponded**	**non**	**ponded**	**non**	**ponded**	**non**	**ponded**	**non**
97	26	27	26	25	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
80	18	18	17	18	1,1	1,1	1,1	0,9	2,3	2,3	2,5	1,8
70	15	15	13	14	2,1	2,1	2,0	1,7	3,8	3,5	3,0	2,9
55	11	12	11	11	2,2	2,3	2,1	1,7	4,3	4,3	4,5	3,5
25	6	6	6	6	3,3	3,4	3,0	2,6	6,0	6,0	6,3	5,0
0	0	0	0	0	4,3	4,6	4,0	3,4	7,4	7,5	7,9	6,4

Table 7: Swelling determine at samples (40 x 40 x 10 mm), starting at 26% RH.

Mean swelling (% of oven dry dimension), N=15 (5 stems)												
RH	**Moisture content [%]**				**radial [%]**				**tangential [%]**			
[%]	**sapwood**		**heartwood**		**sapwood**		**heartwood**		**sapwood**		**heartwood**	
	ponded	**non**	**ponded**	**non**	**ponded**	**non**	**ponded**	**non**	**ponded**	**non**	**ponded**	**non**
0	0	0	0	0	0	0,0	0,0	0	0	0,0	0,0	0
26	6,7	6,8	8	7	1,1	1,2	1,1	0,9	1,6	1,5	1,6	1,4
43	8,5	8,8	10	9	1,4	1,6	1,4	1,2	2,2	2,1	2,1	2
70	13,3	13,4	14	13	2,3	2,5	2,1	1,8	3,7	3,6	3,6	3,3
80	14,9	15,2	15	15	2,8	3,0	2,5	2,2	4,4	4,3	4,3	3,9
97	22,6	22,8	22	22	4	4,4	3,5	3,2	6,8	6,7	6,7	5,9

The reason behind is most likely a release of internal mechanical stress, so called grown strain. Relaxation of these stresses is a natural process occurring after harvesting. It occurs while wood is stored and is therefore not directly related to the process of ponding.

Table 8: Tension in wood, determine at one board (75 mm thick) from each stem including the pith, classified direct after sawing

Tension in wood: saw edge 0=strait; bending of the edge x=weak - xxxxx=severe									
Stem no.		**sapwood**				**heartwood**			
		Closing saw edge		**Opening saw edge**		**Closing saw edge**		**Opening saw edge**	
Non ponded	**ponded**	**Non ponded**	**ponded**	**Non ponded**	**ponded**	**Non ponded**	**ponded**	**Non ponded**	**ponded**
1	7	x	o	x	o	xx	o	xx	xx
2	8	xx	o	xx	o	o	xxx	xx	o
4	9	xxx	o	xxx	o	o	o	x	o
5	10	o	o	xx	o	o	o	o	o
6	11	xxxxx	o	xx	o	o	o	xx	o

Oak is another timber species which has a ponding history in the Netherlands. In the 15^{th} – 17^{th} century round 1000 wooden vessels were built each year on the Dutch shipyards. The approximately 300.000 m³ oak needed, was partly transported on rivers to the Netherlands and the stems were often kept in the water until sawing. This transporting and storages process can be regarded as ponding (Prooijen

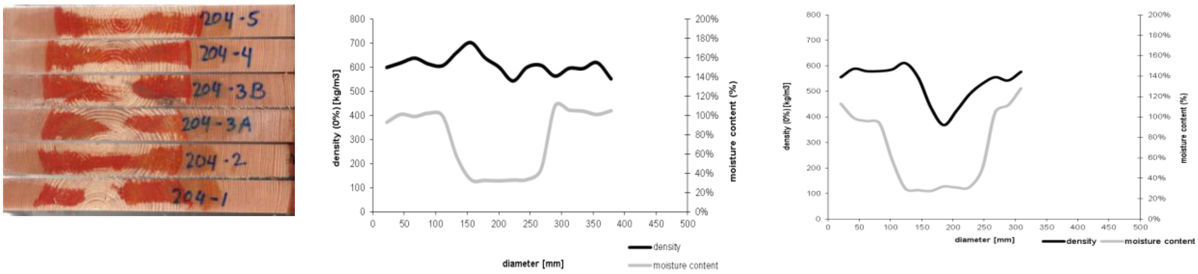
1990). Furthermore, the VOC Company asked special for ponded oak for building their ships and mainly oak heartwood was used (Kerssens & Tolk 2002). If translating the Scots pine heartwood results to oak heartwood, the only advantage of ponding should be the dimension stability, which is probably only indirectly related to the ponding process.

In a non-ponded board the stress release after sawing is strong

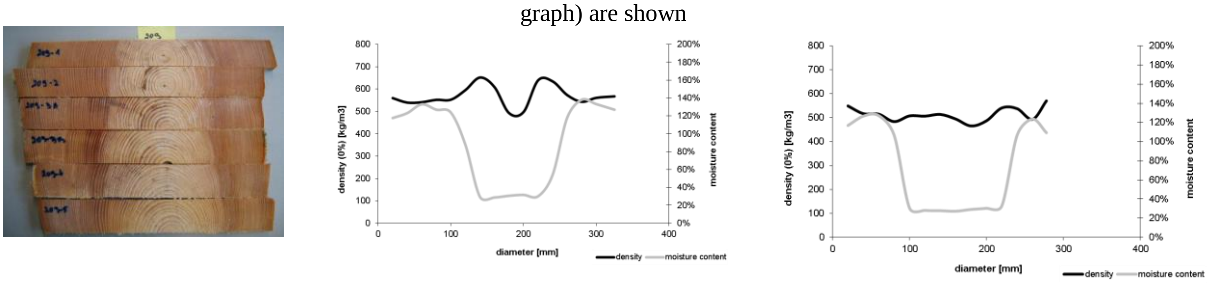
In a ponded board the stress release after sawing in limited.

Fig 4: examples of the effect of ponding on stress release in pine boards (75 mm) direct after sawing

The stems that were sampled each three months show that the extent of bacterial activity proceeds in time, indicated by an increase of the typical smell of the wood. Nevertheless the moisture content of the pine heartwood as well as of the sapwood was found not to be effected by the time of ponding (figure 5). This means that the sapwood was always fully water saturated and that the heartwood maintained its amount of enclosed air. The density of both sapwood and heartwood neither changed during ponding (figure 6 and 7), which means that no substances were included in the wood during ponding or wood extractives washed out from the heartwood.



Non ponded pine stem (78 year rings, 54 sapwood rings) gradient over the stem diameter at 50 cm (left) and 350 cm (right graph) are shown



Pine stem 15 month ponded (74 year rings, 55 sapwood rings) gradient over the stem diameter at 50 cm (left) and 350 cm (right graph) are shown

Fig 5 Two examples of the four meter long stems that have ponded at different periods and were the moisture content and density (at ovendry condition) is determine as a gradient over the stem diameter

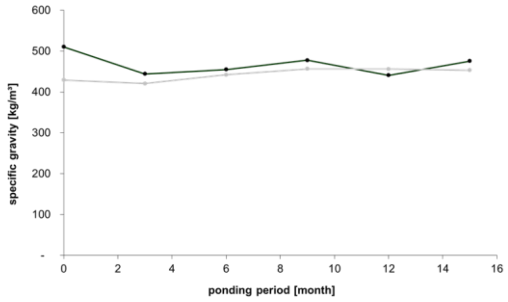


Fig 6 mean density: sapwood grey line) and heartwood (black line) per ponding period. Mean value for each period is based on the gradient over 10 stems.

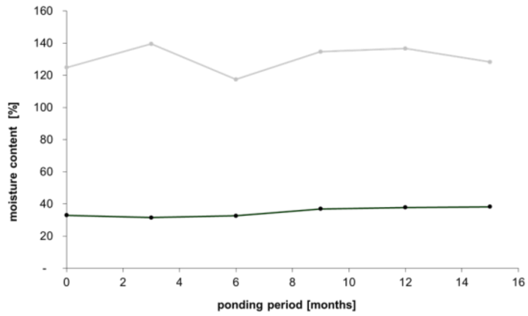


Fig 7 mean moisture content: grey line) and heartwood (black line) per ponding period. Mean value for each period is based on the gradient over 10 stems

The initial wood quality of the ponded pine claddings was high (fully impregnated, homogenous moisture content, cracks free) and after four years of exposure at the Summer house (figure 8) no problems were detected.

Fig. 8 Summer house with new claddings of ponded pine in 2003

CONCLUSIONS

The only direct effect of ponding on Scots pine is an increase in permeability of the sapwood which enables water to enter freely in and out the wood. The increased permeability decreases the risk on local water accumulation and therefore the risk on the appearance of cracks. Although ponded Scots pine has no increased natural durability, the lesser amounts of cracks as well as the fast and homogeneous adaptation of the moisture content to different weather conditions, decreases the chance on fungal infection and fungal activity in the wood. Ponded Scots pine is more dimension stable than non-treated Scots pine but this improvement is regarded as an indirect effect through growth-stress relaxation in (water) storage time.

Because of these properties, ponded Scots pine is only under restrictions useful in outdoor constructions. Outdoor applications as doors and window frames are not recommended. As ponded pine is easy to preserve and dried it is proven to be suitable for outdoor claddings because of its stability and its low risk on cracks.

REFERENCES

Adolf, P., Gerstetter, R. & W. Liese. 1972. Untersuchungen uber einige Eigenschaften von Fichtenholz nach dreijahriger Wasserlagerung. Holzforsch. 26 (1) 18-25.

Benthem van, M. & M. Massop. 1999. Het wateren van hout: onderzoek naar het wateren van hout in Nederland. Studenten scriptie, Hogeschool Larenstein.

Dunleavy, J.A. & A.J. Mc Quire. 1970. The effects of water storage on the cell structure of Sitka spruce (Picea sitchensis) with reference to permeability and preservation. Journal of the Institute of Wood Science 5, 20-30.

Ellwood, E.L. & B.A. Ecklund 1959. pine logs in pond storage. Forest Product Journal 9 (9) 283-292.

Gibbs, J. & J. Webber. 1996. Water storage of timber: experience in Britain forestry. Forestry Commission Bulletin 117 HMSO, London, 48 pp

Gough, D. 1996. Water spray storage of fire salvaged logs in South East Queensland and issues arising that affected log utilisation. Unpublished report, Queensland Forestry Resources Institute Australia, 7 pp.

Groot de, R.C. & X. Scheld. 1972. Biodegradability of sapwood from Southern Pine logs stored under continous water spray. Forest Products Journal 21: 53-55.

Holmgren, H.F. 1961. Impregnation of water-logged pine. Rec. Conv. Brit. Wood Pres. Ass.

Ille, R. 1957. Deep impregnation of refractory softwoods. Die Holzindustrie 10, 57, 93, 133.

Jutte S.M. 1971. Wood structure in relation to excessive absorption – a literature survey -. Houtinstituut TNO, Delft.

Kerssens, D. & P. Tolk (ed.). 2002. Cornelis Corneliszoon van Uitgeest – uitvinder aan de basis van de Gouden eeuw. Walburg pers

Knuth, D.T. & E. McCoy. 1962. Bacterial deterioration of Pine logs in pond storage. Forest Product Journal 12: 437-442.

Liese, W. 1984. Wet storage of windblown conifers in Germany. New Zealand Journal of Forestry 29: 119-135.

Liese, W. & P. Karstedt. 1971. Erfahrungen mit der Wasserlagerung von Windwurfhölzern zur Qualitätserhaltung. Bundesforschungsanstalt fur Forst und Holzwirtschaft, Hamburg-Lohbrügge

Liese, W. & G. Karnop. 1968. On the attack of Coniferous wood by bacteria. Holz als Roh und Werkstoff V 26 part 6: 202-208

Liese, W. & R.D. Peek. 1984. Experiences with wet storage of conifer logs. Dansk Skovforeningens Ridsskrift 69: 73-91.

Liese, W. Schmidt, O. & U. Schmitt. 1995. The behaviour of hardwood pits towards bacteria during water storage. Holzfortschung 49(6): 389-393.

Lutz, J.F., Duncan, C.G. & T.C. Scheffer. 1966. Some effects of bacterial action of rotary-cut Southern pine veneer. Ferst Products journal 16:23.

NNI. 1996. NEN-EN 113: Houtverduurzamingsmiddelen. Beproevingsmethode voor de bepaling van de preventieve werking tegen houtaantastende Basidiomyceten. Bepaling van de giftgrenswaarden. (Incl. Wijzigingsblad A1, 2004). Delft.

NNI. 1994. NEN-EN 350-1: Duurzaamheid van hout en op hout gebaseerde producten. Natuurlijke duurzaamheid van massief hout. Deel 1: richtlijn voor de principes van het beproeven en het classificeren van de natuurlijke duurzaamheid van hout. Delft.

NNI 1998. EN 152: Test methods for wood preservatives; Laboratory method for determining the protective effectiveness of a preservative treatment against blue stain in service. Part 1: Brushing procedure, Part 2: Application by methods other than brushing

Peralta, P.N., Syme, J.H. & R.H. McAlister. 1993. Water storage and plywood processing of Hurricane-downed Southern Pine timber. Forest products journal 43(4), 53-58.

Platzer, H.B. 1971. Zur Technik der Wasserlagerung von Rundholz. Forstarch. 42(1), 1-6.

Platzer, H.B. & S. v. Stackelberg. 1969. Wasserlagerung von Sturmholz in Dänemark. Forstarch. 40(10), 206-208.

Powell, M. & R. Eaton. 1996. Non-decay fungi in water stored Pine following sawmill conversion. In: water storage of timber- experience in Britain forestry. Forestry commission Bulletin 117 HMSO, London, 26-32.

Powell, M.A. Webber, J.F. & R. Eaton. 2000. Changes in moisture, soluble carbohydrates and bacterial numbers during water storage of pine. Forest product journal 50 (3) 74-80.

Prooijen, Van L. 1990. De invoer van Rijnshout per vlot 1650 – 1795. Economisch en sociaal-historisch jaarboek 53: 30-79.

Schmidt, O. & W. Liese. 1994. Occurrence and significance of bacteria in wood. Holzforschung 48: 271-277.

Singh, A.P. Gallagher, S.S. Schmitt, U., Dawson, B.S. & Y.S. Kim. 1998. Ponding of Radiata Pine (Pinus radiata); 2 The effects of ponding on coating penetration into wood. IRG/WP98-10249.

Singh A.P , Dawson, B.S., Schwitzer, M. & M. Singh. 1996. The effect of ponding on wood-coating interaction. In: Proceedings of the third pacific rim bio-based composites symposium (ed. Kajita & Tsunoda). Kyoto, Japan.

Singh, A.P, Y.S. Kim, Schmitt, U. & B.S. Dawson. 1998. Ponding of Radiata Pine (Pinus radiata); 1 The effect of bacteria on wood. IRG/WP98-10265.
Suolahti, O. 1961. The effect of wet storage on the impregnability of wood. Mitt. Dtsch. Ges. Holzforschung 48: 89-92.
Suolahti, O. & A. Wallen. 1958. The effect of water storage on the water absorption capacity of pine sapwood. Holz Roh-u Werkstoff 16: 8.
Syme, J.H. & & J.R. Saucier. 1995. Effects of long-term storage of Southern Pine sawlogs under water sprinklers. Forest Products journal 45 (1): 47-50.
Unligil, H.H. 1969. Effect of water storage and Trichoderma infection on penetrability of wood. For. Prod. Lab. Ottawa report OP-X-12.