Assessment report: State of the wooden construction, fresh water marina, Akkrum

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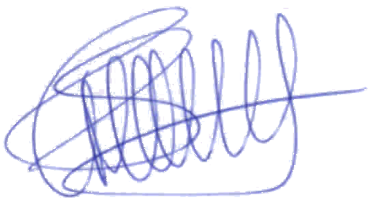

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Entries: Monitoring, timber species, landing stages, sheet pile, gang planks / boards, poles (hewn, sawn, round), purlins, stop logs poles, identification, decay.

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SHR operates according to NEN-EN-ISO/IEC 17025.

Contents

1 Introduction

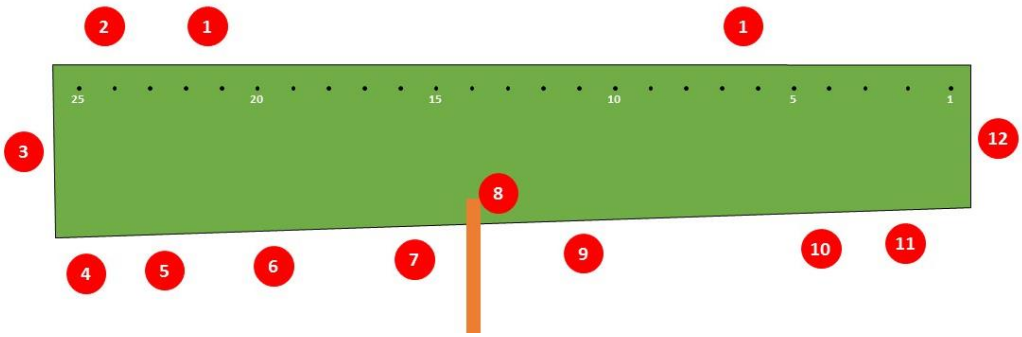
July 17th, 2020 Probos Foundation in Wageningen commissioned SHR to inspect the timber used at an artificial island in the marina of Akkrum.

Eleven years ago (2009), the island was established within the project “Expo Duurzame Waterbouw” (exposition of sustainable water building) in Friesland by “Stichting Hardhoutalternatieven” (foundation for hardwood alternatives) with financial support of “Stichting Doen”. For the Dutch water building working field several well-known and several lesser known timber species, of which some originated from Suriname were used in landing stages (gang boards), poles, sheet pilings and purlins. In addition modified timbers, plastics, steel and concrete were used. All this makes the project a unique project because it offers the opportunity to compare the behaviour of different materials and material types under the same conditions and time span.
The inspection is a first step in the monitoring of the behaviour of different materials in water building constructions. The well-known materials and well known timber species are evaluated for their own behaviour but also regarded as reference for the lesser known materials.
The period of eleven years can be regarded as a minimum period for the lifespan of a water building construction and is long enough to distinguish between materials than can reach the minimum lifespan of 75 years expected for water building constructions.

Reconstruction of the position of the materials used
Based on the available information, https://www.duurzamewaterbouw.nl/introductie, given by Probos, and the information maps on the island, a reconstruction was made of the position of the different materials in different construction parts. The internationally most accepted timber trade names are used but also names used during construction are given between brackets.

Sheet pilings

Numbers pile sheets according sign on location

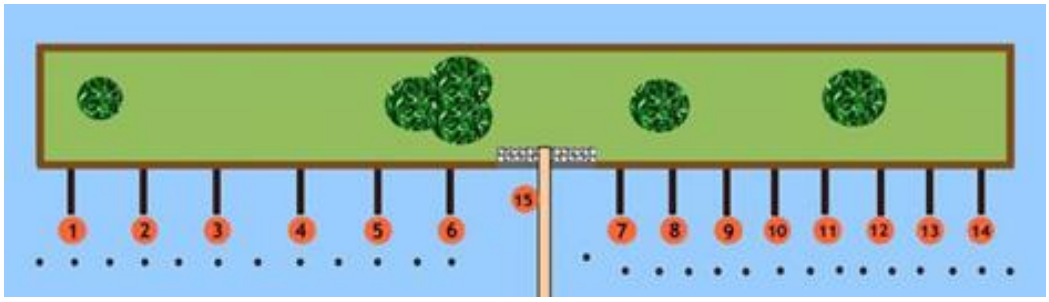


1 Timber species: angelim vermelho, azobé, iroko, roupala (louro faia), gonçalo alves (muiracatiara), massaranduba, okan, araracanga (piquia marfim) and tali; 2: Larch Austria (van Swaay); 3: combination sheet pile angelim vermelho with softwood (van Swaay); 4: Combination sheet pile Accoya with another softwood; 10: thin sheet piling: robinia board, kopie (cupiuba) piles;

Non wooden materials: 5: plastic ; 6: steel; 7: concrete; 8: stone deposits; 9: recycled sheet piles from the same harbour; 11:combination sheet pile recycled PVC and spruce; 12: flat vinyl, reinforced with spruce poles, PE-steel purlins.

Landing stages

The landing stages consist of one pole standing in the water, two horizontal beams carrying 8-10 gang boards about 50 cm wide.

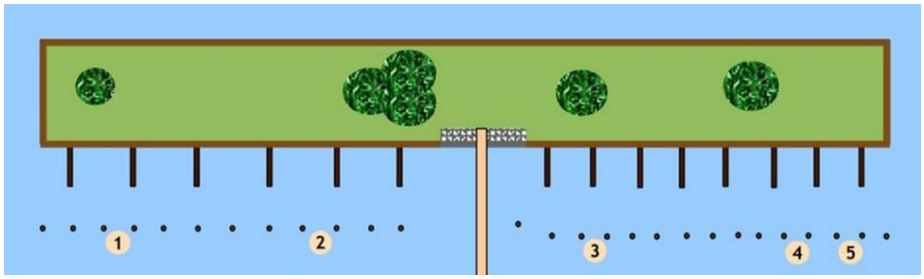


1: Gang boards and horizontal construction both padoek (Eerlijk Tropisch Hout); 2: Gang boards and horizontal construction both gindya udu (tanimbouka), pole angelim vermelho (Nailtra BV); 5: Gang boards, horizontal construction and pole all larch (Van Swaay Duurzaam Hout); 8: treated and untreated timber in gang boards, horizontal construction, pole (Foreco Dalfsen BV); 13: Gang boards manbarklak (mata mata preto), angelim pedra (sapupira), aldina (angelim da campina), faveira amargosa (fava amargoza) and pole acariquara (Precious Woods Europe BV); 14: Gang boards, horizontal construction and pole all azobé (Wijma Kampen BV).

Non wooden materials:

3: Gang boards PP plastic with wood fibre(Bekol International BV); 4: Gang boards, not specify plastic (Fiberplast BV); 6: Gang boards, bamboo composite (Atlas compositen) and bamboo plastic composite (Van der Kooy, general Chiqo BV); 7: gang boards, horizontal construction produced by Haasnoot Composieten; 9: Gang boards and horizontal construction both not specified plastic (Novamarin Glasvezel); 10: Gang boards not specified PE plastic, horizontal construction not specified GVK plastic and pole PE sheet around steelpole (Allflex Watersport); 11: Gang boards and horizontal construction both recycled PE plastic, pole combination of wood and recycled PE plastic (Lankhorst Recycling Products); 12: Gang boards not specify PE plastic, horizontal construction not specify GVK plastic, pole combination of steel with PE plastic sheet (Gampet Plastics BV); 15: stone fill (Leemburg Waterbouw).

Free poles



1: Larch (Van Swaay Duurzaam Hout); 3: azobé (Wijma Kampen BV); 4: cloeziana (Leemburg Waterbouw); 5: treated poles (Foreco Dalfsen BV).

Non wooden materials:

2: not specified PE plastic upper part on steel (Gampet Plastics BV)

2 Material and method

2.1 Reconstruction of the position of the materials used

We based the inspection on the information available and given in chapter 1. Although on the site small plastic signs had been placed with information about the materials present at that specific spot, these were unusable because they had become almost or completely illegible.

2.2 Inspection

On September 17th, 2020 mr. Creemers and mr. Klaassen (both SHR) inspected the wooden construction parts and mr. Van Dijk (Probos) and mr. Van der Wal (Rijkswaterstaat Programma's, Projecten en Onderhoud Techniek en Technisch Management Noord-Nederland) attended the inspection.
For the species used, we rely on the information provided by the signs and available at the website of the project and by Probos. When in doubt, we first tried to confirm the species visually, secondly we took a sample and judged that on its cross section and finally we looked under the microscope. This way of working means that we did not check all the timber elements with regard to their identity and therefore some misinterpretations may have been made. Within the project it was impossible to check everything.
For the sheet piles inspection spots were chosen, based on the visual recognition of a change in material or timber species and on the bases of the amount of different timber species used. On each spot soil was removed behind 2-3 planks in order to see at least the upper 10 cm of the sheet pilings, with an awl the hardness was determined and if necessary wood samples were taken for identification and fungal activity. At the water side the sheet pile above the water and 20 cm below the water level was inspected visually and with the use of an awl. If necessary up to three density profiles were made mostly in one sheet pile only. One from the waterside just above the water level, one on the waterside just below the purlin and one approximately 15 cm higher but taken from the landside, mostly at a downwards angle. If relevant the moisture content was measured capacitively and adapted to the density of the wood.
All landing stages with wooden elements according to the list above were visually inspected and an awl was used. If necessary wood samples were taken.
The free poles were visually inspected from a boat. If necessary wood samples and density profiles were taken. For illustration several pictures were taken.

2.3 Laboratory analyses

With a sharp knife the cross surface of the wood samples taken was smoothened in order to see the wood structure. In most cases additional thin sections were needed to get a full impression of the wood structure needed for identification. Thin sections were made of cross, radial and tangential surfaces and the wood structure was observed with a microscope. The wood structure found was compared with that of the known structure of the species supposed to be used in the project, based on the large information signs on the island and the information received.
Some of the timber producers were contacted (Foreco, GWW houtimport, Reef, Wijma, van Swaay, Accsys, Nailtra and Precious woods) in order to check the information found.

3 Results and discussion

3.1 Inspection sheet piles

It was remarkable that the connection of the upper part of the sheet piles with soil differed between the south part and the rest of the island. The connections was tight in the south and at the other expositions the upper part was often free from the soil and at these positions the soil was somewhat settled. This means that the degree of exposure in the south is higher compared to the rest.
The sheet piles were visually inspected at the water side over their full length and sample wise randomly specific measurements were done. At the water side, the sheet piles were mostly hard and coherent and the finger joints of the supposed combination sheet piles were never observed because they were well connected or they were too deep under water level to be part of the inspection. At the side of the fairway it was in most cases not possible to see all the different wood species. On specific locations only less coherency was found (plant growth) and on two places a softer timber surface. At the landside the hardness was more variable. Wood samples were only taken when needed and possible. If smell was clear (angelim vermelho) or the timber structure was clear like for the softwoods with narrow rings (larch), or wide rings (Accoya, whitish, Nobel wood brownish), samples were not deemed necessary.
In Appendix 1 the specific results of the inspection are given and here the results are summarised.

In the sheet piles and the clamp boards with poles, nine different timber species were found. It is remarkable that in the sheet piles located under number 1 only five species were found: okan, azobé, tali, araracanga and roupala as on the large information signs four additional species were mentioned: angelim vermelho, iroko, gonçalo alves and massaranduba. Angelim vermelho is probably used under number 4, but iroko, gonçalo alves and massaranduba were not found.
Regarding the identification of okan, tali and angelim vermelho it has to be stated that all three species have a similar anatomy. We used smell as additional key identification feature for angelim vermelho and for separating tali and okan we used the ray width and the appearance of storied tissue. Both features are variable and smell may vanish over time. So the identification of these three species is not always certain.

The producers were asked about the species they delivered in this project and the survey below gives the timber species (ordered by producer) as found compared to the signs.
Van Swaay:
2 angelim vermelho (signs give larch),
3 angelim vermelho (signs give angelim vermelho with spruce);
4a accoya (signs give combination pile), Accsys confirmed the combination with spruce;
4b angelim vermelho (not mentioned on the signs);
10 (robinia clamp boards kopie poles (confirmed).
Wijma:
1 azobé and tali (confirmed).
Reef:
1 okan (confirmed)
1 iroko, gonçalo alves (muiracatiara) (both species not found).
GWW houtimport:
1 roupala (louro faia), araracanga (piquia marfim) (confirmed).
Bekol:
1 massaranduba (not found).

Without decay and abundant moss and algae growth one of the okan locations, is best performing. Other species that perform well are angelim vermelho, araracanga, azobé, tali and combination sheet piles of Accoya and angelim vermelho. Both combination sheet piles but especially in Accoya the nails allow plant growth which is a first step in degradation. Of the many combination sheet piles with angelim vermelho inspected, only two show some decay.
Advanced stages of the decay process were found in roupala and robinia. So both roupala and robinia do not act well under these conditions for sheet piling
A remark has to be made for azobé, okan and tali. All three species were found on more than one location and their performance was variable: on some locations they performed well and for okan even very well, while on other locations it was less and for okan even worse. A lesser performance means that the degradation had slowly started.
Special attention should be given to the reused azobé where the variation in decay is large. The reused quality of the azobé is not clear and the good performance of some of the sheet piles can be related to a good selection of the timber after it was removed from its first position.
A survey of the results is given below:

No.	species	combi	condition	remarks
1a	okan		good	clean
1b	azobé		good	
1c	tali		relative good	some inside decay
1d	tali		relative good	some inside / outside decay
1e	tali		relative good	(some inside / outside decay)
1f	tali		good	some weak decay
1g	azobé		questionable	
1h	araracanga		good	some weak decay
1i	roupala		bad	
1j	okan		bad	
2	angelim vermelho	yes	good	with larch
3	angelim vermelho		good	some weak decay, one pile was degraded, rare plant growth through nails
4a	Accoya	yes	good	plant growth through nails
4b	angelim vermelho	yes	good	some weak decay
9	reused azobé		relatively good	some weak decay
10	robinia board		bad	plant growth through nails
10	kopie poles		good	
11	reused azobé		questionable	

3.2 Inspection free water poles

In Appendix 2 the specific results of the inspection are given. Below a summary is given.
In the free water poles four species were found. In the information profiled larch, azobé, cloeziana and treated poles by Foreco were given. Treated poles of Foreco were not found and treatment of whole poles in the furfurylation process is not to be expected as the process needs to treat the timber over the full diameter. Foreco confirmed this.
Manbarklak was found as additional species and Precious woods (Andries van Eckeveld) confirmed that they did a possible delivery.

Survey below gives the timber species (ordered by producer) as found compared to the signs.
Van Swaay:
1 larch (confirmed).
Wijma:
3 azobé (species confirmed but location is 5).
Leemburg waterbouw:
4 cloeziana (species confirmed, but on location 2 and 3)
Foreco:
5 Treated poles by Foreco (not found).
Additional (possible Precious woods):
4 manbarklak (found).

All the inspected poles were still suitable to fulfil their construction demands, although some decay was found around the water line of larch and cloeziana poles. The small galleries in both inspected manbarklak poles were already in the pole at the moment of inserting it in the harbour and were caused by the Ambrosia beetles. The table below summarizes the results:

location	species	shape	condition	
3rd west	larch	round	good	15 mm weak decay, waterline
5th west	cloeziana	round	good	25 mm decay waterline
7th-12th west	cloeziana	round	good	25 mm decay waterline
1st – 2nd far east	azobé	sawn / square	good	
3rd east	manbarklak	round	good	Many small cracks / galleries
4th east	manbarklak	round	good	Many small cracks / galleries
5th-11th east	cloeziana	round	good	

3.3 Inspection of the landing stages

In Appendix 3 the specific results of the inspection are given. Below a summary is given.
Because it was not always possible to take wood samples for identification without visible damage, the identity was only verified by sampling at landing stages 1, 2, 5, 8 (treated radiata pine only), 13 (horizontal construction and pole), and 14.
The maintenance of the gang boards was really good, they were all free of debris and growth of algae and mosses. This improves their lifespan and most of the gang boards were in good condition except for those of treated radiata pine, larch and one location with bamboo (according to the habour manager it was replaced after six years). The supposed differences in behaviour of the two bamboo gang boards can be explain by differences in processing of the planks which can cause significant differences in quality. The horizontal constructions were good except for larch. The table below summarizes the results (gb=gang boards; hc=horizontal construction wood):

No.	species	condition	remarks	
1 gb, hc, pole	padoek	good		
2 gb	*Terminalia* species	good		
2 hc	angelim vermelho	good		
2 pole	probably larch	good	round	
5 gb, hc	larch	bad		
5 pole	larch	good	round	5 mm decay water line
6 gb	bamboo	replaced		
7 gb	bamboo	good		
7 hc	unknown	good		
7 poles	larch	good	round	
8 gb	treated radiata pine	bad		
8 hc	unkown	good		
8 pole	larch	good	Round	
13gb	manbarklak, angelim pedra, aldina, faveira amargosa	good		
13 hc	angelim pedra	good		
13 pole	acariquara	good	Original trunk shape	
14 gb, hc, poles	azobé	good		

4 Conclusion

The timber used in the wood constructions of the fresh water marina in Akkrum gives a unique insight in the behaviour of wood species in time. European timber species, modified timber species (Accoya, and probably a second treatment with radiata pine) and tropical timber species were used. Some of the tropical timbers are generally used species but at the initiation of this harbour project, special attention was given to lesser known species from Suriname like kopie, *Terminalia* species and manbarklak.

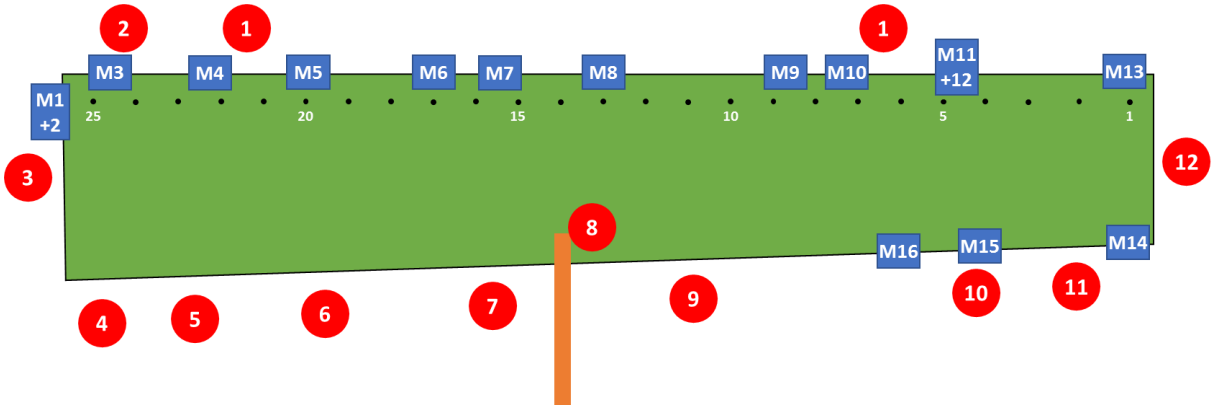
After eleven years it is difficult to recognize some of the species immediately and it is shown that correct administration of the species used is indispensable. The majority of the species mentioned on the information signs on the location and in the information provided, were also found during the inspection. In addition some species were not found and one, not mentioned species, was identified. So at the first place, this study improved the knowledge of the timber species used in this project and their location. This knowledge is essential for a reliable monitoring of the behavior of the timber in function.

Most of the species still fulfill all their construction requirements and this is also valid for all the Surinam species. There are some species which behave differently. Poles of larch are still in good condition but the gang-boards and the horizontal construction beams are at the end of their lifespan after 11 years in function. Also the treated radiata pine gangboards are over their lifespan. Of the tropical timbers in sheet piles roupala is at the end of its lifetime, and some variation in behavior was found for the more widely used species. It is suggested in this study that because of lower initial quality, improper construction and locally higher water or stress load, some of the well performing tropical hardwoods show more decay on some locations. Special attention is given to the reused azobé sheet piles, with a variable state of the timber and it is suggested that it is related to the selection of the timber before installing. Furthermore the robinia boards are at the end of their lifetime. In order to follow the well performing timbers it is suggested that within five years an additional inspection is done, on the basis of the documentation made in this project, in order to get more reliable information on the influence of decay of the timber and the causes of it.

As it is such a unique project, it is suggested that also the other materials used beside timber are inspected and that all water building construction elements are inspected every five years in order to monitor the behavior of indispensable materials used. The results can be used for improving the quality and the lifespan of water building construction materials and will provide background information on the environmental advantage of using biobased materials.

Appendix 1

Specific results on the sheet pilings



In the figure above the location is given were sheet piles were investigated. The numbers in the red balloons refer to the ones on the information shield on the island. The numbers in the blue squares refer to the wood samples taken and the black spots are small poles (numbered 1-25 in white) on the island and are used as orientation for the investigation locations.

The sheet piles were visually inspected and with the use of an awl. Also density profiles were made, for each sheet pile often on three locations: 1) upper part approximately 15 cm below pile and bored from landside towards waterside; 2) just below purlins approximately 30 cm below pile head and bored from waterside towards landside; 3) just above the water level and bored from waterside towards landside. The density profiles (2) taken just below the purlin were used to determine the thickness of the sheet pile. Often the angle in which the profiles 1 upper part and 2 just above the water level were made was not perpendicular to the sheet pile surface and these profiles were therefore longer than the thickness of the sheet pile. In the interpretation of the profiles towards decay this deviation was taken into account.

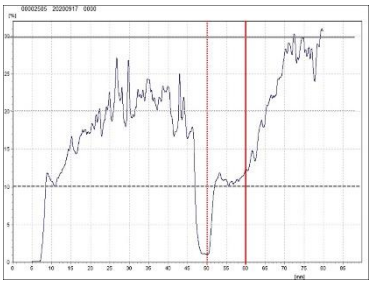
For timber species recognition the key anatomical features were summarized and given in appendix 4. This is done for the species: angelim vermelho, azobé, iroko, roupala (louro faia), gonçalo alves (muiracatiara), massaranduba, okan, araracanga (piquia marfim) and tali.

Description of the sheet piles per location, starting with 1A.

Sheet piles 1a, okan, start from the 25th sheet pile along the main river pathway (after the corner with the combination sheet piles, no. 3), thickness 40 mm, width 255 mm, 26th sheet width 155 mm, following sheets with variable width. Interlocked grain, fine wood structure, compared to all other sheet piles it is remarkable that there was almost no algae, mosses or plant growth; good condition (visually no decay and density profiles show weak decay only in outermost parts op top landside 15 mm, lower at waterside 10 mm). 27th sheet is sampled (M4) and density profiles were made.

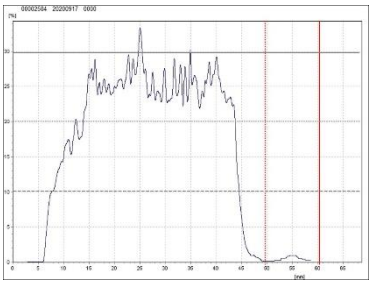
Remarkable little attached growth of algae and mosses

knot



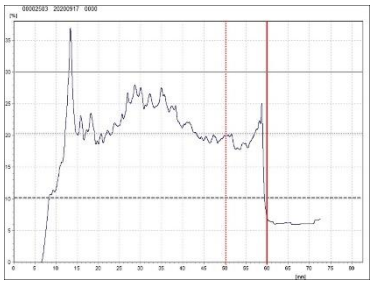
2505: no significant decay only weak decay landside 15 mm

AB upper part (land side, approximately 15 cm from head),



2504: thickness 40 mm; no significant decay only weak decay waterside 10 mm

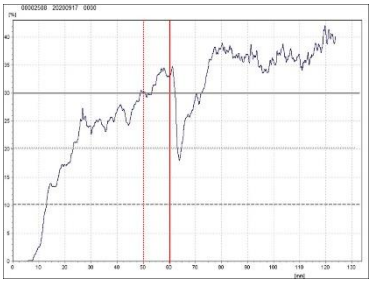
HV just below purlins (water side, 30 cm from head)



2503: no significant decay only weak decay waterside 10 mm

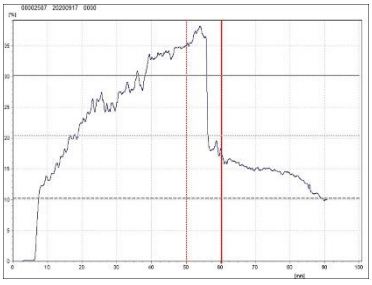
WL just above water level (water side)

Sheet piles 1b, azobé, starts after sheet piles 1a and have variable widths of 240, 310, 320 and 340 mm. They have interlocked grain, fine wood structure, condition good (no visible decay, density profiles show only weak decay top 10 mm at landside, middle 10 mm at waterside and water level 5 mm in middle). 27th sheet is sampled (M5) and density profiles were made.



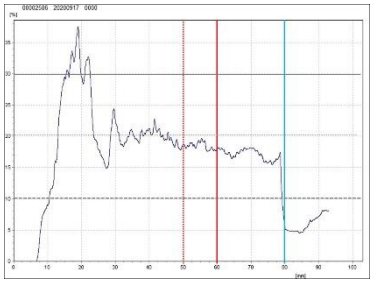
2508: no significant decay only weak decay landside 10 mm

AB upper part (land side, approximately 15 cm from head)



2507 thickness app. 50 mm, no significant decay, only weak decay waterside 10 mm

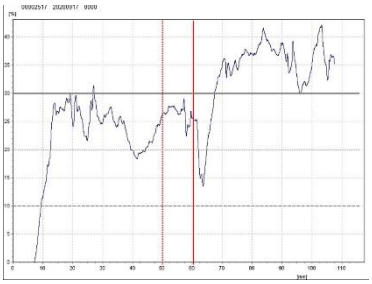
HV just below purlins (water side, 30 cm from head)



2506: no significant decay, only weak decay behind a thin hard layer in 5 mm

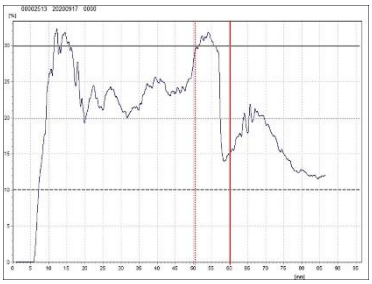
WL just above water level (water side)

Sheets piles, 1c, tali, the next few after 1b sheet piles located near pole 17. Thickness 50 mm. Condition relative good (visible/ awl at top pile landside 5 mm decay, density profiles show only weak decay in the middle parts, most prominent in the upper 250 mm); the same sheet pile is sampled (M6) as from which the density profiles were made.

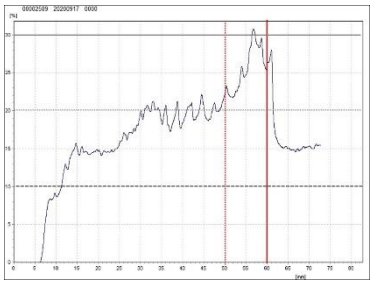


2517: no significant decay, only weak decay in middle 10 mm.

AB upper part (land side, approximately 15 cm from head)

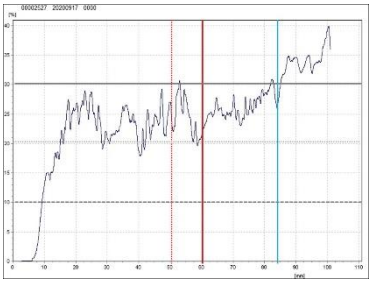


2513: thickness appr. 50 mm; no significant decay, only weak decay in middle 10 mm.
HV just below purlins (water side, 30 cm from head)



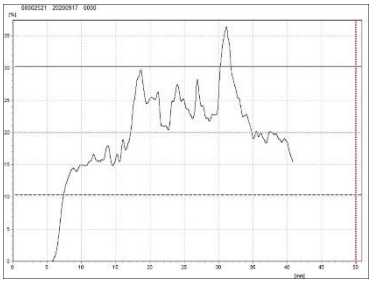
2509: no significant decay, only moderate decay waterside 5 mm and weak decay middle 20 mm
WL just above water level (water side)

Sheets piles 1d, tali, next after 1c sheet piles are located between pole 15 and 16. Thickness at least 40 mm. Condition relative good (visual no decay, density profiles moderate decay 10 mm deep waterside from 150 mm downwards, weak decay landside 5-15 mm top to water level, and middle top to 300 mm downwards 15 mm); the same sheet pile is sampled (M7) as from which the density profiles were made.



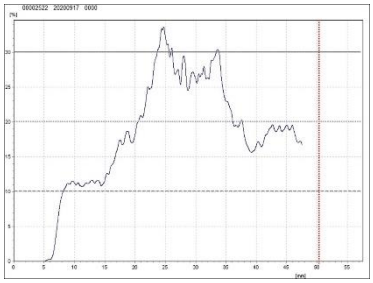
2527: no significant decay, only weak decay landside 5 mm and middle 15 mm

AB upper part (land side, approximately 15 cm from head)



2521 thickness more than 40 mm; moderate decay waterside 10 mm, weak decay landside 15 mm and middle 15 mm

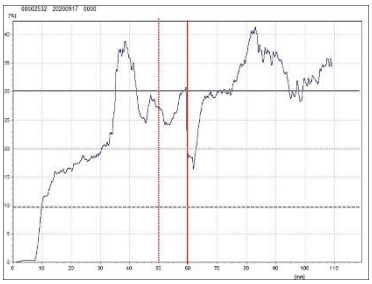
HV just below purlins (water side, 30 cm from head)



2522: moderate decay waterside 10 mm, weak decay landside 15 mm rest no significant decay

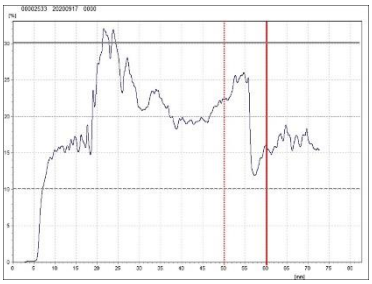
WL just above water level (water side)

Sheet piles 1e, okan, next few sheets piles after 1d sheet piles are located around pole 13. Thickness 50 mm. Condition relative good (visual, awl at top landside 1-2 mm decay, density profiles show weak decay in the middle and at the top landside 20 mm, and at the water level waterside 15 mm); the same sheet pile is sampled (M8) as from which the density profiles were made.



2532: weak decay landside 20 mm and middle 10 mm, rest no significant decay

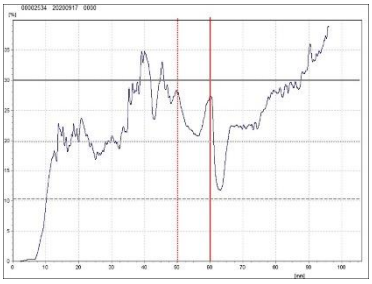
AB upper part (land side, approximately 15 cm from head)



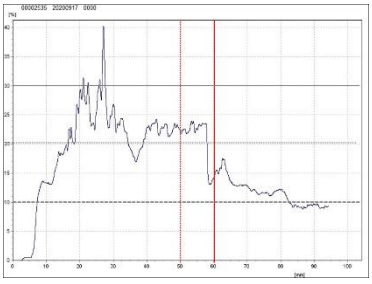
2533 thickness app. 50 mm; weak decay waterside 15 mm and middle 20 mm, rest no significant decay

HV just below purlins (water side, 30 cm from head)

Sheet piles 1f, tali, next few sheets piles after 1e sheet piles are located around pole 9. Thickness 50 mm. Condition is good (density profiles show weak decay at waterside over whole length in 5 mm, and at the top in the middle 5 mm).The same sheet pile is sampled (M9) as from which the density profiles were made.

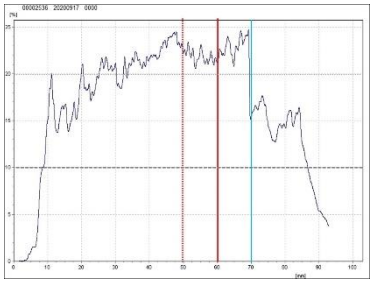


2534: no significant decay, only weak decay landside 5 mm, middle 5 mm (behind hard peal waterside)
AB upper part (land side, approximately 15 cm from head)



2535 thickness app. 50 mm, no significant decay, only weak decay waterside 5 mm

HV just below purlins (water side, 30 cm from head)



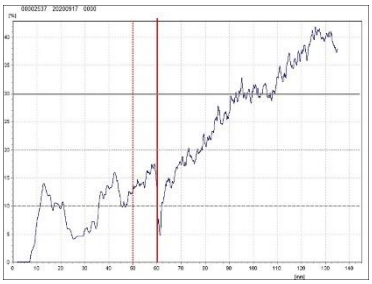
2536: no significant decay, only weak decay behind hard peal waterside 5 mm

WL just above water level (water side)

Sheet piles 1g azobé, next few sheets after 1f sheet piles are located around pole 7. Thickness 50 mm. condition questionable (visual / awl top landside white rot 30 mm deep, density profiles show moderate decay in the upper 300 mm at the landside 10-20 mm and in the middle part 15-25 mm, at the water level the decay is less weak); the same sheet piles is sampled (M10) as from which the density profiles were made.

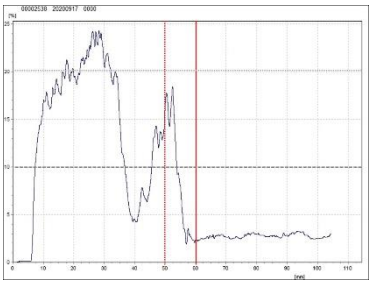
Skewed drilling

Front side sheet piles



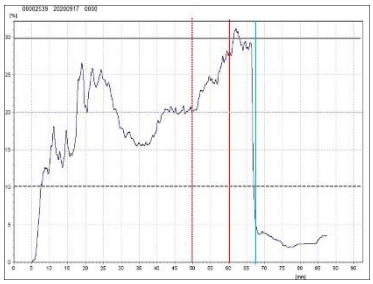
2537: moderate decay landside 10 mm, middle 25 mm, weak decay waterside 15 mm

upper part (land side, approximately 15 cm from head)



2538 thickness app. 50 mm, decay moderate landside 20 mm, moderate -severe middle 15 mm, rest (waterside) no significant decay 25 mm

just below purlins (water side, 30 cm from head)

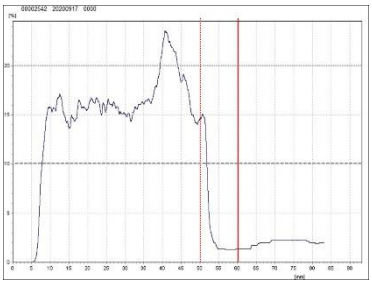


2539: weak decay waterside 10 mm, middle 35 mm, rest (landside 15 mm) no significant decay

just above water level (water side)

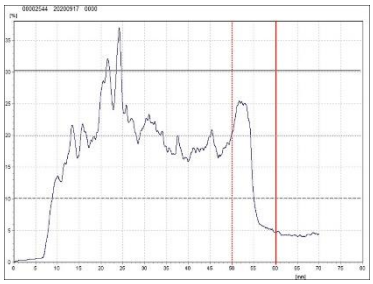
Sheet piles 1h, araracanga, next few sheets after 1g sheet piles are located around pole 5. Thickness 50 mm. Condition good (visual / awl top landside superficial decay, density profiles no significant decay, only weak decay at top both land-and waterside in 5 mm, and at the water level waterside 10 mm and middle 20 mm); the same sheet pile is sampled (M11) as from which the density profiles were made; this is the last pile of this species.

2540: no significant decay, besides weak decay landside behind hard peal 5 mm, waterside 5 mm.
upper part (land side, approximately 15 cm from head)



2542 thickness app. 50 mm, no significant decay

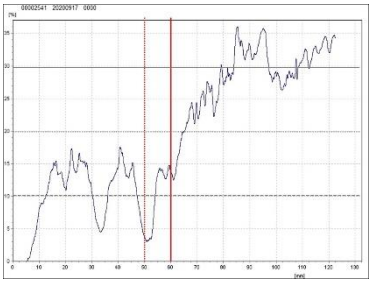
just below purlins (water side, 30 cm from head)



2544: weak decay waterside 10 mm, middle 20 mm, rest no significant decay

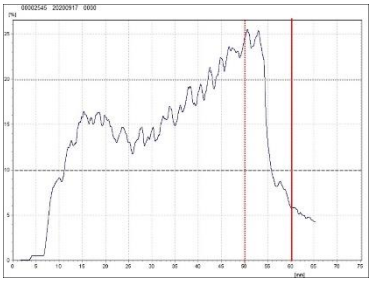
just above water level (water side)

Sheet piles 1i, roupala, next few roupala sheets after 1h sheet piles are located around pole 5. Thickness 50 mm. Condition bad (visual / awl top landside deeply degraded, density profiles show moderate to severe decay in large parts of the pile); the same sheet pile is sampled (M12) as from which the density profiles were made, is the first pile of this species.



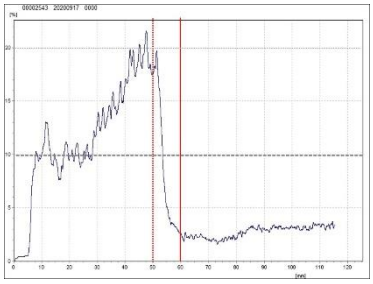
2541: decay moderate to severe over whole thickness.

upper part (land side, approximately 15 cm from head)



2543 thickness app. 50 mm, decay moderate landside 20 mm, middle 20 mm, rest weak of no significant decay

just below purlins (water side, 30 cm from head)



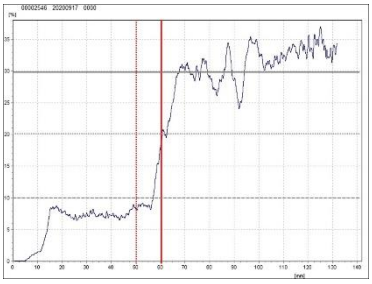
2545: moderate to severe decay waterside, moderate decay middle 20 mm, weak decay landside

just above water level (water side)

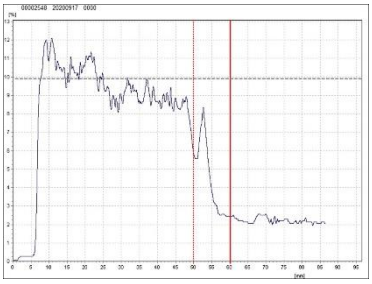
Sheet piles 1j, okan, next few sheets after 1i sheet piles are located near pole 1. Thickness 50 mm. Condition bad (visual / awl top landside 50 mm decay, waterside no significant decay, density profiles show moderate decay in large parts of the pile); the same sheet pile is sampled (M13) as from which the density profiles were made.

The sheet pile left of that last one is another species and its condition better (density profiles show moderate decay throughout the whole thickness in the middle part, top only weak decay landside 10 mm and at water level moderate decay landside 10 mm and weak decay waterside 15 mm).

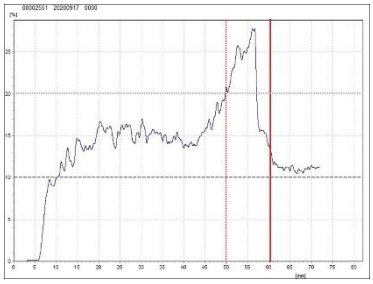
Sheet pile of okan



2546: decay moderate to severe over whole thickness.

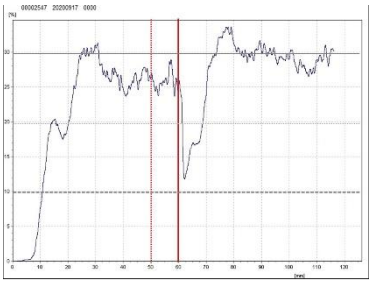


2548: decay moderate to severe over whole thickness



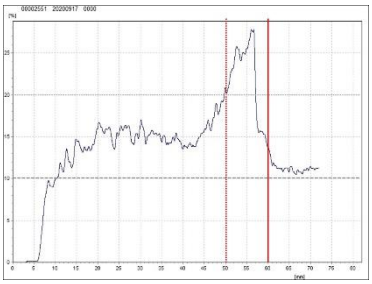
2551 thickness app. 50 mm, decay moderate 45 mm, only weak -no decay landside 5 mm

Sheet piles near the corner of the island



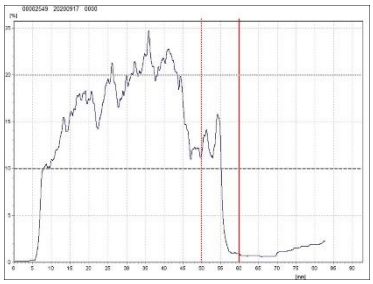
2547: no significant decay, only weak decay landside 10 mm

upper part (land side, approximately 15 cm from head)



2552: moderate decay, weak or no decay landside 5 mm

just below purlins (water side, 30 cm from head)

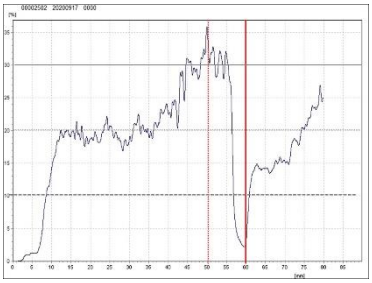


2549: moderate decay landside 10 mm, weak decay waterside 15 mm, rest no significant decay

just above water level (water side)

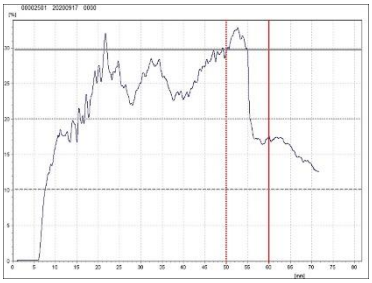
Sheet piles 2, angelim vermelho, the first 24 sheets piles along the main river pathway after the corner with the combination sheet piles 3. It is assumed that the lower parts of the sheet piles is Austrian larch, thickness 45 mm, width approximately 180 mm, rabbet 20 x 20 mm. The condition of the piles is good (no visible or with density profiles detectable decay), third sheet is sampled (M3) and density profiles were made.

Transition of the angelim vermelho -larch sheet piling to sheet pile 1a okan



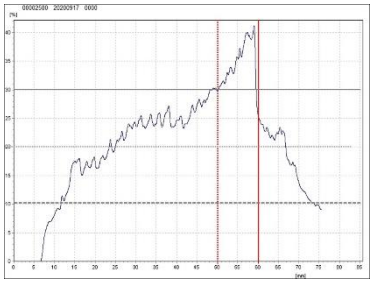
2502: no significant decay both water and landside

AB upper part (land side, approximately 15 cm from head)



2501: thickness is app 45 mm, no significant decay both water and landside

HV just below purlins (water side, 30 cm from head)



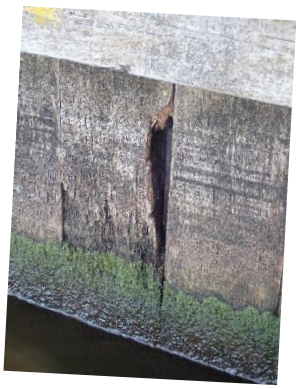
2500: no significant decay only 5 mm weak decay waterside

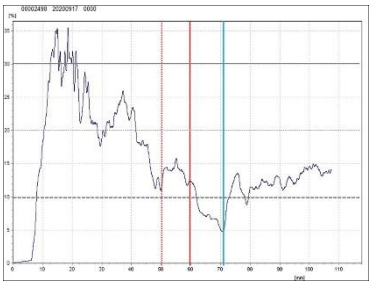
WL just above water level (water side)

Sheet pile 3, combination sheet pile (Van Swaay), situated over the full short end of the island. The upper part is angelim vermelho, thickness 45 mm, width approximately 180 mm, rabbet depth 20 mm, 22 mm wide and the lower part is probably a softwood. Most upper parts are sound, no decay, a few upper parts show some bugling and occasionally some plant growth through the nails.. The condition of the eighth sheet from the corner with the frontside of the island, was questionable (visually degraded, density profiles show weak to moderate decay on waterside at middle) (M1, lost its smell), adjacent sheet was good (visually no decay, density profiles show weak decay in top 15 mm on landside, 10 mm middle), (M2). Both samples confirm the wood species.

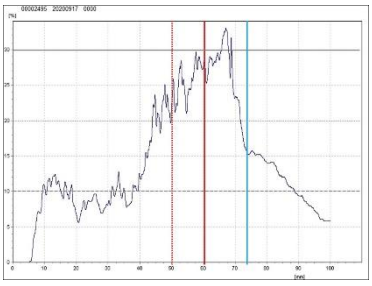




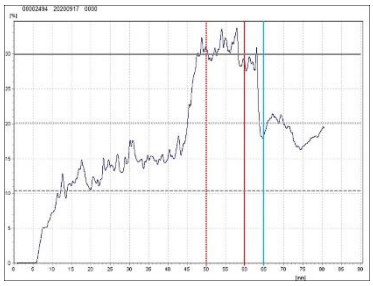



2498: landside no significant decay, weak decay middle 25 mm, moderate decay waterside 10 mm

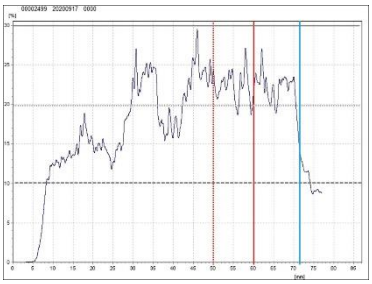


2495: no reliable thickness estimation here because of skewed measurement; landside no significant decay, weak decay middle 10 mm, moderate decay waterside 25 mm



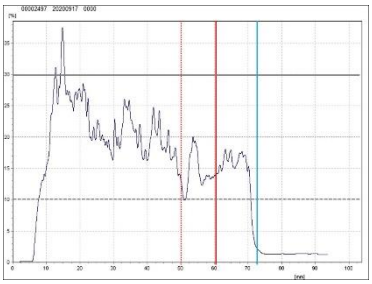
2494: landside no significant decay, weak decay in middle and waterside 35 mm

Degraded sheet (M1)



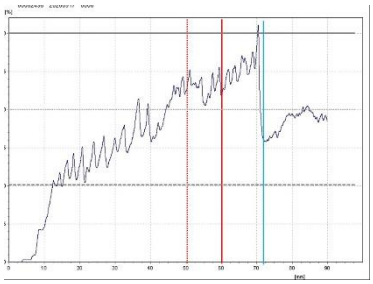
2499: landside weak decay in 15 mm, 10 mm in middle, rest no significant decay

upper part (land side, approximately 15 cm from head),



2497: no reliable thickness estimation here because of skewed measurement; weak decay in middle 10 mm, rest no significant decay

just below purlins (water side, 30 cm from head)



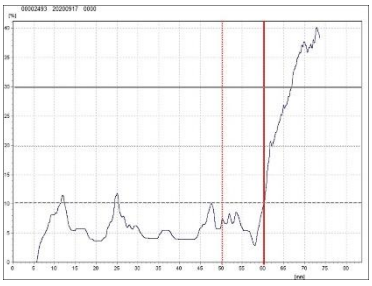
2496: no significant decay for both water and landside

just above water level (water side)

Sheet pile with no visual degradation (M2)

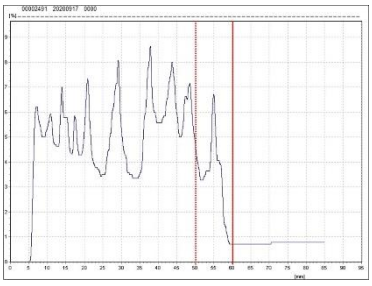
Sheet pile 4a, a combination sheet pile with Accoya

Approximately 39 combination sheet piles with Accoya, thickness 53 mm, width 132 mm, moisture content (at density 0,65 g/cm³) both land and water side 20-35%, no detectible decay, finger joints to the supposed lower spruce part were not detected (between cross surface Accoya and decking at least 5 mm space, some plant grow between the beams.



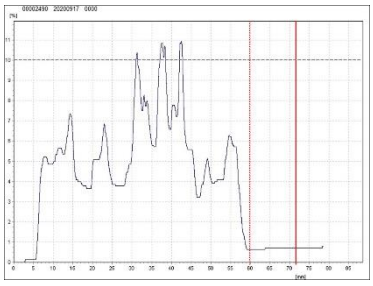
2493: no significant decay both water and landside

upper part (land side, approximately 15 cm from head),



2491: no reliable thickness estimation here because of skewed measurement; no significant decay both water and landside

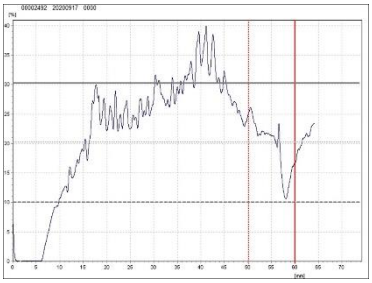
just below purlins (water side, 30 cm from head)



2490: no significant decay both water and landside

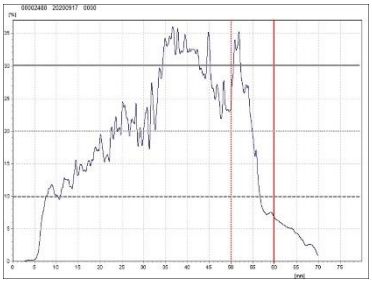
just above water level (water side)

Sheet pile 4b, three combination sheet piles softwood with an upper part of angelim vermelho (specific smell), thickness 53 mm, width 178 mm, rabbet depth 24 mm, moisture content (at density 0,90 g/cm³) landside 14%, waterside high 20-21%, in good condition (only some weak decay in 10 mm landside top; 15 mm waterside and 5 mm middle; 20 mm waterside and 2 mm middle on water level). Finger joints to the supposed lower spruce part were not detected visually or as an uneven connection.



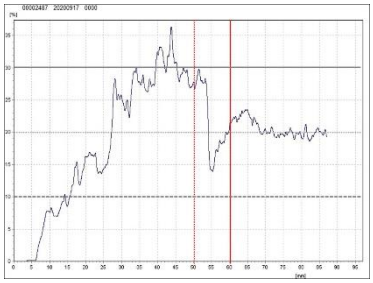
2492: landside weak decay in 10 mm, rest no significant decay

upper part (land side, approximately 15 cm from head)



2488: waterside weak decay in 15 mm, 5 mm in middle, rest no significant decay

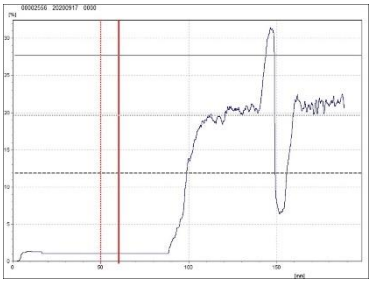
just below purlins (water side, 30 cm from head)



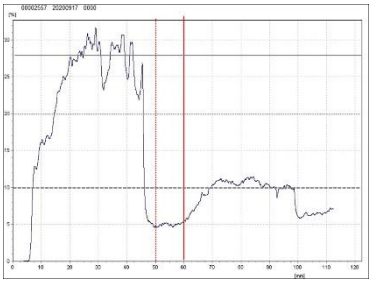
2487: waterside weak decay in 20 mm, 2 mm in middle, rest no significant decay

just above water level (water side)

Sheet piles 9, reused azobé sheet piles. Thickness 50 mm. Condition good (visual / awl top landside superficial decay, density profiles no significant decay, only weak decay at top both land-and waterside in 5 mm, and on the water level waterside 10 mm and middle 20 mm); the same sheet pile is sampled (M16) as from which the density profiles were made, is the last pile of this species. Cover plank severely degraded with many ants.

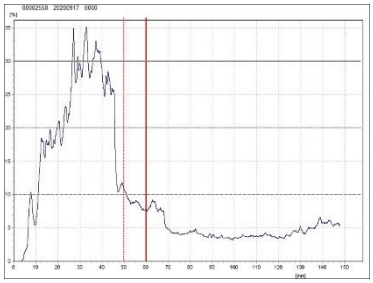


2556: no significant decay, besides weak decay landside behind hard peal 5 mm, waterside 5 mm.
upper part (land side, approximately 15 cm from head),



2557 thickness app. 50 mm, no significant decay

just below purlins (water side, 30 cm from head)



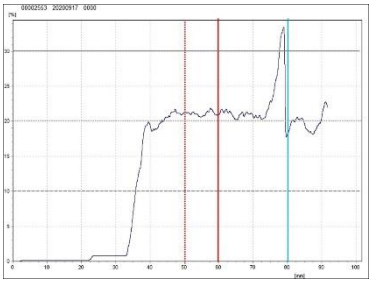
2558: weak decay waterside 10 mm, middle 20 mm, rest no significant decay

just above water level (water side)

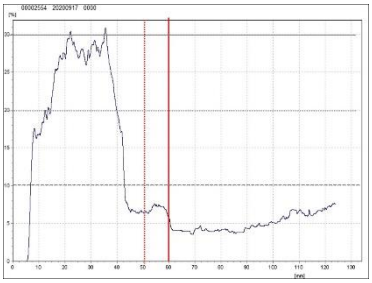
Location 10, robinia bulkhead and kopie (cupiuba) poles. Condition poles good (visual / awl above water part is hard), bulkhead bad (severe decay), wood sample M15. Extensive plant growth was seen.

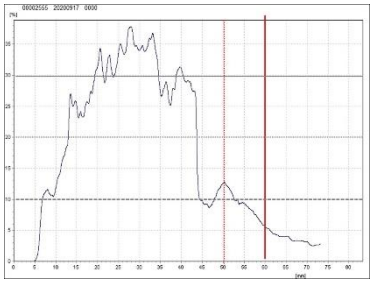



Sheet piles 11, azobé, sheets are a supposed continuation of the reused azobé under 9 until the corner of the island. Thickness 40 mm. Some plants grow through the seams, wall is coherent. Condition questionable (visual / awl waterside hard, landside not reachable, density profiles show moderate decay in upper part and in lower parts weak decay land- and waterside 5-10 mm; the same sheet pile is sampled (M14) as from which the density profiles were made, is the last pile of this species.



2553: weak decay over the full thickness, hard peal waterside.

AB upper part (land side, approximately 15 cm from head)


2554 thickness app. 40 mm, no significant decay, only weak decay land- and waterside 5 mm, HV just below purlins (water side, 30 cm from head)

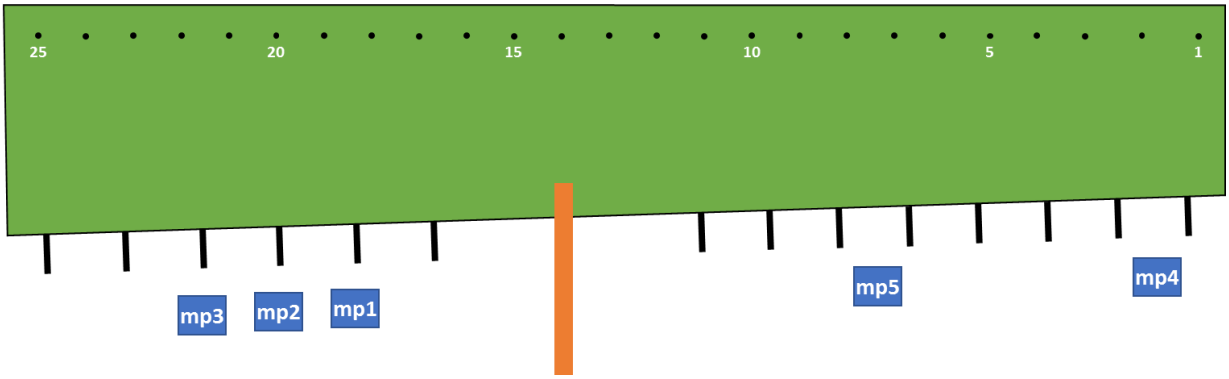

2555: no significant decay, only weak decay land- and waterside 10 mm
WL just above water level (water side)

Remaining not inspected part of the sheet piling are:

5 plastic
6 steel
7 concrete
8 stone deposits
9b as 11
11 combination sheet pile recycled PVC and spruce
12 flat vinyl, reinforced with spruce poles, PE-steel purlins

Appendix 2

Specific results on the free water poles. In the drawing below the free water poles are located at both sides of the entrance landing stage. The blue boxes refer to the samples taken from the poles.

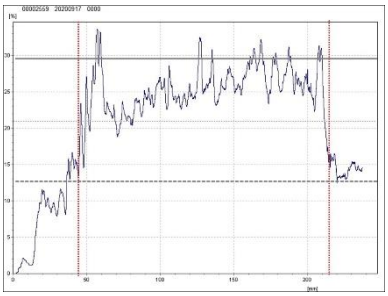


Third pole west from the entrance landing stage, larch
Round softwood pole, above the water line, one large crack and some small cracks, no significant fungal decay. On the water air line 10-20 mm decay, below the water surface sound. Wood sample (MP1) was taken.

Third pole

Fifth pole west from the entrance landing stage, cloeziana
Round hardwood pole, no significant decay on and above the water line. Diameter poles approximately 22 cm. The density profile taken approximately 20 cm above the water line, shows a degraded outer most sheet of 20-30 mm. Wood sample (MP2) was taken.

Fifth pole (MP2)



11th and 10th pole left from the entrance landing stage

Adjacent poles (7th, 8th, 9th, 10th, 11th and 12th from the entrance landing stage), cloesiana.
Similar in species and decay as the fifth pole. From pole 7th a wood sample (MP3) was taken

Two poles at eastern corner are sawn azobé poles, without significant decay.

Third pole from corner east, manbarklak
Round hardwood poles, diameter 24 cm in the part above the water level with many cracks perpendicular to the fibre angle, many small holes (< 1 mm in diameter longitudinal or cross cut) of pinhole borers, further no significant decay, wood sample (MP4).



Left picture: poles at the right of but close to the entrance landing stage, middle and right pictures: 3rd pole from which sample MP4 was taken

Fourth pole from the corner, similar to the third one.

Adjacent 5th pole, cloeziana.
No remarks.

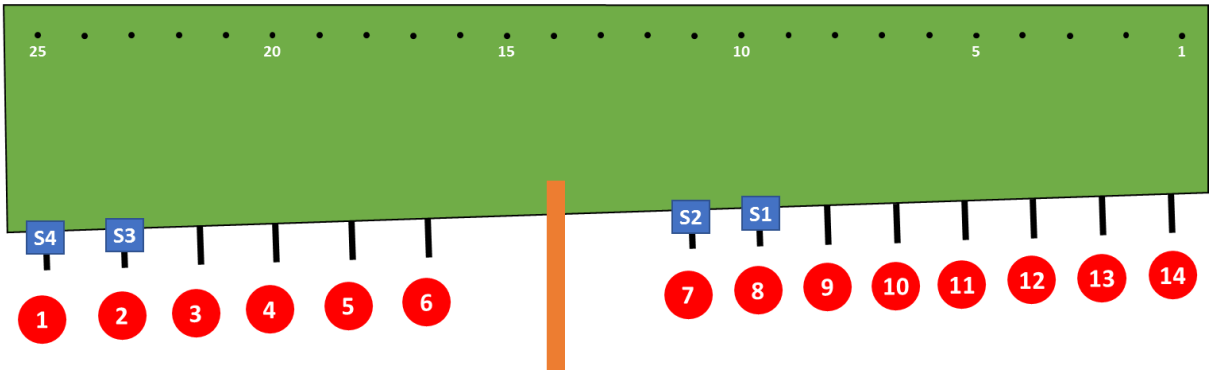
Pole 6th, 7th, 8th, 9th, 10th and 11th poles from the corner, cloeziana.
No remarks, from the 6th pole a slice of wood was removed above the water level. From the 11th pole above the water level wood sample MP5 was taken.



Left picture: 6th pole from the corner

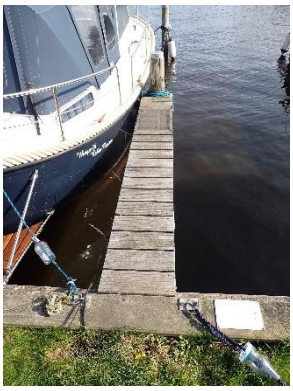
Appendix 3

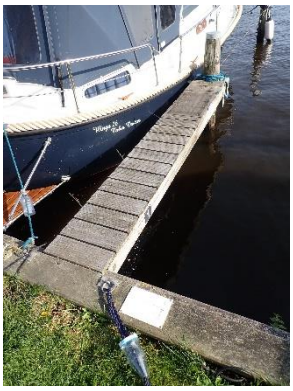
Specific results on the landing stages. In the drawing below in the rood balloons the number of the landing stages is given, the blue boxes give the location were samples were taken.



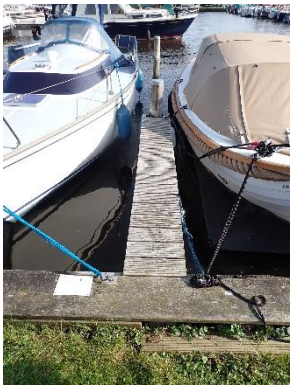
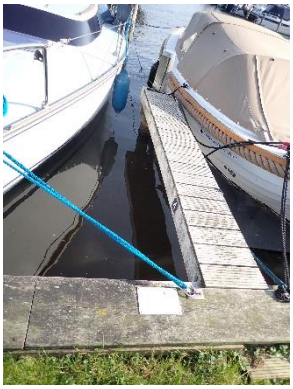
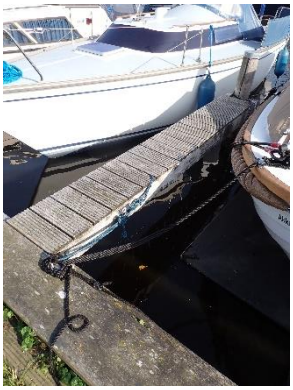
Timber species according to the large information sign:

Landing stage 1 padoek in both gang boards and horizontal construction.
Condition good, sample taken from gangboard (S4), species confirmed





Landing stage 2 *Terminalia* species in both gang boards and horizontal construction, pole probably larch.
Condition good, sample taken from gangboard (S3).

Landing stage 5 larch in all, gang boards, horizontal construction beams and pole. The gangboards are positioned with the heart side above, always. The gang boards and the horizontal construction beams are approaching their end of life stage, because of decay. In the gang boards the decay is mainly around the screws (especially at the 1st, 7th, 14th, 15th, 16th, 17th and 18th gang board). Because of the degradation, the screw connection is less tight and all boards can move somewhat compared to the horizontal beams. Also decay is found in the horizontal beams, where it is local and extending from the horizontal surface downwards. The condition of the pole is good above and below the water line, on the water line a 5 mm thick layer of weak decay is present only.


Board 1-4

Board 5-7

Board 8-10

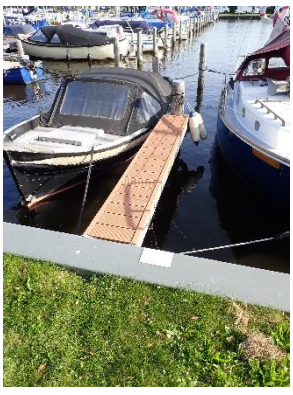
Board 11-13

Board 14-16

Board 17-19

Landing stage 6 with bamboo composite gang boards

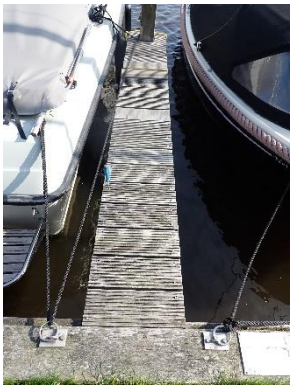
According to the harbour manager the original boards were replaced after six years. As the new gang boards are not made of wood, they were not inspected.



Landing stage 7 gangs boards are bamboo and two larch round poles.
The condition of the gang boards, horizontal beams and the poles are good. Sample is taken from the gang boards (S2).

Sign with landing stage seven turns out to be incorrect. The gang boards are made of bamboo and not of tanimbuca (= gindya udu), and the horizontal construction of angelim vermelho.

Landing stage 8 gangs boards are treated radiata pine. It is unclear if the horizontal construction beams are also treated radiata pine but the pole is larch.
The condition of the gang boards is not good, half of them are severely degraded from the cross surface onwards or already replaced, and in the other half there is some decay around the screws.
Wood sample (S1) was taken from one of the gang boards.
The condition of the pole and the horizontal beams are good.



Landing stage 13 gangs boards of several species (manbarklak, angelim pedra, aldina, faveira amargosa), horizontal construction beams based on the goms flecks identified as angelim pedra, and the acariquara pole with the original tree trunk shape (non-machinable, e.g. non sawn).
The condition of gang boards, horizontal construction beams and pole is good.

Landing stage 14 gang boards, horizontal construction beams and a sawn pole are all azobé. The condition of the gang boards, horizontal construction beams and pole is good.

Appendix 4

Identification of the samples and references descriptions.
M1-M16 are samples taken from sheet piles, MP1-MP4 are samples taken from the free water poles and S1 to S3 are samples taken from the gang boards.

M1: angelim vermelho
Macroscopic observations
M2: angelim vermelho
Macroscopical observations
M3: angelim vermelho
Smell, vessels few, large, some smaller, solitaire or rows to 5, pits 6 µm, parenchyma paratracheal, aliform, confluent, strands 4-6 cells, rays 2(-3) seriate, homogeneous
M4 okan
no smell, vessels few, large, some smaller, solitaire, pits 5 µm, vessel-ray pits similar, parenchyma thin sheets paratracheal, weak aliform, strands 3-4 cells, crystals in chambered cells, rays 3-4 seriate, homogeneous
M5 azobé
no smell, vessels 3/mm², 100 µm diameter, smaller, solitaire, parenchyma in 4-5 cell wide continuous bands in a regular pattern, strands > 8 cells, rays 2(-3) seriate, homogeneous
M6 tali
no smell, vessels 150-200 µm, 5/mm², solitaire or rows to 5, pits 4 µm, parenchyma paratracheal, aliform, confluent, strands 4 cells, rays 2-3 seriate, homogeneous or weak marginal one row.
M7 tali
no smell, vessels 150 µm, 10/mm², solitaire or rows to 5, pits 6 µm, parenchyma paratracheal, aliform, confluent, strands >5 cells, rays 2-3 seriate, homogeneous, weakly storied. Tali because of tendency for storing although wider rays
M8 okan
no smell, vessels 100 µm, 10/mm², solitaire or rows to 5, pits 4 µm, parenchyma paratracheal, aliform, confluent, bands, marginal, strands (4-)6 cells, rays (2-)3-4 seriate, homogeneous.
M9 tali
no smell, vessels 100-150 µm, 6/mm², solitaire or rows to 3, pits 6 µm, parenchyma paratracheal, aliform, confluent, strands 3-4 cells, crystals in chambered cells, rays (2-) 3-4 (-5) seriate, homogeneous, weakly storied. Tali because of tendency for storing although wider rays
M10 azobé
no smell, vessels 200-250 µm, 4/mm², solitaire or rows 2(-4), (vessel-ray) pits and 4 µm, parenchyma in bands, aliform, confluent, strands >8 cells, rays 2(1-3) seriate, homogeneous, 300 (-900)µm high.
M11 araracanga
no smell, vessels 100 µm, 13/mm², solitaire, pits 4 µm, parenchyma scare paratracheal, diffuse, strands 2,3-8 cells, rays 1-2(-3) seriate, homogeneous sometimes weak marginal one row.
M12 roupala
Macroscopical observations
M13 okan
no smell, vessels 150-200 µm, 5/mm², solitaire, pits 8-9 µm, parenchyma paratracheal to lozenge aliform, strands 2-4 cells, crystals in chambered cells, rays 2-3(-4) seriate, homogeneous, 300 µm high, occasionally with idioblasts sheetcells, one axial resincanal

M14 azobé

no smell, vessels 200 µm, 3/mm², solitaire or rows 2(-4), pits 4 µm, parenchyma in 3-5 cell wide bands, strands >8 cells, crystals in chambered cells, rays 2 seriate, homogeneous.

M15 robinia

Macroscopical observations

M16 azobé

no smell, vessels 160 µm, 5/mm², solitaire or rows 2(-4), pits 4 µm, parenchyma in 3-5 cell wide bands, strands (4-) 8 (-10) cells, rays (1-) 2 (-3) seriate, homogeneous.

MP1 Larch

Softwood wood structure, sharp demarcation between early- and late wood, axial and radial canals, double rows of tracheid pits.

MP2 cloesiana

No smell, vessels in two sizes appr. 50 and 150 µm, 15/mm², diagonal orientation, solitaire, pits 8 µm, parenchyma scares paratracheal, vessel-tracheids, strands 4 cells, fibres with clear pits, rays 1 (-2) seriate, homogeneous.

MP4 manbarklak

no smell, vessels 150(-200) µm, 7/mm², in radial rows of 2-7, (vessel-ray)pits 6 µm, parenchyma regular 1-2 cell wide thin bands, strands (5-)7 cells, rays uniseriate, mixture of square and rectangular cells, height 500-1000 µm, silica abundant in ray cells

S1 Treated radiata pine

Softwood structure, *Pinus radiata*, with included substances resin alike. Based on these observations, and the available information of the project it is likely that this was modified timber.

S2 bamboo

Compressed vessel bundles and ground tissue.

S3 a *Terminalia* species alike.

no smell, vessels 90-140 µm, 15/mm², solitaire and in radial rows of 2-10, (vessel-ray)pits 7-9 µm, parenchyma scare paratracheal or incomplete aliform winglike, diffuse, strands (2-)4 cells, rays uniseriate, homogeneous, height 300 µm, crystals in enlarged cells.

Angelim Vermelho *Dinizia excelsa*
Vessel 150 µm, 5/mm², solitaire or radial rows of 2-3, pits 5 µm, parenchyma lozenge aliform sometime confluent, strands 2-4 cells, rays 2-3 seriate homogeneous, sometimes weakly with one row of square marginal cells.

Iroko *Millicia excelsa*
Vessel 200 µm, 5/mm², solitaire or radial rows of 2-3, pits 10 µm, parenchyma lozenge aliform confluent, strands 2-4 cells, rays 3-5 seriate heterogenous with one row of square marginal cells

gonçalo alves *Astronium spp*.
Vessel 50-100 µm, 10-20/mm², solitaire or in radial rows of 2-3, thylosis common, pits 7-10 µm, vessel-ray pits similar coalescent, vestured, parenchyma absent, scares paratracheal, (strands 2(-4) cells), crystals, rays 1-2 seriate heterogenous mixture of cells, radial canals.

Okan *Cylicodiscus gabunensis*
Vessel 150-200 µm, 5/mm², solitaire or radial rows of (2-)3-4(-5), pits 4-10 µm, vestured; parenchyma vasicentric, lozenge aliform, crystals in chambered cells, strands 2-4 cells, rays (1-)2-4 seriate homogeneous.

Tali *Erythrophleum ivorense*
Vessel 150 µm, 5/mm², solitaire or radial rows of 2-3, pits 7-10 µm, vestured; parenchyma vasicentric, lozenge aliform sometime confluent, occacionally unilateral, strands 4 cells, crystals in chambered cells, rays (1-) 2 (-3) seriate homogeneous, sometimes unregular storied
Compared to okan tali has more parenchyma, sometime unilateral parenchyma and sometimes storied tissue.

Gindya udu *Buchenavia tetraphylla*
Vessel 150-200 µm, 5-10/mm², solitaire or radial rows of 2-3, pits 4-10 µm, parenchyma, lozenge aliform, confluent, crystals in chambered cells, strands 4-8 cells, rays 1- seriate homogeneous, or weak one marginal row

angelim pedra *Hymenolobium* spp.
Vessel 150-200 µm, 5/mm², solitaire or radial rows of 2-3, pits 7-10 µm, parenchyma vasicentric, lozenge aliform, confluent banded, crystals in chambered cells, strands 3-4 cells, rays 1-3 seriate homogeneous or one marginal row, storied, gom flecks

faveira amargosa *Vatairea spp / Vataireopsis spp.*
Vessel 150-200 µm, 5/mm², solitaire or radial rows of 2-3, pits 7-10 µm, parenchyma vasicentric, lozenge aliform, confluent, crystals in chambered cells, strands 4 cells, rays 1-3 seriate homogeneous or with one marginal row

Azobé *Lophira alata*
Vessel 150 µm, 5/mm², solitaire or radial rows of 2-3, pits <4 (-7) µm, parenchyma 2-4(-4) cell wide continuous regular bands, strands > 8 cells, crystals in chambered cells, rays 1-3 seriate homogeneous.

Roupala
chain vessel combination and wide rays

Massaranduba *Manilkara bidentata*
Vessel 50-150 µm, 10-20/mm², solitaire or in radial rows of 2-3, in a radial pattern, pits 4-10 µm, parenchyma small continuous bands, reticulate, strands 4-8 cells, crystals, rays 1-3 seriate heterogenous multiseritate part as wide as uniseriated part.

Araracanga *Aspidosperma polyneuron*
Vessel 50-150 µm, >20/mm², exclusively solitaire, thylosis common, pits 4(-7) µm, vestured, parenchyma diffuse, strands (4-)8 (-10) cells, rays 2 seriate homogenous or sometimes weakly one rows of marginal cells.

Kopie *Goupia glabra*
Vessel 100-200 µm, 5-20/mm², solitaire, simple and scalariform perforations, pits 4-7 µm, parenchyma diffuse diffuse in aggregates, strands 7-8 cells, rays 1-3 seriate heterogeneous, multiseriated portion as wide as uniseriated

Manbarklak *Eschweilera pedicellate*
Vessel 100-200 µm, 10/mm², solitaire or radial rows of 2-3, pits 7-10 µm, parenchyma thin bands, reticulate aliform, strands (5-) 8 cells, rays 1-3 seriate homogeneous, some weak one marginal rows, silica bodies

Aldina *Aldina heterophylla*
Vessel 150-200 µm, 5/mm², solitaire or radial rows of 2-3, pits 4-10 µm, parenchyma vasicentric, lozenge aliform, confluent, crystals in chambered cells, strands 2-4 cells, rays 1-3 seriate homogeneous, storied