Accoya wood
in Dutch waterworks constructions

Tim Bartels

Technical and commercial feasibility study for

Accoya® wood in Dutch civil waterworks constructions

Thesis assignment of **Van Hall Larenstein University of Applied Sciences**

Author: Tim Bartels
Student International Timber Trade

Commissioned by: Accsys Technologies plc.

Internal supervisors: Sander van Riel
Product Development Engineer

External supervisor: Ad Olsthoorn
University of Applied Sciences
Van Hall Larenstein

Publication: Arnhem, august, 2011

ACCSYS TECHNOLOGIES

University of Applied Sciences
VAN HALL LARENSTEIN
PART OF WAGENINGEN UR

The cover of this report is made of raw Accoya® boards on the outside with a sanded surface on the inside. This report is bound by applying a Japanese binding method, the boards are screwed with four stainless steel screws to create the book. The report is a miniature of affixed Accoya wood in civil waterworks. The title page shows several typical waterworks constructions as on the left, the bridge in Sneek, made of laminated and finger jointed Accoya wood, two typical civil waterway shore protection constructions. On the right the „Moses" bridge which is also made of Accoya wood, and on the left in the down corner a degraded wooden pole in water contact.

This report is printed on recycled paper carrying a FSC certificate.

Abstract

Accsys Technologies PLC, is the official holder of the producing technology and registered brand: Accoya® wood,. They wanted to know if Accoya wood is technical and financial an alternative for materials used in civil waterworks constructions; such as lock gates, piers, jetty‟s and timber piling.

The market for Civil waterworks applications is a stable market. Constructions for these waterworks applications made of timber have the highest demands according the norm EN 335-1 with mostly use classes 3 to 5. The most used timber species have durability classes 1 or 2 of EN 350 and come mainly from tropical forests, the European union has developed legislation to prevent the decline of tropical forests. Besides this other European and national legislation is developed in the field of toxicity and safety, this changes the usage of materials.

Accoya® wood is a modified piece of non-tropical timber, this modifying takes place by a acetylation process whereby a non-durable piece of wood is modified into a durable piece of wood with enhanced properties like durability class 1, and dimensional stability, which has been proven by several tests, to qualify Accoya‟s qualities. This has already resulted in a guarantee by Accsys Technologies on a long life time for Accoya wood of 25 years in use class 4(fresh water or ground contact) of EN 335-1 and 50 years for use class 1to 3 (not in water or ground contact) of EN 335-1.

To find the demands for Dutch civil waterworks constructions literature was studied and an Internet Survey was created and sent to customers of civil waterworks constructions such as most Dutch water boards, *Rijkswaterstaat* and the province of North Holland. This created a broader vision of what is used and what appeals to them, while gaining a understanding on what they demand. Where after, interviews were held with parties involved with advising and certifying; several customers: and a constructor, to get a better idea on their vision. To start the discussion in this thesis a SWOT analyses was made with the main findings on Accoya. The needed properties were studied and compared to the most used timber species in civil waterworks constructions.

The conclusion of this study is that Accoya is a feasible alternative in civil waterworks applications when a long life time of the construction is wanted with shown durable materials and no CE Mark or KOMO certificate according BRL 2905-3 is required or willingness to do tests to qualify Accoya strength grade. Accoya, as a softwood, can serve better than preservative treated because the modification method, to gain the highest durability, is throughout the timber and non-toxic. Accoya is financially interesting to be used in civil waterworks when costs on maintenance and a guaranty on the lifetime are found more important. than the purchase costs.

The main importance for Accoya wood, to become a used alternative, is to get Accoya wood CE graded and to create more awareness on the properties of Accoya wood under clients and designers of civil waterworks and show the benefits with results of tests and on-going projects.

Preface

This is my final thesis report on the Technical- and financial feasibility of Accoya® wood in Civil waterworks applications. The thesis is written on behalf and in cooperation with Accsys Technologies for my study International Timber trade at Van Hall Larenstein. This subject got my special interests because of the innovation part of Accoya® wood, taking a not durable wood species and modifying this into a durable piece of wood. After doing a traineeship at a hardwood trading company and a softwood trading company I wanted to know more about modifying wood. Accoya wood is a piece of modified wood of which the producer wanted to know if Accoya wood is a feasible alternative as materials used in civil waterworks applications. After a solicitation interview the topic of a technical and financial feasibility study came to existence. This final thesis was not an easy subject because of the wide range of applications and materials used and regulations and working methods in the GWW sector. It was interesting because I learned a lot about Accoya® wood and civil waterworks applications with their demands in different circumstances, for example in fresh and salt water. I got to know more about the clients of the civil waterworks applications and their vision and procedures to realise these civil waterworks applications and how this has, and probably, will change through the years.

The work to bring this thesis to its final being would not have been possible without the help of Accsys Technologies colleagues in Arnhem and with help, time and patience of my dear friends and family. With special thanks to my supervisor S. van Riel and advice by F. Bongers at Accsys Technologies in Arnhem and A. Olsthoorn at Van Hall Larenstein.

Tim Bartels,

Arnhem, August 2011.

Contents

List of Figures

List of Tables

Text Box

1. Introduction

Wood is used in the Netherlands for all kinds of applications, including civil waterworks construction. This largely has to do with both the location of the Netherlands and its culture. Around 4500 BC, the Netherlands was covered with forests, both softwoods and hardwoods. The Dutch used wood for all kinds of works and activities until there was hardly any forest left. Eventually by around 1800 a mere 2% of the national‟s landscape was covered with forest (Buis, 1985). Trade activities with the Far East and Africa during the Dutch *Golden Era* led to the discovery of new tropical timber species, whose properties exceeded the performance of local Dutch wood species

Civil waterworks constructions occur in salt-, brackish- and freshwater environments. Typical waterworks applications as part of hydraulic engineering include: bridges and (bridge) decks, lock gates, jetties, piers, sheet piling and poles for bank and coast protection These applications are often demanding for timber in service as water, in combination with oxygen and "warm" climate (5+ degrees Celsius) causes micro-organisms to attack the wood. As a result, the Dutch are constantly searching for materials that can resist such environmental conditions. Materials like concrete and steel are used more frequently in large waterworks applications. However, wood products with good resistance to biological attack, often sourced from tropical rainforest, are also often used for these demanding applications.

Although some tropical wood species have proven over the centuries to perform well in waterworks applications, it appears that the recent increase in (public) environmental awareness is threatening their position in the market. In the beginning, Non-Governmental Organizations (NGO‟s) like the *World Wildlife Fund* (WWF) and *Greenpeace* opposed the use of tropical hardwoods in order to conserve the rainforests. Later the *European Union* (EU) drafted legislation which is meant to restrict the use of tropical hardwoods by enforcing laws and regulations which will come into effect in 2013. These regulations have already led to the decline in imports of tropical hardwood logs and have also triggered consumers to look for alternative materials, also in the civil waterworks (constructions) market (Probos, 2010).

Alternatives for Woody Materials

Popular materials used for civil waterworks applications are metal, concrete and wood. Due to the size and dimensions of steel and concrete, they are often used when large length and big sized structures are required. Often the structure still partly consists of wood. Where an alternative to tropical hardwoods is wanted, twin wood applications consisting of hardwood above the waterline and softwoods under the waterline are seen as a more environmental alternative, as well as thermal modified woods. Thermal modified wood is treated by high temperatures, giving it a higher durability class than the original timber species. New alternatives like recycled plastics and PVC materials, as well as WPC (Wood Plastic Composites), are being used for civil waterworks constructions, with mixed findings for the users. Such as toxic leaching effect with recycled plastics and composite materials, although this was much less than with CCA treated wood (Weis *et al.*, 1992). Another problem is the brittleness of plastics and risk of cracking in water during frost periods.

Accoya® Wood as an alternative

Accoya wood is created via a non-toxic wood modification process called *wood acetylation*. Currently, Radiata pine (*Pinus radiata*) is used as raw material for commercial production. Other species such as Alder (*Alnus* spp.), Southern Yellow Pine (*Pinus* spp.), Scots pine (*Pinus sylvestris*), and Beech (*Fagus sylvatica*) are under development.

This non-toxic acetylation process forms Accoya wood which offers several advantages. Firstly, it offers good resistance against fungal decay (durability class 1 according to EN 350-1). Secondly, the dimensional stability in comparison with most other timber species is improved. While the strength of the original timber species „*Radiata pine*" is slightly improved after it is modified to Accoya wood (Accsys, 2010a). A further explanation about Accoya wood is presented in Chapter 4.

With the non-tropical rainforest source (New Zealand and Chilli) with optional FSC (Forest Stewardship Council) or PEFC (Programme for the Endorsement of Forest Certification) qualifications, improved durability and technical properties, Accoya wood seems to have the qualities to be applied as a material in civil waterworks applications.

As there is no warrantee given for the lifetime of Accoya when it is placed in contact with salt water (Accsys, 2011), this study focuses on applications to be placed in the freshwater.

The Company

Accsys Technology PLC is the official holder of the producing technology and registered brand; Accoya® wood. Accsys Technologies is an environmental science and technology company with departments in the United States, United Kingdom and the Netherlands. The production plant, office and laboratory is located in Arnhem (the Netherlands) with responsibilities to produce, sell and research Accoya wood. One of the fields that needs more research is the application in civil waterworks.

1.1 Aim of the study

The main purpose of this study is to answer the following main question:

Is Accoya® wood a feasible alternative for currently used materials in civil waterworks applications?

To answer the main question, the following sub questions are given:

1) Is Accoya® wood a feasible *technical* alternative for waterworks applications?
2) Is Accoya® wood a *financially* feasible alternative in civil waterworks applications?
3) What are the *threats* of using Accoya® wood in civil waterworks applications?
4) What are the *opportunities* of using Accoya® wood in civil waterworks applications?

1.2 Methodology

To answer the question of the *technical* feasibility of Accoya in civil waterworks applications, it is important to know what regulations and legislation exists at European and National level regarding to materials and applications. Literature sources were studied and interviews with market parties were conducted. The literature on regulations was compared to the key findings of the self-made interactive Internet Survey and results of the interviews.

A market study based on reports and the interactive Internet Survey was conducted to determine which parties are of interest for Accoya and subsequently the type of applications they can be using it for as well as the factors that affect their decision-making process. In addition, the internet survey was sent to several market parties and NGO‟s in the Netherlands. The questions in this web survey are included together with the answers in Appendix3

To give the threats and opportunities for Accoya wood as alternative in civil waterworks constructions a Strengths, Weaknesses, Opportunities and Threats (SWOT*)* analyses was made with the key findings to be discussed and come to a conclusion with recommendations for the use of Accoya wood in Civil waterworks constructions.

2. Civil Waterworks constructions

The civil waterworks materials market consists of applications where the materials are in contact with salt-and freshwater. These applications of materials are for submerged and contact conditions in the Netherlands.

The Netherlands has the most dense waterways network in Europe with a total length of 6220 km (CBS, 2010), which is after Finland with 8000 km and Germany with 7000 km, the third largest in Europe (CBS, 2009). This enormous amount of waterways is separated into three categories of waterways; „*The second structure scheme of transport and traffic" of* the Dutch ministry of infrastructure and environment / VROM (VROM, 1991). These three waterway categories are based on their size and function, as described below and shown in Figure 2.1

The first category is; Main transport waterways (*hoofdtransportassen*) such as; De Waal, the Amsterdam-Rhine channel (*Amsterdam-Rijnkanaal*) and the Scheldt-Rhine connection (*Schelde-Rijnverbinding*). These main transport waterways have a total length of 500 km, which connects the harbours of Rotterdam and Amsterdam to the main ports in the Netherlands and countries abroad, with harbours in Germany, Belgium and other countries with river harbours.

Figure 2.1 Types of waterways (CBS, 2009).

Hoofdtransportassen = Main transport waterways
Hoofdvaarweg = Main waterways
Overige vaarweg = Other waterways

The second category is; „Main waterways" (*hoofdvaarwegen*) such as the Maas, Lek, IJssel and the Ijsselmeer with a total length of 900 km. These main waterways connect the provinces and can be used by container boats for national and international transport.

The third and final category is „other waterways" (*overige vaarwegen*), which is the biggest category in length and amount of waterways in the Netherlands with a total length of around 4820 km. These „other waterways" are used for smaller transport, recreation and to drain the water for the safety of the Netherlands which has about 26% of its land surface located below sea level (BVB, 2011).

The waterways play an important role for the transport and for the economy in The Netherlands. In 1999, over 234 million tonnes (Kraan, 2002) and in 2006 over 314 million tonnes was transported by ship. This is 30% of the total goods transported (excluding air and sea transport) within the Netherlands in 2006 (CBS, 2009). Goods were exported to European destinations with over 60% being by ship (excluding air and sea transport).Water transport holds the second place following road transport (Bureauvoorlichtingbinnenvaart, 2011).

In addition to the transport function, waterways play an important role for recreation, water storage, nature and drinking water. Safety plays another important role of waterworks constructions because; 26% of the Netherlands is situated below sea level, 70% of the area would be flooded without coastal defence, and 70% of the GDP is earned in areas below sea level (RWS

& NWP, 2011). To describe this, Figure 2.2 illustrates the relative functions and locations of waterworks, economic and housing areas in the Netherlands.

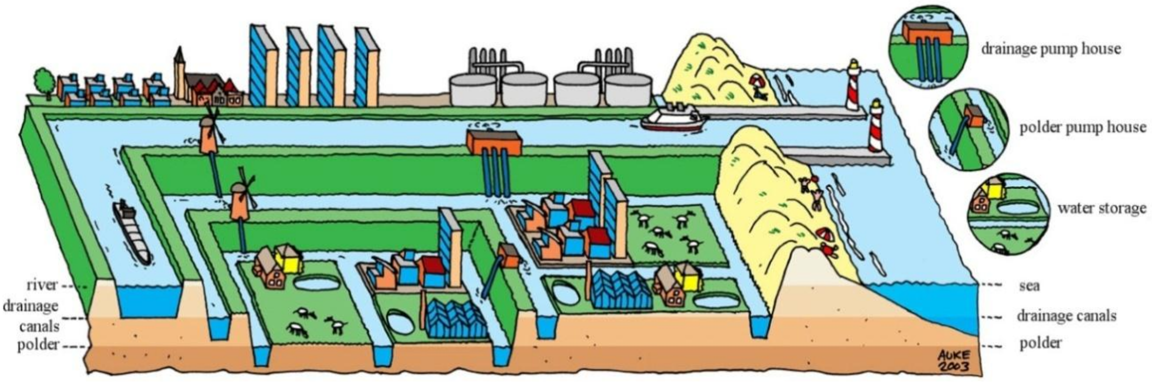


Figure 2.2.Types of waterways in the Netherlands (Hoogheemraadschap Delfland, 2011).

2.1 History

The Netherlands has a long tradition of hydraulic engineering and its civil waterworks applications. Without civil waterworks, the Netherlands would not be as it is now. The Romans were the first to construct waterways in the beginning of the era. They named the Rhine as a border for their empire. To move their troops quickly, they dug the *Cobulocanal* and the *Drususcanal*. The *Cobuluscanal* or *Forsa Corbulo* was a connection between the Meuse and Rhine. Local waterways or canals were constructed, usually as a short connection between two natural waterways. With civil waterworks constructions, such as a lock gate with point doors, was built in 1253 close to *Spaandam* to disconnect the waterway *Spaarne* from the lake *„het IJ"* and prevent flooding. In the 16th and 17th century there were more canals constructed in the Southern part of the Netherlands and in 1618 was the first barge service established (Brolsma, 2010). Due to mechanization and increased volumes and sizes of the ships, the demand for civil waterworks -applications grew and -constructions became bigger.

Before the 19th century, timber was the main material used for civil waterworks. Due to its longevity and durability under adverse conditions, timber was virtually unrivalled for a long period. The Dutch gained a great deal of experience with the commonly used timber species. These were mainly the species that were available in; big sizes, quantities and were durable (long life span) for the use in waterworks. This trusted experience has led to the usage of only a few timber species (Wellink & Ravenhorst, 2008). Buis (1985) stated that before World War II and few years after, most Dutch wooden civil waterworks were mostly made of oak and beech, this wood the beginning mainly sourced in The Netherlands and later mainly from Germany and France.

Trade activities overseas with the Far East and South Africa, resulted in the Dutch discovery of the tropical hardwood species (Wassink, 1983). Today, half of the wooden civil waterworks in the Netherlands are made completely or partly out of Ekki (azobé) (DWW, 1944). This tropical hardwood was difficult to transport and shape into materials for houses or furniture during the 17th century. After the 2nd World War, the Dutch started to import more tropical hardwoods for many applications that they built and restored after bombings in and beside the large amounts of waterways in the Netherlands such as canals, rivers and lakes (Wellink & Ravenhorst, 2008). Nowadays, the Dutch still import large quantities of hardwood while the demand worldwide has risen and the interpretation of nature maintenance and size of forests have changed since the 16th century.

2.2 Used materials

Civil waterworks constructions, as identified in Chapter 1, are designed to assist, to guide and to create safety and continuity regarding to water management with respect to transport and communities. With all these applications all kinds of different structures are constructed. Depending on the structure and the materials used, different standard, regulations, and (practical) guidelines apply in respect to design, engineering and maintenance.

By choosing a building material for a structure, aspects such as material knowledge by all parties play a big role; with what kind of material is the designer familiar (properties) and on the other hand the designer has the clients wishes. There are few aspects that important in choosing the best material, such as, strength to weight ratio of a material, life time of a material, availability in the required dimensions and shaping and assembling options.

The most used materials are metal, concrete, and timber. The most used metal in waterworks applications is steel, which consist for a big part of iron (Fe), reinforced with carbon (C) to increase its strength (Van den Dobbelsteen & Alberts, 2001). The amount of energy needed for the production of metal products is higher compared to concrete and wood. Extracting metals from the earth often causes destruction and pollution of the environment. The Netherlands as well as Europe does not have much iron ore and this is why ore or metal has to be shipped. It is often used when long lengths are required and the form of the structure has to be relative thin (Van den Herik, 2011). Steel is also frequently used for sheet pilling, „large" bridges and retaining structures. CUR (2005) states that the estimated life time of steel is 10 years for each 0.1 until 2.0 mm thickness because of corrosion aspects. The benefit of steel or metal is its strength in combination with its relative thin thickness and availability in long lengths. The disadvantage of metal is that it corrodes when it comes in contact with oxygen and water. This problem can be reduced by coating. There are also new technologies regarding the making of metal which could prolong its lifetime, for example with a help of additives such as aluminium, which reduces the rate of corrosion.

Concrete, is made out of the raw materials cement, water, sand and gravel one thing that these materials have in common is the high mass to volume ratio, resulting in higher energy consumption and effects on the environment when transported. The extraction of the raw materials causes damage to the environment. Fresh concrete may release toxic metals and/or release constituents that increase the *pH* of water (Smith, 2007). Concrete can be recycled or re-used. Availability of the raw materials is sufficient in the Netherlands (Van den Dobbelsteen & Alberts, 2001). Concrete is usually used for the „big" structures in civil waterworks constructions such as big fixed waterway crossings and sometimes as prefab construction alongside water. The advantage of concrete is its long life time, around 100 years. Furthermore it can be made in different shapes. In addition, concretes disadvantages are its relative heavy weight, the high price and it is difficult to repair (especially under water).

Timber is the oldest building material in civil waterworks and traditionally commercial requirements are large volumes, continuity of supply and price. These requirements are combined with the technical requirements such as large sizes, long lengths, high strength and good durability (resistance against fungal decay). Because of these, there were only a small number of timber species used in civil waterworks. The species used are mainly tropical hardwoods which have proven their benefits in service. Temperate hardwood species, such as oak, chestnut, robinia, and softwoods, such as Douglas-fir, Scots pine and larch, are used in lower quantities at less demanding locations or for renovation when the same timber species is requested (Oldenburger & van den Briel, 2009). Based on the Internet Survey and Bogaardt (2000), the hardwood species Ekki, is the most used timber species in addition to Basrolocus and Angelim vermelho. Softwood species are regular used for: poles, sheet pilling, and post to boarding structures, to protect the shore from erosion (CUR, 2005). For a short explanation of the most used timber species and there usage in civil waterworks constructions see Appendix 1.

Timber can have a long life time which depends on the chosen wood species, the exposure condition and how it is used and assembled. For example; Ekki has an estimated average life of more than 25 years Accoya has an estimated average life time of above 25 years (not in salt water) (Titanwood, n.d.), and soft wood has an estimated average life time of 5 years (at water level) or above 25 years (kept under 10 cm of the waterline). Based on the assigned use class (EN335) combined with field tests (VHN, 2011). More explanation about this can be found in Chapter 3.

A rule of thumb in Dutch Civil waterworks is that for water bank protections, combining some of the aspects just mentioned above is that with water sides more than 6 meters deep: steel is used for sheet piling and when it is less than 6 meters deep often hardwood is used. In general Ekki is used because of the availability of timber sizes and its strength. Concrete is not used often, only for projects with buildings or housing and for building projects where railways cross a waterway (Van den Herik, 2011).

2.3 The market

There are three kinds of customers in the market for civil waterworks constructions; Governmental parties, companies, such as harbours, and a small category of land owners (private persons). The governmental parties can be subdivided by four parties, which are the National government (*Rijkswaterstaat*), Provinces, Water boards and City councils, as shown in Figure 2.3. The government and its local parties have to make sure that the usage of the total amount of 6220 kilometres civil waterways is safe in the long term. This demands maintenance of waterways and its applications by these parties (Dutch Civil Code Art. 78 lid 2 Wschw).

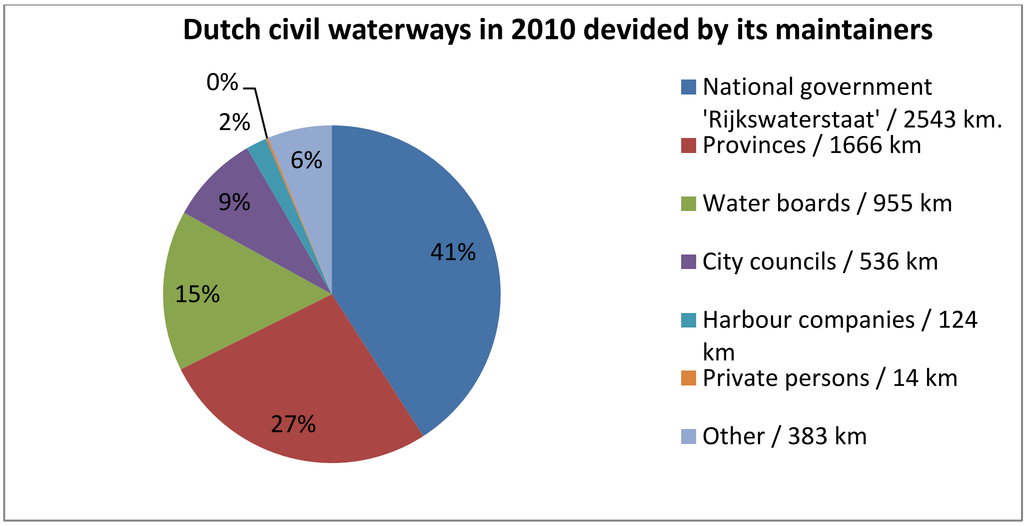


Figure 2.3 Dutch civil Waterways in kilometers by their maintainer (care keeper) 2010 (CBS lengte waterwegen, 2011).

This demand by Art78 lid 2 can be explained as a structural demand for maintenance and development of (new) waterways and its applications, which can explain the data provided in Table 2.1 and Table 2.2, assembled by the Central Bureau of Statistics (CBS on the field of work concerning waterways for the period 2001 until 2010. As shown in both tables, the amount of money involved in developing waterways and developing applications is increasing from the period of 2001 to 2010.With the development and maintenance of waterways (Table 2.2) is in general more money involved than with the development and maintaining for waterways constructions.

Development of Waterways

The year 2000 = 100

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Januari	101	102	107	109	117	120	127	132	132	132
April	101	104	107	113	118	122	129	136	130	136
Juli	102	104	107	116	119	125	131	141	130	137
Oktober	102	105	107	117	120	126	130	137	131	137

Table 2.1. Price index numbers Civil Waterways (CBS Statline GWW, 2011).

Development of Civil waterway constructions

The year 2000 = 100

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Januari	105	107	108	106	107	111	118	122	131	119
April	105	107	107	108	107	112	119	126	127	120
Juli	105	108	107	110	108	114	118	133	124	120
Oktober	105	108	107	108	108	115	118	131	120	120

Table 2.2. Price index numbers Civil waterway applications (CBS Statline GWW, 2011).

While the EU Timber Regulation has not come into action yet, the economic crisis (late 2000) in the EU made the usage of tropical timber species decline since 2008 according the Central Bureau of Statistics in the Netherlands (CBS) and Probos. The import of tropical timber has dropped with 39 percent from 2007 until 2009, as shown in Table 2.3.

Year:	**1988**	**1990**	**1995**	**2000**	**2005**	**2007**	**2008**	**2009**
	Million m^3 round wood equivalent without bark							
Total	1,5	1,5	1,0	1,3	1,21	1,34	1,17	0,82
Round wood	0,14	0,11	0,12	0,10	0,06	0,04	0,01	0,01
Sawn timber	0,92	0,95	0,56	0,79	0,81	0,94	0,82	0,57
Triplex, multiplex en finer	0,45	0,47	0,29	0,39	0,34	0,36	0,34	0,25

Table 2.3. Tropical timber usage in the Netherlands between 1988 and 2009 (Probos/ CBS 02-2011).

As illustrated in Table 2.3, the Netherlands imports yearly more than one million cubic meters of tropical hardwoods, until 2009. In the economic crisis years (around late 2007) this import quantity is reduced with 13 percent in 2008 and 30 percent in 2009. Since 2004 the Dutch used around 33 thousand cubic meters of tropical round wood per year. In 2009 this dropped to 21 thousand cubic meters which is 45 percent lower. Consisting mainly out of Ekki from West Africa, which is for a big part used for civil waterworks applications.

SBH performed a study on the use of timber in the Dutch Civil Water works in 1998. The results are shown in Table 2.4. The amount of tropical hardwoods whereof the percentage Ekki is high in 1998, like for lock gates and dolphin structures. All tropical hardwood used was Ekki. The amount of preservative treated wood was also big especially in sheet pilling and poles post to board constructions for shore protection (Bogaardt, 2000).

Market segment application	Tropical hardwood (total)	Species Ekki	Other Tropical Hardwood	Non tropical hardwood	Softwood	Preservative treated timber	Total for product
Fender wood	6077	4577	1500	300	0	50	6427
Lock gates	2026	2026	0	100	0	0	2126
Meerstoelen / Dolphin (structure)	2196	2196	0	200	0	0	2396
Schot balken / Stoplogs	2137	2026	111	360	0	0	2497
Sheetpilling	17285	15855	1430	7540	8507	10150	43482
Round wood poles, post to boards	75	75	0	3220	10650	5000	18945
Square edged poles, post to boards	16304	5375	10929	1730	2475	2700	23209
Perkoenen / Modular piles	0	0	0	6800	5765	4350	16915
Landing stages	9815	1360	8455	150	125	1600	11690
Bridges	4205	2250	1955	900	225	50	5380
Water- bed and bank protection	783	643	140	0	0	0	783
Total	60903	36383	24520	21300	27747	23900	133850

Table 2.4 Market segment matrix for civil waterworks market of the Netherlands in 1998, measured timber usage in m^3 sawn wood, exclusion for round wood and modular piles, these are given in m^3 round wood.

3. Technical requirements for wooden applications in civil waterworks.

There are numerous waterworks constructions, each having technical requirements that depend its location, the size and loads it has to retain. The most common requirements for civil waterworks made of timber will be discussed in this chapter. In the paragraphs below the technical requirements for civil waterworks constructions are discussed; resistance against biological decay by fungi, insects and marine borers, strength properties and wood dimensions.

3.1 Natural threats to timber used in civil waterworks.

Timber used in civil waterworks constructions is under constant threat of degradation mechanisms as fungi, insects and marine borers.

Fungal decay

Under and above water, fungi can cause staining, decay and loss of strength which can result in complete destruction of a timber construction. The fastest rate of fungal decay is seen around the waterline because its inhibits, the best environment for fungal decay. For fungal decay the wood moisture content should be high enough (unmodified wood species >20%) in combination with sufficient oxygen, temperature (5 to 40°C), a food source (wood) in absence of toxic substances (see Figure 3.1). Some timber species are by nature toxic for humans and organisms which makes a timber species more durable. Preservatives like CCA treatment have also been used to make wood more durable. These requirements for fungal decay are occurring most days of the year in civil waterworks applications.

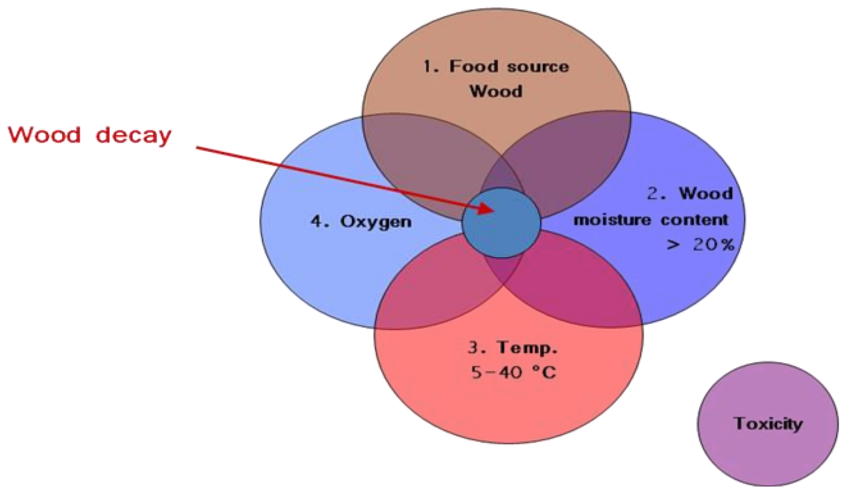


Figure 3.1 Factors required for wood rotting fungi (CUR, 2003)

In the Netherlands, there are two kinds of wood rotting fungi that affect the strength of timber components used in water environments on a large scale. Firstly, wet rot fungi form the main threat because it attacks the wood from within, on and above the (fluctuating) water level zone. Wet rot can cause severe loss of strength because it weakens the wood cells from within. Secondly, soft rot fungi attacks timber which is in constant contact with water. Soft rot erodes the timber from the outside at a relatively slow rate, making it softer. While white rot plays a very small decaying role for timber used in civil waterworks applications, another small risk are bacteria. Research showed that bacteria can cause degradation of wood on the long term, even under water. Furthermore not all wood species are sensitive for bacterial degradation. Therefore degradation by bacteria plays a small role and usually occurs in combination with soft rot fungi (CUR, 2003; Crossman & Simm, 2004).

Insects

Another risk for timber, is the degradation caused by insects. The influence of insects on timber used in waterworks is minimal for above water while for the part under water a difference is seen in the percentage of salt in water (CUR, 2003).

Fresh water

Insect attack is usually limited for applications in fresh water to the perishable sapwood of a timber component, or weakened wood by fungal decay and forms a limited threat. In salt water the risk of timber getting attacked by insects forms a much bigger threat (Crossman & Simm, 2004).

Salt water

When the timber application is in contact with salt water, it can be attacked by insects such as; marine borers. Marine borers make holes in the wood which weakens its strength properties. In the Netherlands there live two main kinds of marine borers in salt water:

Limnoria spp. (Gribble/*Waterpissebed*)

The gribble (Figure 3.2) is 1.5 until 5 millimetres long, looks like a rough woodlouse and can be found in water of 5^{o}C and above with a salinity of 10 ‰ or more. The attack of the gribble (Figure 3.2) on applications made of timber results in a network of galleries under the waterline varying in 1-3 millimetres in diameter at or just below the wood surface. Extensive attack can result in erosion of the surface layers by tidal action which can be accelerated by the action of soft rot fungi (Crossman & Simm, 2004).

Teredo spp. (Shipworm/*Paalworm)*

The Shipworm grows in the Netherlands to a length of 60 centimetres and is found mostly in good quality salt water, requiring at least 5^{o}C and a salinity of 7 ‰ and more. The North Sea has a salinity of 35‰ (Mumm, 2011). The attack of the shipworm on wood applications is found less frequent as with the gribble. As a result, a hole (usually along the grain as shown in Figure 3.4) in which the shipworm lives through its stages as displayed in Figure 3.3 (A) Young larvae, (B-C) Older larvae, (D-G) Stage of burrowing, to make the hole true the timber in where it lives, gets its food, oxygen and releases its waste (DWW, 1999; Crossman & Simm, 2004).

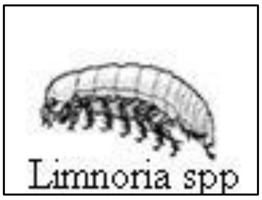


Figure 3.2 Gribble (waterpissebed)

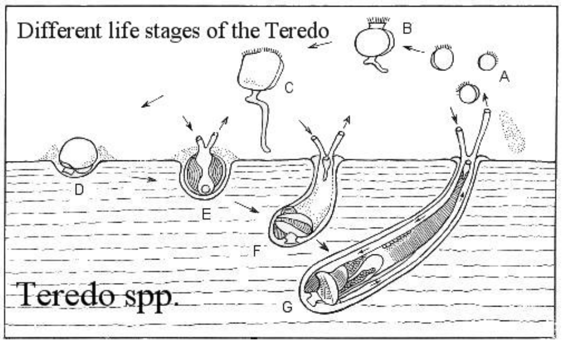


Figure 3.3 Shipworm (paalworm)

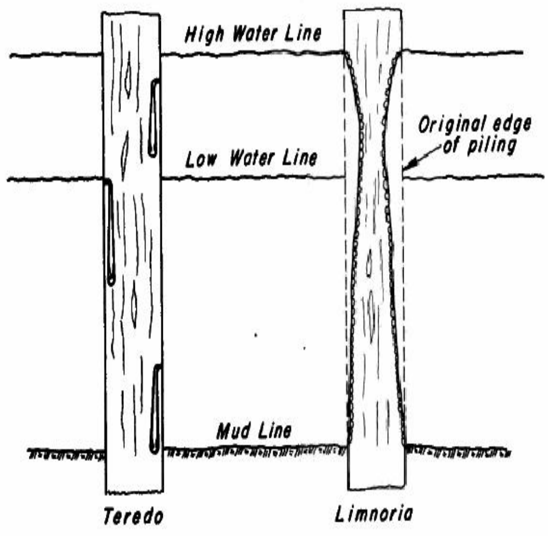


Figure 3.4 Sketch of cross-sectional piling in salt water, with patterns of both marine borers.

Prolonging the life time of timber can be done in two ways; good design of a structure and making the right choice of durability class or preserving method of a wood species (DWW, 1999a).

The best protection against marine borers is by prevention, because after the intrusion of a marine borer removal is almost impossible. Prevention is done by using timber species in salt water that have a high natural resistance against attach by marine borers due to high amount of silica, akaloides and/or a high density combined with a high hardness (DWW, 1999b).

3.2 Natural durability and use class of timber

Wood species offer a certain natural resistance against biological attack. This resistance is often referred as Natural durability. It is important to know that this term only refers to the heartwood of a timber species and generally the amount of allowable sapwood needs to be restricted. Depending on the final application, some sapwood may be accepted, as long as it is exposed to less severe conditions than traditional ground/water contact. In the EU, this natural durability is for many timber species tested according to a so called „graveyard test". These tests are done to compare the durability of timber species in natural circumstances. The main norm applicable to tell the natural durability of a timber species is EN 350: durability of wood and wood-based products. Natural durability of solid wood, EN 350-2, tells the natural durability and treatability of tested wood species (CUR, 2003). VHN (2011) stated that the expected life time is differed by the five different durability classes when in contact with ground and or fresh water as shown in Table 3.1.

Durability class (EN 350-2)	Durability, in-ground / water situations	Average life span (VHN, 2011)
1	Very durable	25 years and more
2	Durable	15 – 25 years
3	Moderately durable	10 – 15 years
4	Slightly durable	5 – 10 years
5	Not durable	Less than 5 years

Table 3.1 Durability class according EN 350-1 and 2.

EN 335 has been established to define serving conditions for timber based products, in which moisture, wetting and ground contact play a role. In the European Norm EN 335-1 on wood protection, five different service situations are distinguished as shown in Table 3.2.

Use class (EN 335-1)	Conditions of used timber	Wetting	Wood moisture content
1	No contact with the ground, sheltered and dry	Permanently dry	Permanent exposure < 20%
2	No contact with the ground, sheltered with little chance of wetting	Occasionally exposed to moisture	Incidental, short-term exposure > 20%
3	No contact with the ground, not sheltered in all weather conditions	Regularly exposed to moisture	Regular, short-term exposure > 20%
4	Ground contact, fresh water.	Permanently exposed to water and or fresh water	Permanent exposure > 20%
5	In contact with salt or brackish water	Permanently exposed to salt water	Permanent exposure > 20%

Table 3.2 Use classes for wood used in EU norms (EN 335-1).

For civil waterworks constructions, the use of class 3, 4 and 5 are the most common. The main advice for improving the durability of timber structures in use class 3 is to provide drainage from timber and ensure good ventilation of surfaces. Further advice is to protect exposed end grain, tops of horizontal members and avoid water traps and capillary paths. In use class 4 the risk lays at the point where oxygen and water meet, the fluctuation zone of timber in water contact. Soft rot forms here the biggest threat. For wood permanently positioned under fresh water the risk of degradation by fungi is very small because of a lack of oxygen. In use class 5 this is the same only here lays the risk of damage by marine borers.

The European Standard EN 460 gives guidance as shown in Table 3.3 on the selection of wood species based on their natural durability (EN 350-2) to attack, by bio organisms, in the use classes defined in EN 335-1.

Use class EN335-1	Durability class (EN 350-2)				
	1	2	3	4	5
1	O	O	o	o	o
2	O	O	o	(o)	(o)
3	O	O	(o)	(o) – (x)	(o) – (x)
4	O	(o)	(x)	x	x
5	O	(x)	(x)	x	x

Explanation symbols Table 3.3	
o	Durability sufficient.
(o)	Normally durability sufficient, but some end uses may require additional treatment.
(o) – (x)	Durability may be sufficient, but depending on end uses and wood species.
(x)	Additional treatment is advisable.
x	Additional treatment is necessary.

Table 3.3 Guideline for selecting wood species in respect to use class (source: EN 460).

3.3 Strength requirements of timber

For load-bearing applications such as *duckdalfs* and *fender wood* alongside bridges, lock gates and harbours, the mechanical properties of the materials should be known to make calculations . The strength requirements for timber used in civil waterworks constructions are for a big part based on the quality and volume mass of the timber. With tropical hardwood species a volume mass of 750 kg/m^3 (12% moisture content) is found to be sufficient in general (CUR 2003).

The way the grains develop in a tree can cause the timber to have more or less strength when applied, like cross grain in timber species, this gives the timber more strength against forces coming from alongside (*shearing strength*). This is especially recommended for fender wood (CUR 2003). Wellink and Ravenhorst (2008) stated that much cross grain in combination with sizes below 40mm may cause unwanted deformation. Therefore good assemblage and well thought timber choices are needed while knowledge about timber species stays essential.

CUR (2003) states that a Janka hardness of at least 6 kN on the side is required. For Constructions with a bigger chance to be damaged like *lock gates* and *duckdalfs* a hardness of 8 kN is advised (CUR 2003). Pine walls are usually made of ungraded wood assuming the strength grade is at least C16/C18 (Kuilen, 2008).

3.4 Dimensional stability and straightness

Another requirement for especially long lengths is the dimensional stability of timber, this is required to avoid distortions. The movement of timber is caused by shrinkage or swelling. Shrinkage occurs when the timber dries in general below about 30% moisture content, or the fibre saturation point. The movement of timber is different for each wood species and even each piece of wood. Movement of timber can cause distortions like twisting and bowing of timber components. This distortion can be reduced by well managed drying in combination with right fixing and design (CUR, 2003). The grading specifications like in NEN 5493 for hardwoods and the BRL 2905 for European softwoods deal with the maximum allowance of distortion in timber to be applied in/as described civil waterworks applications in the Netherlands. For the maximum allowance in distortions the grading terms of BRL 2903 for softwoods in Appendix 2 under the part distortions can be taken as example.

3.5 Sizes of constructions in civil waterworks

Requirements for materials used in civil waterworks constructions are also based on the size for the different applications. Civil waterworks constructions often require big sizes of materials, because of the depth of waterways. Sizes can traditionally go up to 24 meters long and 300 to 400 millimetre thickness for pilling and the thickness of fender wood goes from 200 millimetre until 300 millimetre thickness. For fender wood, timber of durability class 1 or 2 is required, to give assistance or guide harbouring ships, for example by constructions as bridges, sluices or lock gates in waterways.

Improved principles for the design of fender wood is based on assembling more timber of less durable (class 2-3) wood species, this can be done because the impact energy (of a ship) is divided over more beams. Lock gates require thick and long lengths which depend on the size of the lock gate doors, going up to 340 mm thickness (Crossman & Simm, 2004).

For the shore protection of smaller waterways, a „plank and post to boarding" structure is often used. With smaller sized, poles (king posts) of 80 x 80 millimetres (thickness x width) and lengths of around 1.5 to 2 meters, depending on the depth of the waterway and boards of 25 x 180 millimetres. For more demanding shore protection (under influence of bigger waves), an anchored timber pilling construction should do with 25 millimetres thick profiled planks of 175 millimetres wide, with lengths of around 1 until 2,5 meters (Leusen, 1975).

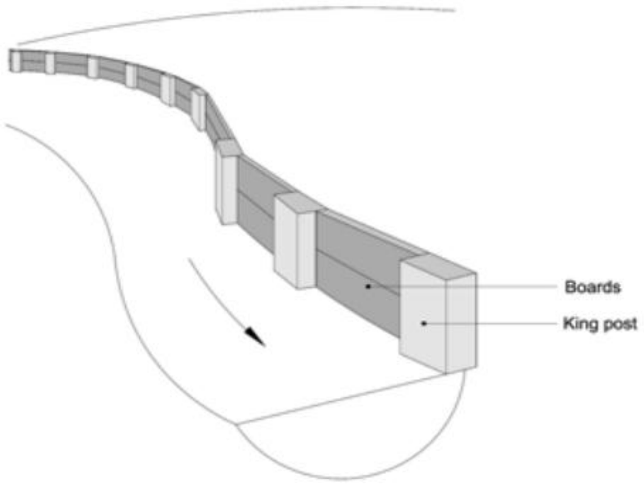


Figure 3.5 Plank and post to boarding (Environment Agency, 1999).

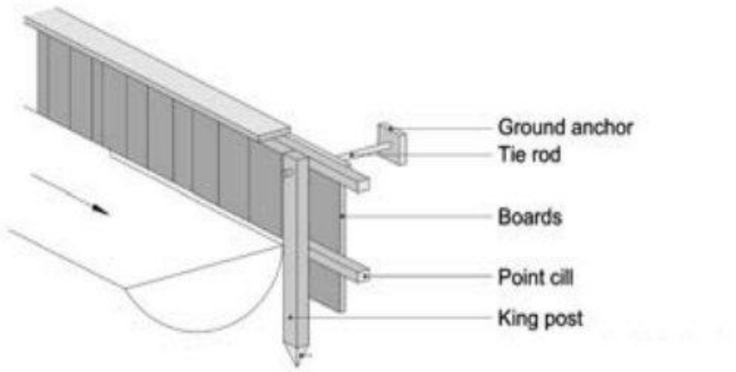


Figure 3.6 Anchored timber pilling (Environment Agency, 1999).

4. Accoya® wood

Acetylation of wood with un-catalysed acetic anhydride as with Accoya wood has been studied extensively and shown to be a promising method for the improvement of the technical properties of wood products. The non-toxic treatment has shown to result in a very durable, dimensionally stable and UV-resistant material with all mechanical properties of the untreated wood maintained or improved (Beckers *et al.* 1998). This acetylation process is now carried out in a large scale on Radiata pine and brought on the market as Accoya wood.

4.1 The Process

At this time (2010/2011), Accoya wood is made of the softwood timber species *Pinus radiata*. The timber of this conifer tree is obtained from well managed plantations in New-Zealand or Chilli where it is sawn in the dimensions of the sawmill with optional FSC or PEFC certificate. Then, it is transported by trucks and ship to the acetylation plant in Arnhem, the Netherlands, to undergo the modification process.

The chemical structure of Radiata pine in comparison with Accoya wood is changed by the acetylation process. The chemical structure of wood (Wood-OH) normally contains a high amount of hydroxyl (OH) groups. This causes the wood to absorb high amounts of water (H_2O) molecules what causes the wood to swell (See Figure 4.1). This makes the wood attractive to biological attack, and causes decay.

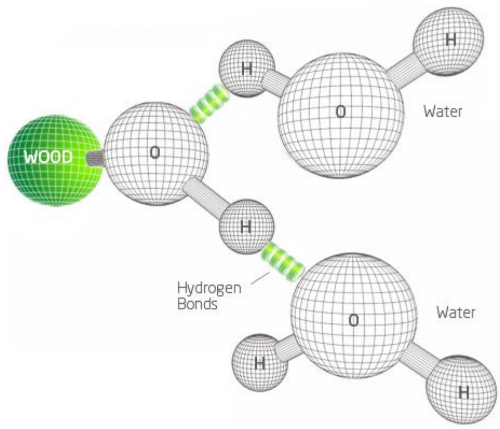


Figure 4.1 Basic chemical structure of wood.

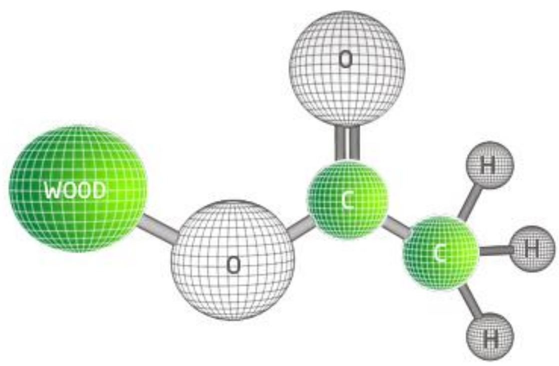


Figure 4.2 Basic chemical structure of Accoya wood.

The acetylation process of Accoya wood changes its physical properties, resulting in the reduction of the absorption of moisture by the wood and reducing the shrink and swelling properties. This is done by increasing the amount of „*acetyl*" molecules in wood (Figure 4.2) (Accoya, 2010).

The basic chemical changes in wood during the acetylation process are displayed in Figure 4.3. During the acetylation process as shown in Figure 4.3 the hydroxyl groups in the wood are replaced by acetyl groups due to the reaction with impregnated acetic anhydride at elevated temperature. After the acetylation reaction the by-product acetic acid is almost completely removed from the wood.

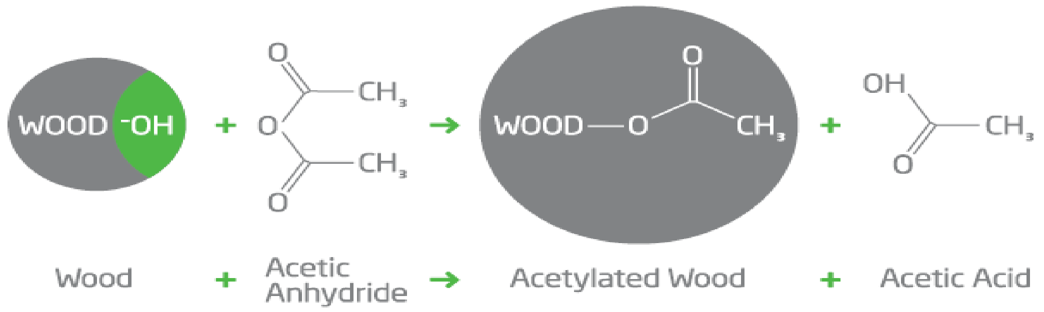


Figure 4.3 Acetylation reaction.

4.2 Accoya® Wood

Accoya wood, as shown in Figure 4.4, is made from fast growing wood species, obtained from well managed forests. At this moment, the used timber species for Accoya wood is Radiata Pine (*Pinus radiata*). Accoya wood consists a high amount acetyl molecules, which causes Accoya wood to swell, due to the bulky acetyl groups that replace the hydroxyl groups. This makes Accoya wood more dimensionally stable, better UV resistible and more durable as it is classified as durability class 1.

Accoya wood has undergone several tests and assessments to determine its qualities, the basics are summarized in Table 4.1. In the paragraphs below the performed tests and results are described, while Accoya has a guaranteed lifetime period of 25 years when used in use class 4- as defined in EN 335-1 and 50 years when Accoya is used in use class 1, 2 and 3 as defined in EN 335-1 (Titan wood, n.d.).

Figure 4.4 Beam of Accoya wood.

Durability class (EN 350-1)	1
To be applied in use class (EN335-1)	1,2,3 and 4
Density	510 kg/m^3
Equilibrium moisture content	3-5 % (65% rel. humidity 20^{o}C)
Swelling (oven dry – wet)	Radial 0.7%
	Tangential 1.5%
Bending strength	39 N/mm^2
Bending stiffness	8790 N/mm^2
Hardness (janka)	Alongside 4100 N Head 6600 N

Table 4.1 executive Executive summary Accoya wood.

Accoya wood is available in the following dimensions: from 25 until 100 millimetres thickness,100 until 200 millimetres width and 2.4 until 4.8 meters in length (Data sheet Accoya, 2010). The maximum dimensions are given because of the chemical process that gives limitations to modify thick dimensions of timber. When larger sizes are wanted, finger jointed Accoya wood is also available. All sizes available are shown in Appendix 2 (Table A2), together with the table with grading specifications for Accoya wood.

4.3 Tests results on Accoya Wood

Natural Durability

The durability of Accoya wood, in accordance to EN 350-1, is proven by tests assessed by SHR timber research (*Stichting Hout Research*) in 2007 (SHR 2007). The tests show the resistance of Accoya towards brown-, white-, and soft rot fungi and used to determine the durability class according EN 350-1. The test result given in SHR test report 6.244-3, shows that Accoya wood classifies durability class 1. At this degree of acetylation the variation in fungal decay within the samples is decreased, resulting in a higher durability of first class Accoya wood, which is the highest under EN 350-1, in comparison to untreated Radiata pine falling in class 5 (the lowest durability class in EN 350-1).

Accoya wood is suitable to be used in use class 1 until use class 4 of the norm EN 335-2 (SKH, 2010). Acetylated wood used in salt water contact (use class 5) can undergo attack by marine borers. Klüppel *et al.* (2010) did tests according to European Standard EN 275v in which it was attacked by marine borers. He stated that: "Modification through acetylation increases the resistance of wood to both gribbles and shipworms.".

Dimensional stability

The dimensional stability of Accoya wood is proven by tests assessed by SHR in 2007. The test results are given by SHR of which the summary is shown in

Table 4.2. These results show that Accoya wood produced from Radiata pine has a substantial reduction of 66% in hygroscopicity (equilibrium moisture content) compared to untreated Radiata pine under the same moisture conditions (relative humidity). The dimensional stability (swelling and shrinking) of Accoya wood is increased with 80%, compared with (untreated) Radiata pine (SHR, 2007).

Aspect	Accoya™ wood	Radiata Pine	Improvement
Equilibrium Moisture Content (at 65% RH, 20°C) [%]	3.3	9.8	66%
Density (at 65% RH, 20°C) [kg/m³]	510	466	-
Swelling (oven dry – water saturated)			
- radial [%]	0.69	3.40	80%
- tangential [%]	1.47	7.89	81%

Table 4.2 Comparison between Swelling and EMC of Accoya and radiata pine (SHR, 2007).

Impact bending strength

The Impact bending strength of Accoya wood has been determined according to DIN 52189. In Table 4.3 the results are given. Due to the acetylation process the average impact bending strength Accoya is slightly improved from 48 KJ/m^2 for untreated Radiata pine to 50 KJ/m^2 for Accoya wood (SHR 2006).

		Impact bending strength		65% RH; 20 °C Density	Moisture content
	batch number	[kJ/m²]	[stdev]	[kg/m3]	[%]
Accoya™ wood					
	LG118	48	*14*	535	4,2
	LG122	54	*19*	535	4,1
	LG123	47	*19*	508	4,1
average		**50**	***17***	**526**	**4,1**
Radiata Pine	Ref-LG122	**48**	***15***	**515**	**12,1**

Table 4.3 Average impact bending strength Accoya and (untreated) Radiata Pine (SHR, 2006).

Strength grade

Accoya wood is a modified piece of wood and has a changed behaviour as previously discussed, because of the modification, Accoya has no strength grade that has yet been approved. Therefore, currently, Accoya wood may not be used in structures wherefore calculations (bearing, carrying) are made, without doing special grading tests on the timber that will be applied for the specific structure (SKH, 2011). The expected strength based on tests by SHR in 2006 (SHR, 2006b) and on-going tests by Accsys Technologies give an expected strength grade of C18/ C24 (Bongers, 2011).

Janka hardness

The Janka hardness of Accoya wood has been determined by tests assessed by SHR in 2006, the test records are brought under in the SHR test report 6.352 (SHR, 2006c). The test was done according ASTM D143 under climate conditions of 65% RH and 20°C.

The test results describe the average Janka hardness of Accoya wood in radial, tangential and end grain orientation, as shown in Table 4.4, these are increased with 47%, 52% and 81% when compared to untreated Radiata Pine. While the density increased with 8%, the percentage of moisture content decreased with 65%.

	Janka hardness Radial [N]	Tangential [N]	Cross cut [N]	Density* [kg/m³]	Moisture content* [%]
Accoya™	4050	4190	6600	520	4.2
Radiata Pine	2750	2750	3640	480	12.1

Table 4.4 Average Janka Hardness, density and moisture content of Accoya and Radiata pine.

Processing of Accoya

The processing (machine ability) of Accoya wood is investigated by Titan wood in 2006, the test records are brought under in Titan Wood Research Report 200601. The test was done according to a constructed format and in cooperation with two joinery producers. The format described different production processing aspects for window frames. The findings were studied and compared, while a general impression was given towards the machine ability of Accoya compared to other (traditional) wood species.

The test results of Titan Wood Research report 200601 show that Accoya wood is easy to process and results in a smooth surface compared to other commonly used wood species in the joinery industry. While with the general impression the comments were given that processing Accoya wood is comparable with that of Meranti (*Shorea* spp.) and Larch (*Larix* spp.) The processing of Accoya wood was many times better than with Robinia (*Robinia pseudoacacia*) or

Merbau (*Intsia bijuga*). Accoya is also found to be easy to handle, due to its light weight (+/-510 kg/m3). These findings gave a good and positive impression towards the processing ability of Accoya wood (Titan Wood, 2006).

Reaction with metals

The reaction of Accoya wood with metals also referred to corrodibility of metals. These properties have been determined by tests assessed by Titan Wood, with an accelerated test (water sprinkling / temperature) and outdoor exposure and by SHR in 2006, the test records are brought under in SHR test report 6.058

The test results of Titan Wood show that (iron) metal elements protected with a thin layer of "corrosion resistant" metals (zinc, aluminium, chromium) do not offer fully protection to corrosion. Only stainless steel (A2) seems to be able to resist corrosion caused by the presence of acetic acid (Titan Wood, 2007).

The test results in SHR rapport 6.058 state that a protective coating on the metal of two layers of powder coating can, as long as the coating layer is complete, offer a good protection against corrosion (SHR, 2006d).

Toxicity

Heavy metals

Tests on contents of heavy metals taken by TÜV SÜD PSB Singapore have shown that Accoya does not carry detection able halogenated or aromatic amounts of heavy metals such as; Cadmium, Lead, Mercury or Hexavalent Chromium ,as stated in test report S9CHM4351-2-Titan wood. (Titan Wood, 2010).

Formaldehyde emissions

TÜV SÜD PSB Singapore also tested the formaldehyde emissions of Accoya. Hereby Accoya was classified at the lowest level of ClassE1 according to EN 13986. As stated in test report S09CHM04351-01-Titan wood (Titan Wood, 2010).

The WKI Fraunhofer Institute (Germany) also tested the formaldehyde emissions according EN 717-1 (2005) and concluded that the emissions were complying the German regulations as stated in test report WKI – Formaldehyde Accoya (Titan Wood, 2010).

General statement toxicity

SHR declared in their letter with ref. BT/JG/06.508. that wood acetylated and post treated according the Titan Wood process is not toxic. This is valid both for the human-toxicity and the eco-toxicity (SHR, 2006e). The modification method for Accoya is also excluded from the Biocide Directive (98/8/EC) solely due to the modified structure of the wood (Titan Wood, 2010).

Certification

KOMO certificate

The conformity of Accoya wood is based on BRL 0605 „Modified timber‟ this is in accordance with SKH Regulations for Certification. The accordance is given in KOMO® product certificate; „Modified Timber Accoya®‟

"The KOMO® product certificate for modified Timber Accoya declares that there is legitimate confidence that the technical specifications, laid down in this product certificate, provided that the modified timber has been marked with the KOMO® -mark, under number 33058, as indicated in this product certificate which summarises the most important previously described tests (Titan Wood, 2007) .

Sustainable obtained material.

Accoya wood can be sourced with a FSC certificate under the code CU-COC-807363 or PEFC certificate under the code: CU-PEFC-807363, whereby it qualifies TPAC criteria (Titan Wood, 2007).

Cradle to Cradle

The safety of Accoya wood for humans and the environment is tested on criteria in respect to healthy future life cycles of materials, also referred to as „Cradle 2 Cradle" criteria. Accoya wood has been awarded with a gold cradle to cradle level certificate. This certificate has been awarded by MDBC (Mc Donough Braungart Design Chemistry) in 2010 and is below Platinum, the second highest in cradle 2 cradle certification level.

The declaration coming with the gold level certificate from Camco (a global developer of greenhouse gas emissions reduction and clean energy projects) in 2010 which states that Accoya wood has adopted a companywide water stewardship guidelines, characterized energy sources, developed a strategy to include renewable energy and developed a strategy to optimize all remaining problematic chemicals and technical nutrients to be recycled (Accsys, 2010b).

4.4 Products and constructions made of Accoya wood

At this moment (2011) Accoya wood is being used for multiple constructions and products. Because of its stability, durability and other previously explained properties it is widely used as building material for houses, such as; window frames, door frames and cladding of houses and other buildings. Because of the stability and improved UV resistance of Accoya wood in comparison with other timber, the paint lasts longer and doors and windows find less stability issue due to changing wood moisture conditions. Several projects have been completed successfully with Accoya wood being the main material used, such as the two road bridges(2008 and 2010) in Sneek (the Netherlands) made of laminated and finger-jointed Accoya (Figure 4.6). Accoya wood is in the *„moses bridge"*project (2011) used to withhold the water from flooding the path, as shown in Figure 4.5. One of the first projects (1994) is a 20 meters water bank construction (Figure 4.7) with Accoya wood planks, where the test was with acetylated Popular and Scots pine, to protect the shore of the canal from erosion.

Figure 4.5 Moses 'bridge' made of Accoya **Figure 4.6 Sneek bridge made of finger-jointed and laminated Accoya.**

Figure 4.7 Accoya post to board as shore protection construction waterway in Flevoland.

5. Commercial requirements for wooden civil waterworks constructions.

The commercial requirements for civil waterworks, made of timber are very important, not only for the technical aspects of the wood and the purchasing costs, but also in the long run, the needed maintenance costs to keep them in good condition. In addition, a new aspect, the legality of the timber, is important and will become more so.

Governmental organisations are the biggest player for civil waterworks and its constructions, as shown in Figure 2.4. They represent the Dutch population and gained more awareness for nature and the environment, shown by programs like the CSR (Corporate Social Responsibility) plan, which is also known as MVO (*Maatschappelijk Verantwoord Ondernemen*), play an important role in the criteria of the government and the making of development programs in the building market, such as, the program: *„duurzaam bouwen"* (durable building), made to stimulate the durability and sustainability aspects in constructions. For civil waterworks and their constructions there are more advising reports on sourcing materials, such as the one given out by *VROM, "Ministry of Housing, Spatial Planning and the Environment".* This document is named: „Criteria for sustainable sourcing for waterworks constructions" (*Criterria voor duurzaam inkopen van waterbouwkundige constructies)* (VROM, 2010).

New regulations from the government and requests from the Dutch population, as the opinion of NGO"s, focus for a big part on profit for the population and the planet and are often presented in companies and organisations, by a as previously discussed, a CSR plan. When a company or organisation starts with CSR, it takes more effort from the designer to find the appropriate material and find a supplier and constructor to deliver and assemble it. These programs are excessively interesting and worthy for companies to be creative in looking for other materials and methods to be applied to save costs in the long term for maintenance.

5.1 Regulations and legislation

The maintenance obligation of the government for waterworks applications is governed under the Dutch law. The government and the local parties have the responsibility to take care and maintain the Dutch waterways and its applications. The main reason is to make (safe) usage possible for the long term (Dutch Civil Code Art. 78 lid 2 Wschw).

Toxic materials used in civil waterworks

In Dutch law restrictions are given for usage of toxic materials that can pollute the water for civil water applications, such as Copper chromium Arsenic (CCA). Therefore it is not allowed to use most preservative treated woods in or beside waterways, because the leaching of toxic materials into the water is prohibited unless an official permit is given by a Dutch water board (Dutch Civil Code Art. 6.2 Wtw).

Sourcing of timber, Legality

Legality is the most important factor when sourcing the materials. The EU has developed so-called "EU Timber Regulations" in which the European buyer needs to show the authorities that the timber is sourced legally, in accordance to the law of the country where the timber had its origin. This kind of legality will be realized in 2013.

These EU Timber Regulations will apply from 3 March 2013 onwards and affect timber trade of all 27 EU Member States, including the Netherlands. As an action plan for these regulations (EU FLEGT, 2011), the EU developed the Forest Law Enforcement, Governance and Trade (FLEGT) action plan together with Voluntary Partnership Agreements (VPA‟s) for the timber producing countries (Regulation (EU) No 995/2010).

In the meantime the Dutch national government has a public procurement for wood based products for governments. These are advised to follow up the criteria for timber certification schemes put up by the Timber Procurement Assessment Committee (TPAC). To make sure the timber sourced is sustainably, a review has been done by Baalen *et al*.(2011), which stated that certain governments did not meet their goal required in 2011. National government, municipalities and provinces aim at 100% of their timber purchases being sustainably produced by 2015 (VROM 2011). Here the main used certificates are FSC and PEFC, where PEFC is the most used certificate for softwoods and FSC for tropical hardwoods. FSC is also the most known under the Dutch population. Some governments have a covenant with FSC and only prescribe the use of FSC certified timber in their projects.

FSC is found the best certification for timber by NGO‟s, as stated by *Greenpeace* and the survey of Baalen *et al*. (2011), PEFC has weak statements in some countries, as Malaysia, according to these NGO‟s.

Besides legislation and certifying there are other factors which are also important, such as getting the material on time to the building site, also referred to as „sourcing‟. To source tropical timber, harvesting of timber in tropical countries takes place where it can be badly influenced by tropical weather, bad roads, which raise transport costs and delays in deliveries. Which is found as a weakness of tropical hardwood (Oliver & Donker, 2010).

5.2 Projects/Statement of Work

Since the government is the biggest player in civil waterworks applications the work procedure, of a project, in combination with a *statement of work* is the most used method in the Netherlands to realise a project with the help of contractors. As part of the contract a list of material specifications and application requirements is created. In this way several contractors can apply with various methods to realise the project at a competing price for the customer/owner of the final project. Thus the ministry (VROM), Ministry of Housing, Spatial Planning and the Environment made the document; criteria for sustainable procurement waterworks constructions, of which a translated part, is shown in text box 5.1:

> *"Ensuring sustainability requires that within the sourcing organization on an early stage, before the formal start of the procurement process, the sustainability aspects of the project are being considered. In practice this will be an interplay between the project (spokesman of technique and outcome project), the buyer (financial interests) and for example, the environmental coordinator (spokesman of sustainability).*
> *With the sustainable design of structures, some important conditions for a good organization and the contribution of sustainability in the process. "*

Text box 5.1 (translated text) out of; Criteria voor duurzaam inkopen van waterbouwkundige constructies.

Directive (CPD 93/68/EEG) applies. This European directive is one of the „New Approach" Directives that aim to create a single European market by removing the technical barriers to trade between Member States through the use of harmonized standards and approvals. The CPD advises what kind of norms or regulations for a material could or should be taken into account. For waterworks applications made of timber there are several advising reports available which will be mentioned later. The norms and regulations for the Netherlands are maintained and released by the Dutch Institute for National-, International Norms and Regulations (*Nederlandse Normen*) *the NEN*. The Eurocodes have been drawn up by the European Union (EU) and have to be followed up by their member states. Each member state can make national appendixes to make the Eurocode fulfil national requirements, hereby in the Netherlands this is written in NEN-EN norms or as national appendix (*Nationale Bijlage*).

The norms offer advice for materials and constructions, on how they should be built to ensure an optimal situation. For some materials and constructions the information is given as the minimum requirement (norm) while for others this is only an advice. The national appendix and norms state what is seen as norm and what an advice is. With these Norms the manufacturers declare that their product complies with the essential requirements of the relevant European health, safety and environmental protection legislation. In practice it is similarly called Product Directives (NEN, 2011).

To build a civil waterworks construction the following norms apply, see Table 5.1. These norms are the basic norms, referring to further norms applicable or to be taken into consideration. NEN-EN 1990 forms the basis for structural designs in Civil Waterworks applications. It depends on what materials are used and what structure is made to build an application. Several NEN norms can be applicable since they are often cross referred. These norms can be found while following up the norms mentioned in Table 5.1.

Wood is a natural product and grown in nature which can cause defects, this is why timber in structural applications also needs a visual or mechanical inspection to grade the wood on defects. For hardwood used in civil waterworks applications, a norm called „NEN 5493" (Quality requirements for hardwoods in civil engineering works and other structural applications) is applicable. Meanwhile CUR (2003) gives advice on the usage and appliance of timber in bigger civil waterworks constructions. For softwoods there is a KOMO product certificate which applies BRL 2905/02 (Review guideline for sawn European softwood used in civil engineering works) of which a summary of minimum requirements is given in Appendix 2.

General EU norms	**NEN-EN 1990** Eurocode 0: Basis of structural design	
	NEN-EN 1991 *Eurocode 1:*Design basis of buildings and other civil engineering works, including some geotechnical aspects.	
General Dutch Norms	**NEN 6700 TGB 1990** Technical principles for building structures	
	NEN 6701 TGB 1990 Names and symbols for quantities	
	NEN 6702 TGB 1990 Loading and deformation	
Investigation EU norms	Terrain investigation	**NEN- EN- ISO 22475** Geotechnical investigation and testing
Investigation Dutch Norms	Terrain investigation	**NEN 5140** Probes (electrical cone)
		NEN 5104 Classification of unpaved soil
		NEN 5106 Determination of undrained shear strength - Field vinproef/ *situ vane test*
		NEN-EN-ISO 22475-1 Sampling methods and groundwater measurements
Design EU norms	**NEN-EN 1995** *Eurocode 5: Design of timber structures* *Part 1-1: General - Common rules and rules for buildings* *Part 1-2: General – Structural fire design*	
Design EU norms	**NEN-EN 1997** *Eurocode 7: Geotechnical design –* *Part 1: General rules* *Part 2: Ground investigation and testing*	
Design Dutch Norms	***National Annex to NEN-EN 1997-1:2005/NB:2008 en***	
Design Dutch Norms	***National Annex to NEN-EN 1995-1-1 Eurocode 5:*** *Design of timber structures - Part 1-1: General - Common rules and rules for buildings (includes C1:2006 and A1:2008)*	

Table 5.1 Norms that apply in general when building a civil waterworks construction from timber.

5.4 Internet Survey

To get a good understanding of the market, surveys were sent to the Dutch water boards, the ministry of infrastructure and the environment (RWS), the province of North Holland, and None Governmental Organisations (NGO‟s); Greenpeace and Milieu defensive. All Dutch water boards were asked to take part in the survey, because they represent a large number (Chapter 2 Table 2.1) of various waterways and are in general for the biggest part involved with waterworks constructions. RWS, on the other hand, has one department for infrastructure (DWI) with one person focussed on timber being used. For the NGO‟s a different questionnaire was made, focussing on what materials they favour to be used and why. This online survey was used to gain a better and broader understanding on what moves the parties to their materials of choice.

Out of the Internet Survey for the Dutch water boards it can be seen that in general concrete is the most preferred material to make civil waterworks constructions with 28% of the total points that could be given. Timber came in second place with 24% and steel in third place with 21% (Figure 5.2). For RWS the scores were different here concrete comes at the last place and timber at the first. NGO‟s favoured timber but had a remark that they prefer recycled timber to be applied in civil waterworks constructions.

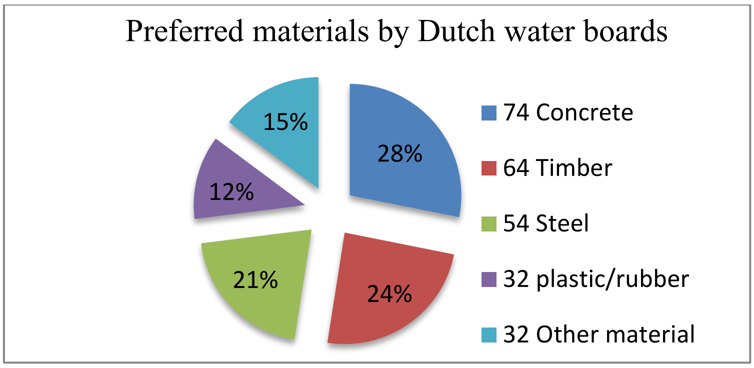


Figure 5.1 Preferred materials by clients with the percentage and amount of total points on the right with the name.

On the question „what is found more important while choosing a material", the water boards responded that durability is a very important factor to be known, followed by sustainability and certificates that prove the sustainability, while the price comes remarkably at a low point (Figure 5.2).

RWS found the sustainability certificates and sustainability the most important and knowledge about the supplier the least important. The price seems of less importance.

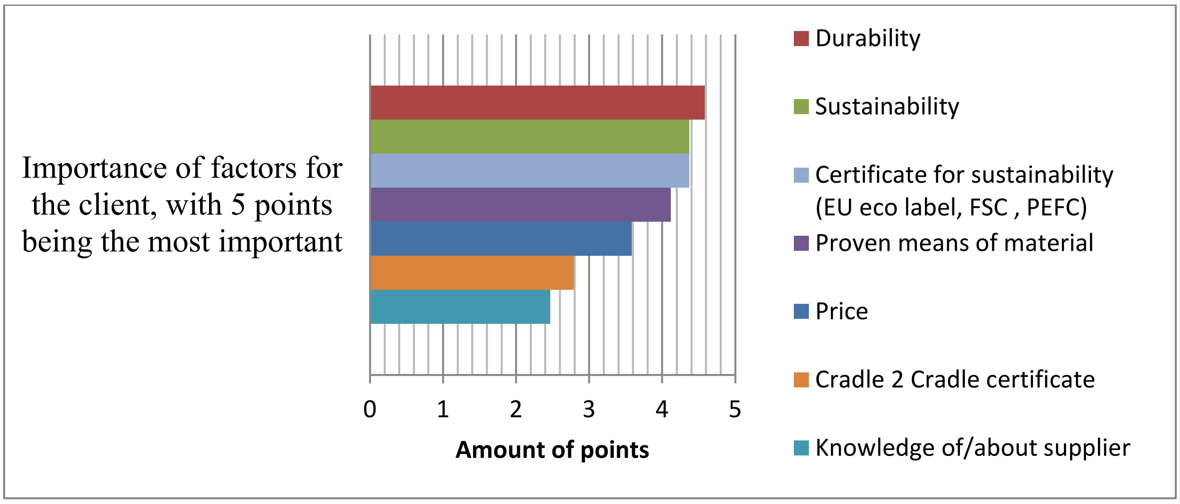


Figure 5.2 Importance of several factors for Dutch water boards to choose a material.

On the question „what information source is found the most important for building materials", the water boards stated that this is „their own knowledge". Followed by advising reports and independent consultancy office. Remarkably, getting more information about building materials from the supplier/timber trader is apparently the least interesting (Figure 5.3). For RWS information from FSC was found the least important and then information from a supplier was also found not that important and came at the second lowest place While their own knowledge is found as the most important information resource.

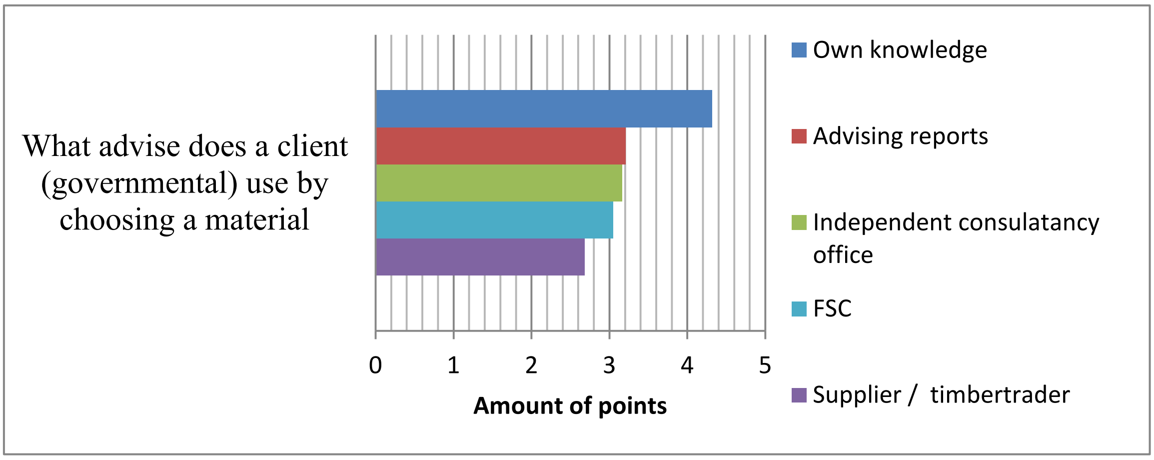


Figure 5.3 Importance of knowledge / advice according client.

In this study the percentage of responding organizations using timber for civil waterworks constructions has also been researched. The amount of organizations that uses or prescribes timber for civil waterworks constructions is spectacularly high with approximately 95%. Remarkably only 5% of the correspondents said they do not use, or prescribe, timber in civil waterworks constructions (Figure 5.4).

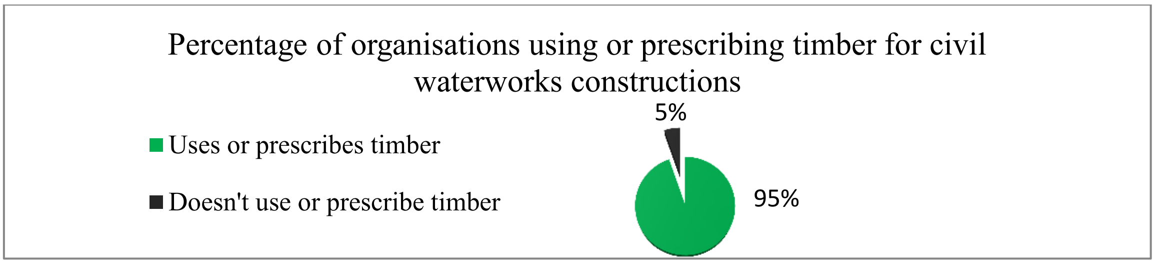


Figure 5.4 Percentage of responders on survey using or prescribing timber.

Another finding is that more organisations used thermo treated wood than acetylated wood or Aqua wood and only CCA treated wood is used regular while ACQ treated wood is also only used sometimes as shown in Figure 5.5.

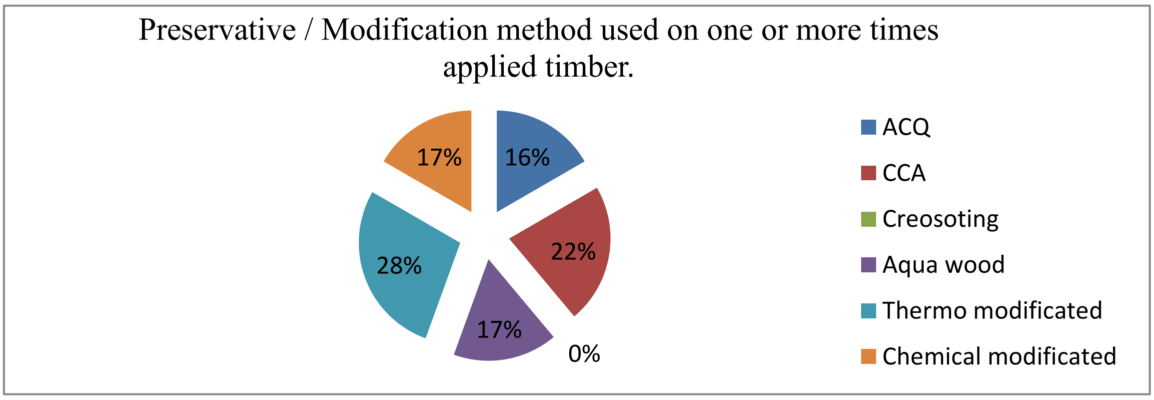


Figure 5.5 Percentage of organizations that applied preservative or modification method treated wood.

6. SWOT analyses

The making of this SWOT analyses is done to find the strengths and weaknesses of Accoya wood applied in civil waterworks applications while looking at the opportunities and threats to the material Accoya wood. This analysis is done by studying the findings as previously discussed, during the project by literature studies and interviews with experts. In Table 6.1 the results of the SWOT analyses are summarised. More explanation is given in paragraphs 6.1 (technical aspects), 6.2 (financial) and 6.3 (environmental).

6.1 SWOT Technical

Strengths

Accoya has a KOMO® certificate and grading terms on its modification method ensuring the quality of the raw product. The acetylation modification process has shown in several tests that Accoya falls in durability class 1 and is better than several other wood species that also fall in durability class 1 in its length of life under the same circumstances (SKH, 2010). Accoya® wood is a light weight material that is comparable with softwoods, as Norway spruce, with around 500 kg/m^3., commonly used durable (class 1-2) (tropical) hardwoods are much heavier, for instance Ekki ±1200 kg/m^3 The dimensional stability is, with the acetylation process improved to less than 1 % in average movement of the wood. Mounting of the material is relatively easy because its softness , pre boring is not required and its easier to saw than most hardwoods. When Accoya wood is sawn or bored it does not reduces its durability because the acetylation is performed throughout the timber. While with for example CCA treatment only the outer side is more durable. Accoya, requires low maintenance because of its high dimensional stability, reducing movement effects as cracking, bowing and twisting, this results in longer life for coatings, applied on Accoya, compared to other frequent used timber species (Masdar, 2011).

Weaknesses

Accoya wood can cause corrosion on most metals, therefore only stainless steel is advised to be used for fastening. Accoya wood is available in given sizes(Appendix 2, table 2.); when larger dimensions are required, Accoya can be finger-jointed or laminated, which makes it more expensive. Accoya is only delivered rough sawn by Accsys Technologies, meaning that customers need to further process the material to meet the exact dimensions and profiles. At this moment Accoya wood has no strength class and can therefore not be CE graded.

Opportunities

When mounting constructions of Accoya wood, the machinery doesn‟t need to be heavy machinery because of its relative light weight and is easiness to saw and drill holes in the timber (Titan wood, 2006). When long sizes are required Accoya wood can be finger-jointed with KOMO certificate, making extended lengths available, while laminating can increase the thickness. Accoya has proven its being in waterway bank construction over a period of 17 years (2011) as boards post to piles construction (Chapter 4.4), which can give extra insurance for the long life of Accoya in waterworks applications.

Threats

Lower weight of a material can make the material more difficult to drill it into the soil. Another problem is gaining the KOMO certificate for European softwood used in waterworks because of the non -European Radiata pine causing that Accoya may not be graded by the BRL 2905 and the bigger year rings (+5mm) in Accoya wood that make Accoya wood automatically fall in the low grade (Class C) of BRL 2905(Appendix 2. Table 3).

6.2 SWOT Financial

Strengths

With the Guarantee of quality by the KOMO certificate for Accoya wood (SKH, 2010) and the warranty time of 25 years on the product, when the product is in water-ground contact, and 50 years above ground and water contact, more assurance can be given to the owner of the construction. The acetylation modification method of Accoya is completely(no perishable parts) which makes it unnecessary to worry about not durable parts as sapwood as in hardwoods. The light weight of Accoya wood makes it possible to transport more by truck or boat than with heavy hardwoods, concrete or steel. It does not need any heavy machines to reshape Accoya timber which makes it easier and cheaper to change raw Accoya wood into an end product (producing/assembling costs). Accsys technologies has its own Research and Development department to give exact advice on what is possible and opportunities.

Weaknesses

To produce Accoya wood an acetylation process is needed, this process is new and relative expensive which makes the material also expensive.

Opportunities

The rising price of good and large quantities of hardwoods, while the quality of the wood declines of the well-known timber species, because the biggest trees have mostly been cut away and costs of labour are rising in most tropical countries (Oliver, R., & Donker, B., 2010). This can make Accoya wood a good alternative for the long lengths of waterways in and around cities or nature reserves, with shallow water and small recreational boats making use of it (category 3 waterways), causing the shore needing protection against erosion. Accoya wood can bring a durable solution with a simple plank post to boarding construction or (plank) timber pilling construction, with the high durability, lower maintenance costs can be gained, which results in less material needed for the life time of a structure. The constructor can save on the input of materials in the long run (25 years guarantee) and on heavy and expensive machinery because Accoya is relative light in weight. Large quantities of the same product can be offered because of the large amount of well managed Radiata forests in the world.

Threats

Despite the fact that Accoya wood can help in low maintenance costs, this is not well known, and governemenatl organisations are not used to less maintenance as later to be mentioned. Thermo treated wood and composites are the biggest competitors of Accoya wood as alternative for tropical hardwoods to be used in civil waterworks application (Internet Survey, 2011). It is the biggest threat to Accoya because the Internet Survey (§5.5 Figure 5.4) show, that more players in civil waterworks know/used thermo treated wood, such as Plato which has a guarantee of 15 years and durability class2 for its materials (Appendix 1 Table 5). While governmental organisations that govern the waterworks applications are rather conservative and used to regular maintenance intervals which makes more durable wood, which is expensive to purchase but cheaper in the long term, difficult to sell to these groups because of projects given to constructors by tendering. It is usually focussed on low purchase costs and properties of the most used materials.

6.3 SWOT Environmental

Strengths

In 2010 Accoya wood was awarded with a cradle to cradle gold certificate, which guarantees that the final product; Accoya wood and its production process are not harm full for environment. Tests (§4.3) have shown that Accoya doesn‟t contain any toxics which are valid for the human and the environmental system (SHR, 2006e). Other tests have shown that Accoya woood is totally recyclable as a natural timber species. Besides that, Accoya wood its life time is extended to one of the most durable pieces of wood. While all wood stores CO2 if applied as construction, Accoya wood can store more because Pinus Radiata grows fast and is in the plantation replanted.

Weaknesses

To produce Accoya wood, *Radiata pine* is sourced from New Zealand, which necessitates that the wood has to travel a long distance before it can be modified into Accoya wood in the Accsys Technologies factory in Arnhem. Despite the fact that Accoya has been awarded a couple of awards, the modification process is still needed to create a perfect Accoya wood.

Opportunities

Accoya wood will have more environmental benefits, in the Acetylation process, when this process uses European Radiata pine. Applications made of Accoya wood are a benefit for nature because once installed (in the right way) it will last a long time, leaving nature to do its thing while storing carbon dioxide as a timber application.

Threats

The threat is a misunderstanding of the processing of Accoya wood, because of the use of „chemicals‟ and at present a lower awareness for nature by the Dutch government and less money available for nature projects in the coming years, after 2011.

Table 6.1 The strengths, weaknesses, opportunities, and threats of Accoya wood for Dutch civil water applications.

Strengths	**Weaknesses**

• *Technical*
  • KOMO certificate on modification method
    ○ Consistent measurable quality
    ○ Own grading specifications
  • Durability class 1
  • Low weight
  • High dimensional stability
  • No pre boring/drilling needed.
  • No special „hard“ saw blades needed.
  • Durable throughout the cross section of the timber piece.
	• *Technical*
	  • Only stainless steel mounting equipment can be used.
	  • Availability sizes Accoya® limited
	  • Only fixed timber sizes available
	  • No Strength class for Accoya
	  • No CE mark for Accoya

• *Financial*
  • Guarantee of quality by KOMO certificate.
  • Material warranty of:
    ○ 25 years when in water contact.
    ○ 50 years above ground and water.
  • More m3 Accoya® transported by (light) trucks/boats. (light weight product)
  • Own R&D department that gives solutions and can help with questions on Accoya wood.
	• *Financial*
	  • Acetylating is an expensive process with high processing costs.

• *Environmental*
  • Contributes to healthy environment
  • Cradle 2 cradle gold certificate which ensures good properties for environment
  • LCAs Show a low overall environmental impact
    ○ No tropical wood from rainforest
    ○ Chemical used are non-toxic,
  • No toxic waste produced
    ○ 100% recyclable
  • Co2 storage as timber material
	• *Environmental*
	  • None EU Radiata Pine used to produce Accoya®
	  • Chemical process needed to create Accoya®

Opportunities	**Threats**

• *Technical*
  • Less maintenance needed
  • Less mounting equipment needed because high dimensional stability.
  • Finger joining Accoya for longer lengths
  • Apply Komo certificate BRL 2905 on Accoya
	• *Technical*
	  • Low weight can make a pole easily change its way while drilling it into the soil.
	  • Norms and regulations on civil waterworks constructions are conservative and less suitable for acetylated wood.
	  • Big year rings (+ 5cm) in Accoya are not allowed for high grade (BRL 2905)

• *Financial*
  • Tropical hardwoods rise in price
  • Long lengths of shallow water ways
  • Lower maintenance costs
  • Less replacing needed
  • Less expensive/heavy machinery needed to install/ shape civil waterworks made of Accoya
  • Large quantities of the same quality Accoya available.
	• *Financial*
	  • Higher purchase costs than with several other materials (tendering for projects)
	  • Increased costs for sourcing raw material (Radiata)
	  • Depending on raw material costs of acetic anhydride and Radiata pine
	  • Governmental organisations governing the waterworks applications are rather conservative.
	  • Focussing of client on purchase costs Accoya® wood with tendering for projects.

• *Environmental*
For Accsys technologies
  • Usage of European timber for Acetylation
For the client
  • Less interruption of nature because of maintenance is needed.
  • Increasing awareness of environmental costs of materials being used.
	• *Environmental*
	  • Misunderstanding of Acetylation process (chemical)
	  • Lower environmental awareness

7. Discussion

During the research and interviews for this study, the main question is; “Is Accoya® wood a suitable alternative for currently used materials in civil waterworks applications?”. Several discussion points were raised. Accoya wood has a lot of favourable features for civil waterworks applications with high demands of the materials being applied.

7.1 Technical alternative

The market of civil waterworks applications is a big market, as described in chapter 2, and can be considered stable because of legislation that demands the maintenance of waterways. While the demand for sustainable materials is increasing, with new national and European legislation and norms, these new developments require that non-durable sourced timber, polluting-materials and/or -conservation methods (Dutch Civil Code art. 6.2 Wtw) to be replaced by durable materials and environmental friendly materials which can fulfil the requirements and specifications requested by civil waterworks constructions. other used alternatives as recycled plastics and composite materials, have shown to have a toxic leaching effect, although this was much less than with CCA treated wood (Weis *et al*., 1992) this can come in favour for Accoya wood which has shown to be not toxic.

The durability is important for civil waterworks since these applications have the highest demands according the defined use classes 3, 4 and 5 by NEN-EN 335. Hereby, according to several tests, wherein Accoya wood is compared with other natural „durable‟ wood species and preservative treated wood species. Such as the recently ended graveyard test of six years in New Zealand by SCION a research institute of the New Zealand forest association. In this test, there were three natural durable hardwood species (Teak, Cypress and Cedar), two pieces of Radiata pine treated with two different amounts of Copper Chrome Arsenic (CCA) to New Zealand standards H3.2 and H4 and one piece of Accoya wood were compared in decay conditions for 6 years (Page et al. 2011).

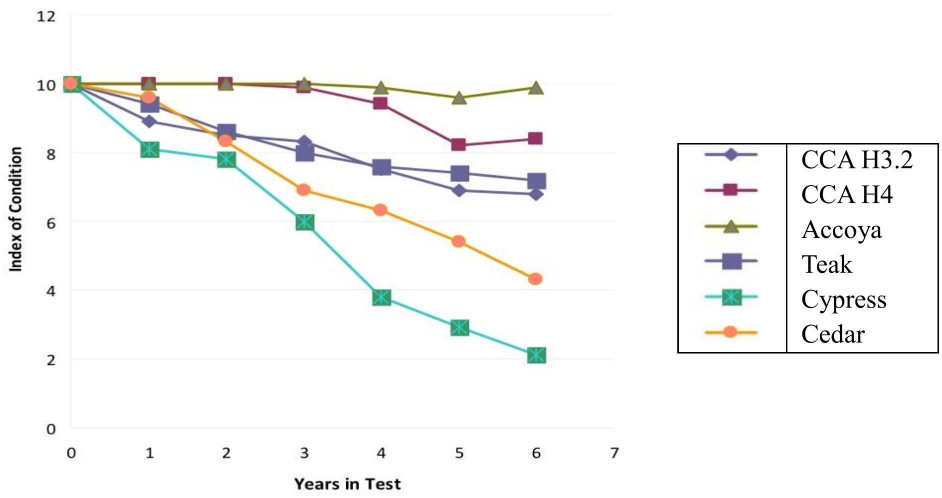


Figure 7.1. Decay rates of fungus cellar stakelets.

The results, as shown in Figure 7.1, present that from the six stakelets (small poles of timber) tested, Accoya wood remained in the best condition while in ground contact, compared to the other five wooden stakelets, which were exactly in the same circumstances and of the same dimensions. Unfortunately none of such tests have been done to the most used timber species for waterworks applications in comparison with Accoya, although these tests show that Accoya is a good durable alternative for other durable wood species and preservative methods such as CCA treatment.

The strength properties of a material are important to show the dimensions needed to build an application so it can with stand the foreseen or calculated loads. For timber this is determined by strength grading and CE marking of the materials. For acetylated wood there is no strength class available yet. This situation requires several tests on Accoya wood for that specific application when CE-marked timber is required. These needed tests make the price of a construction made of/with Accoya wood much more expensive than it is without these tests.

For Accoya wood made by acetylating Radiata pine, sourced from outside Europe, there are no norms to qualify a strength grade at this moment. For Radiata pine sourced from Spain, it could be easier, but these are different in physical character. Beside the source difficulty there are no appropriate norms for acetylated wood species as yet.

Accoya wood has been tested by SKH on its strength properties (§4) which resulted in Accoya wood qualifying for strength class C22, but these results could only be gained after several tests. A normal visual- or machine grade inspection couldn‟t fulfil the requested requirements now.

Test results of the influence of moisture content on the stiffness are shown in Table 7.1 The tests are performed in climate class I according to EN 408. For exterior use, as in the case of civil waterworks, the construction will be exposed in climate class III. Both 90 % RH and water soaked conditions belong to climate class III, although water saturated wood in most instances is not acceptable for wooden constructions. According to Eurocode 5 a reduction of 20% of the MOE is used. This value match with the value found (Table 7.1) for untreated Radiata pine, going from conditioned 65% RH to 90% RH. Acetylated Radiata pine shows only half of this stiffness reduction. Even more outstanding is the different behaviour under the water soaked condition. The acetylated wood shows no further reduction of the stiffness, where the stiffness of untreated wood decreases with app. 36% compared to climate class I. For the MOR a similar effect was found (Tjeerdsma B.F *et al*., 2007).

Table 7.1 Decrease of bending stiffness (MOE) when moisture content increases (Reference 65% RH).

Moisture Content Condition causing stiffness reduction			
	65 % RH	90% RH	Water soaked
		[%]	[%]
Radiata pine	-[d]	-20.0[e]	-36.9[f]
Acetylated radiate pine	-[a]	- 9.6[b]	- 8.6[c]

Moisture content: [a]3,7%, [b]6%, [c]36%,[d]12%, [e]17%, [f]52%

Accoya wood cannot compete with hardwoods and softwoods applied in all applications because some applications require wood with a high hardness, as with lock gates and fender wood, where 8kN is advised in combination with cross grained timber species.(Appendix 1, Table A1.2) With long length wood, as with dolphin structures where lengths of 24 meters or more are sometimes required, calculations have to be made, to estimate the minimum requirements and find the best material. While for structures as poles post to boards, as shore protection on the sides of the category of waterways in the Netherlands; other waterways (§ 2) where CCA treated wood was previously often used and sometimes Ekki (§ 2, Table 2.5). Here, the requirements are mostly consisting out of a durability class and available dimensions.

7.2 Financial feasibility

The price of a material used is not very important according to the Internet Survey. The survey results show that the price of materials came at fifth place of the seven of which they found important. This was behind the durability and sustainability properties proved that regarding the changes of Accoya being applied by them in civil waterworks projects the price subject raised and was mentioned as being important because work is given out by government bodies by a statement of work (*bestek*) which often involves tendering (*aanbesteding*). Here the durability, sustainability and source of a material are the most important aspects. Accoya wood has been proved to last longer than other wood species applied in civil waterworks applications. It carries also a FSC or PEFC - ‚cradle to cradle gold certificate and less maintenance is needed. These requirements, for example: at least 25 years guarantee on wood placed in water contact and low shrink and swell properties with a maximal of 2.5%, are usually not put into the specifications for the statement of works of a waterworks project. In the most used specifications the material Accoya falls out of focus mainly because of the pricing in whereas it meets the strength criteria and sustainability requested.

Another point is that government authorities seem to focus only in the time that the governing body, in case of water boards, a general administrative body (*raad van bestuur*) of the water board holds its position. This is four years and when maintenance costs are reduced during the time of the following general administrative body, than they seem to pay less attention to the costs reduction involved with maintenance. Because the general administrative body get a budget amount only for four years, the plans regarding a certain project area can change (Twist &De Wit, 2011). In the meantime the ministry VROM advise the government agents how to source the materials: Criteria for sustainable sourcing of waterworks constructions‟ (*Criterria voor duurzaam inkopen van waterbouwkundige constructies*) (VROM, 2010). This document gives an advise on the required lifetime of a construction and applying cradle to cradle criteria for the materials used, which is constructed so to reduce the footprint on the environment. Simply because of that, this advice is often disregarded. For these points on durability, Accoya offers a better score than most other used materials.

The price for materials used in civil waterworks is difficult to obtain and compare, the price depends mostly on the volume, sizes and quality of the material that will be applied. Investigation and an interview with a co-worker at Accsys (2011) showed that at this moment the prices are relative low for timber, compared to ± 5 years ago, but they are increasing (Figure 7.2). This relative low price can be explained by a lower demand in the Dutch building industry caused by the economic crisis around 2007 in the Netherlands, while the demand increased in other countries (America, Asia), this can explain the rising price of Ekki. The price for steel has increased in 2010 while the price for plastic was relative constant after a fall in 2009 (Cobouw, 2011). The prices (Appendix 1) ‚received partly from a timber trader (Timbertrader, 2011) and partly from Stiho Utrecht (Stiho, 2011) show that the price for Ekki is relative low when compared to Angelim vermelho. While untreated Norway spruce is the cheapest to purchase, and Plato® spruce is almost as expensive as Accoya® wood for the use in the civil waterworks. The prices can be reflected to the durability and only Plato and Accoya offer a guarantee on the timber. These prices are indications for the first half year of 2011 and depend on the volume ordered and quality.

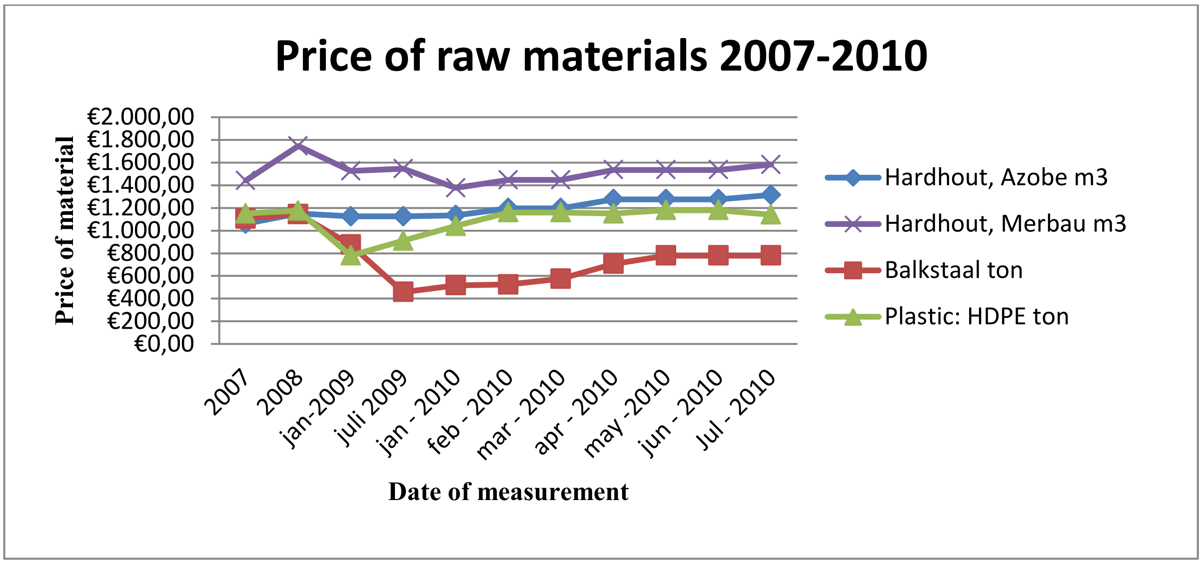


Figure 7.2 Price matrix indication for materials from 2007 until 2010 (Cobouw, 2011).

* Hardhout: Hardwood

* Balkstaal: Steel

7.3 Threats

In the; „*sustainability criteria for wood used for the making of civil waterworks applications*", decreed by the ministry *VROM* states: „wood may not be used when it is in contact with the ground". Therefore RWS changed the word; „wood" into „not durable wood", for the RWS building criteria. But for most government organisations, this can make them decide not to choose any wood for parts in constructions such as poles or boards in ground contact.

The norms with their grading terms for civil waterworks applications are mainly based on hardwoods, since hardwoods generally have the highest durability (class 1, 2 and 3) . When softwoods are used, the practical guideline BRL 2905 can be used. Although this guideline is based on European softwoods, it comes the closest to Accoya® wood but can"t be applied according to SKH who also certify companies with a KOMO certificate based on BRL 2905. This is because Accoya is acetylated non-European Radiata pine. BRL 2905 is based on European softwoods and uses visual grading methods.

New approved technologies, with machine strength grading, can offer new and better opportunities in favour for innovation and better usage of timber as building material than with old visual grading terms based on, for example, the size of year rings such as in BRL 2905. For Accoya wood this would mean, that based on the size of year rings of Radiata pine, all Accoya wood will fall in class C.

At this moment the lower price of alternatives such as thermo wood and tropical hardwoods will lower the demand in civil waterworks constructions for Accoya wood. The usage of tendering methods in which they focus on purchasing costs, by organisations such as governments, results mostly in less innovative materials as Accoya wood, to be applied in civil waterworks applications for smaller projects for city councils costing under €1,2 million and national government under the €4,5 million (Koenen, 2011).

7.4 Opportunities

The opportunities for Accoya are; in the field of pricing. This has to do with the price of other materials with the same durability. Since Accoya is the only wood material with a 25 years guarantee in the Netherlands rising prices and increasing rules, for the import of wood and the usage of it is likely that in time Accoya will become more and more interesting to apply as a building material for civil waterworks constructions, where it meets the required properties or innovation is wanted. The reduced maintenance costs can give the material an extra feature especially for places where nature plays an important role, like nature reserves.

The Dutch government has as goal, to purchase 100% sustainable sourced timber by 2015, following the program of TPAC. The National government‟s goal is to purchase 100% sustainable material by 2015. City councils have a goal of 75% and other governments 50% by 2010. The NGO party „*Milieu defensie*" came with a critical review in April 2011; „*Van oerwoud naar overheid*" (From jungle to government), that stated that the timber purchase of the government was not completely fulfilling their stated goals for the sustainable purchasing of timber. *Milieu defensie* stated that water boards and provinces met their goal of purchasing 50 % sustainable. The national government did not fulfil their goal of 100% sustainable purchasing (Baalen *et al.,* 2011). The Government is doing well but needs further improvement, as stated by Milieu defensive.

7.5 The Research

In this study, literature was studied and online surveys were constructed to get the information given in this study. Invitations for the Internet Survey were sent to several Dutch water boards, *Rijkswater staat* and the engineering department of the province of North Holland. There were some small problems before and during the sending out of the invitations, with good cooperation these problems were quickly solved. The cooperation with the targeted organisations for the online survey was good, which resulted in a high response for the online survey of more than 70%. After the surveys were sent, some interviews were held to get better understanding about the given information with the Internet Survey.

Beside questionnaires, literature were studied to get information regarding to this research. The literature gave me a broader view on matters that rise to build civil waterworks applications from timber, most literature was either for wood or other materials. There is hardly any literature that takes basic building materials (concrete, metal, timber) into consideration. This makes it difficult to compare different kinds of materials. However the Internet Survey and the interviews gave more information over the choice made for materials. Another difficult thing to find were pricing patterns and history of prices for materials, especially for timber.

To get a better idea on the options for Accoya a constructor was contacted, but since the deadlines were not met, by this constructor this part of the study, with a comparison of costs for construction materials could not be made. For further studies in the field of comparisons for construction and maintenance costs, an engineering and advice company should be contacted for a follow up study.

8. Conclusion

Accoya wood is highly resistant to decay, dimensionally stable and easy to process which makes it technically suitable for use in civil waterworks constructions. Only Accoya does not have strength grading criteria for CE marking and cannot be graded according BRL 2905 which is the only grading method for softwoods used in civil waterworks applications in the Netherlands. This is because it is sourced from outside Europe. Resulting in the fact that Accoya can be used for constructions that do not require CE marked or graded timber according KOMO BRL 2905. Constructions where this is usually not required are water bank protection constructions as timber pilling and planks post to boarding constructions. The long guaranteed life time of 25 years for Accoya wood applied in use class 4 of EN 335 (in contact with ground or fresh water) and improved properties like dimensional stability and easy to handle (510 kg/m3) and reshape make Accoya wood cost saving, in the fabricating period, and on the long run on maintenance costs of a structure, this can make Accoya wood financially interesting.

The threat for Accoya wood is that customers and decision makers do not know Accoya wood with its properties (as shown by the Internet Survey) the properties of Accoya are in line with advising reports mentioned in § 5. „Criteria for sustainable sourcing for waterworks constructions". The usual methods to obtain materials applied in civil waterworks constructions form another threat with tendering, with this method the focus lays mainly in lower purchase costs, while the requirements put down are formulated in favour of the most used materials/ tropical hardwoods and not on a longer lifetime with a lower footprint on the environment.

The opportunities for Accsys Technologies are therefore to create more awareness by decision maker on the existence of Accoya wood with its properties and certificates which are in line with the demands of their advising reports on purchasing materials and not on purchasing costs. For the producing of Accoya wood the opportunity lays in getting CE mark criteria and search for wood that can be graded by a norm used for civil waterworks applications or that grading norms are adapted in a way that Accoya wood can be graded.

9. Recommendations

To make Accoya wood more attractive for use as material in civil waterworks, some tests for example the on-going test applied in 1994 (§4.4) have to be published to show the long life time and properties of Accoya used as water bank protection in civil waterworks constructions.

9.1 Technical

When building with Accoya® wood, the architect/constructor will be able to use the same equipment and machinery as previously for CCA preservative treated timber and lighter equipment than for most used hardwoods species, metal or concrete. It is because m3 Accoya wood weight less than most other materials. Meanwhile they have to make sure that there are no metals used that could react to the small amount of Acetyl in Accoya Wood (Chapter 4, reaction with metal). The advice, from Accsys Technologies, to builders is to use Stainless Steel (RVS) material to connect or assemble Accoya wood products, which makes the assembling a little more expensive but at the same time more durable.

Accoya wood can benefit, with its key selling points of sustainability and durability proven by tests and certificates, by the government‟s 100% sustainable sourced timber goal of 2015

For the production of Accoya wood, the use of European Radiata pine gives options on grading by BRL 2905, which makes it possible to sell Accoya wood with a KOMO certificate, only here the question rises, does the purchase cost of EU Radiata pine (Spain) cover the price of Accoya wood with a BRL 2905 KOMO certificate. Are the year rings of EU Radiate pine smaller than New Zealand Radiate pine? Besides these points small modifications have to be made in the standard grading criteria of Accoya wood as shown in Appendix 2.

The following two questions remain and need further research; are the year rings of EU radiate pine smaller than New Zealand radiate pine if so Accoya can be graded as class B, and will the purchase costs of EU Radiata pine (Spain) be covered by the price of Accoya wood with BRL 2905 KOMO certificate?

9.2 Financial

The benefits of Accoya wood is that it is easy to handle, process (saw) into shape and to place, because of its smooth surface and relative light weight in comparison to durable hardwoods. While the maintenance and environmental costs are lower than with materials other than wood and with most hardwoods with the same durability class 1. Because it does not maintain alkaloids as in several tropical hardwoods, reshaping materials will last longer. Together with the fact, that Accoya wood lasts longer with a guarantee of 25 years when in contact with fresh water. To prove these facts the following actions should be taken into consideration:

1. Comparison calculations of purchase and maintenance costs structures.

For this a cost overview should be made for several waterworks applications for which Accoya can be used, with calculations of; the purchase costs and maintenance costs over a period of 25 years (warranty time Accoya). When these costs are also compared to other materials, a comparison table should be made, which can show, when the optimum situation is reached ,in regard to the most used other timber species, thermo treated wood and optional, other materials as plastics and composites.

2. Differences in civil waterworks applications projects

For projects where the installation costs of civil waterworks constructions are not paid by the one who is installing the construction (national government), but the one installing has to carry the maintenance costs then Accoya wood can offer even better benefits for this party.

9.3 Environment

For the construction of civil waterworks applications as water bank protections, the usage of recycled Accoya wood can be taken into consideration. While tests shown that Accoya wood is good for the environment should be shown, to give an extra argument why using Accoya wood can be recommended or the construction of civil waterworks application.

Glossary of Abbreviations and Names

ASTM	American Society for the Testing and Materials
BRL	*Beoordelingrichtlijnen* (in de bouwsector) / Assessment Guidelines (mainly in construction)
Camco	A global developer of greenhouse gas emissions reduction and clean energy projects.
CBS	*Central Bureau voor de Statistiek /* Statistics Netherlands, is an organization which has responsibility for collecting and processing data in order to publish statistics to be used in practice, by policymakers and for scientific research
CCA treatment	Chromatid Copper Arsenate treatment, preservative treatment method for timber/
CE marking	(Mandatory) confirmatory mark for products placed on the market in the European economic area.
Cobouw	An information portal, newspaper for construction and all necessary information in the building and construction industry.
CSR (MVO)	Corporate Social Responsibility (Maatschapelijk Verantwoord Ondernemen) plan.
CUR	*Civieltechnisch Centrum Uitvoering Research en Regelgeving /* Centre for civil engineering research and advise with several advising reports.
EN – xxx	European norms for products, materials or procedures.
EU	European Union
FLEGT	Forest Law Enforcement Governance and Trade, is the European union"s to the global problem of illegal logging and the trade in timber products
FSC	Forest Stewardship Council, for the certification of forests and timber sourced from the certified forests.
GDP	Gross Domestic Product
GWW	*Grond- , weg-, en waterbouw* / Buildt in land, road and water
KOMO®	Certificaat voor *Onafhankelijk getoetste kwaliteit* (*een kwaliteitsmerk dat in de Nederlandse bouw gebruikt wordt)* / An authoritative for the building industry which is used for the Dutch construction (B&U and Civil Engineering)
MC	Moisture content
NEN	*Nederlandse Norm* / non-profit institute for the maintaining/ evaluating and implementing of Norms products in the Netherlands

NGO	Non-governmental organization
PEFC	Programme for the Endorsement of Forest Certification
RH	Relative Humidity
RWS	*Rijkswaterstaat* / Executive arm of the Dutch ministry of infrastructure and the environment
SBH/Probos	*Stichting Bos en Hout* / A Dutch independent, non-profit forest and wood research organization
SHR	*Stichting Hout Research* / Independent timber research institute
SKH	*Stichting Keur Hout* / Independent timber branch certification institute
TPAC	Timber Procurement Assessment Committee
VHN	*Verduurzaamd Hout in Nederland* / Association of companies in the wood treatment business
VPA	Voluntary Partnership Agreements, are bilateral agreements between the EU and tropical wood exporting countries. It is made to guarantee that the wood imported into the EU come from legal sources.
VROM	*Ministerie van Volkshuisvesting, Ruimtelijke ordening en Milieubeheer* / The Dutch ministry of infrastructure and environment

References

Accsys, 2010a. *Wood Properties Research Reports*. [Online]
Available at: http://www.accoya.com/downloads/#
[Accessed 22 June 2011]

Accsys, 2010b. *Accoya® hout behaalt cradle to cradle certificaat.* [Online] (Press announcement)
Available at: http://www.slideshare.net/Wissekomm/accoyahout-behaalt-cradle-to-cradlecertificaat
[Accessed 20 March 2011]

Accsys, 2011. Accoya: General brochure English 2011 [Online]
Available at: http://www.accoya.com/wp-content/uploads/2011/05/CB_EU_v1.1.pdf
[accessed 20 MArch 2011]

Baalen, van A., Ankersmit, C., & Stofberg, N., 2011. Van oerwoud naar overheid, een onderzoek naar duurzaam houtgebruik in bouwprojecten van de overheid. *Milieu defensie*. 4-2011.
Available at: http://milieudefensie.nl/publicaties/rapporten/van-oerwoud-naar-overheid/at_download/file
[Accessed: 2 May 2011].

Beckers, E.P.J., Meijer, M. de, Militz, H. and Stevens, M. (1998). Performance of finishes on wood that is chemically modified by acetylation. Journal of Coatings Technology.

Benthem, M., 2009, Duurzaamgeproduceerd hout in de gww. *Civiele techniek*, [Online]. 5(6),
Available at:
http://www.probos.nl/home/pdf/Duurzaam%20geproduceerd%20hout%20in%20GWW_Civiele%20Techniek_56_2009.pdf
[Accessed at: 5 May 2011].

Bogaardt, V., 2000. *Hout op de grens van land en water.* Stichting Bos en Hout/ Probos. [Online].
Available at: http://www.probos.nl/home/bosbericht_bestanden/bosenhoutberichten2000-09.pdf
[Accessed 12 June 2011].

Bongers, F. 2011. On-going tests on Accoya wood. [interview] (Personal communication, 15 June 2011)

Bongers, H.P.M. & Beckers, E.P.J. 2003. Mechanical properties of acetylated solid wood treated on pilot plant scale. *Proceedings of the first European Conference on Wood Modification*.341-350.

Bluyssen, W.J., 2011. *Prijs van Accoya voor civile waterwerk applicaties*. [Email] (Personal communication, 16 May 2011).

Brolsma, J.U., 2010. *Beknopte geschiedenis van binnenvaart en vaarwegen Rijkswatertstaat, Dienst Verkeer en Scheepvaart*. [Online]
Available at:
http://www.wcc2011.nl/docs/Beknopte%20geschiedenis%20van%20binnenvaart%20en%20vaarwegen.pdf
[Accessed 6 June 2011].

Buis, J., 1985. Historia Forestis: Nederlandse Bosgeschiedenis. *HES Studia Historica (Post-doctoral thesis), parts I and II*. 1&2. Utrecht: HES Publishers.

Buis, J.,1993. Holland Houtland, De geschiedenis van het Nederlandse bos. *HES Studia Historica.* The Netherlands: Amsterdam.

Bureauvoorlichtingbinnenvaart, 2011. Bureau voorlichting binnenvaart, Vaarwegen Nederland. Availeble at: http://www.bureauvoorlichtingbinnenvaart.nl/over/basiskennis/vaarwegen
[Accessed 26 April 2011]

BVB., 2011, Bureauvoorlichtingbinnenvaart 2011 Bureau voorlichting binnenvaart, Vaarwegen Nederland.
Available at: http://www.bureauvoorlichtingbinnenvaart.nl/over/basiskennis/vaarwegen
[Accessed 26 april 2011]

CBS – StatlineGWW, 2010. Prijsindexcijfers grond-, weg- en waterbouw (GWW). *Centraal Bureau statistiek, 2000 = 100.* [Online].
Available at:
http://statline.CBS.nl/StatWeb/publication/?VW=T&DM=SLNL&PA=70945ned&D1=10-13&D2=a&HD=110505-1221&STB=G1,T&CHARTTYPE=1
[Accessed 5 May 2011].

CBS, 2010. *Lengte van vaarwegen; naar vaarwegkenmerken en provincie.* [Online] (Updated 22 November 2010)
Available at:
http://statline.CBS.nl/StatWeb/publication/?VW=T&DM=SLNL&PA=71531ned&D1=0-33&D2=0&D3=a&HD=110527-1354&HDR=G1,G2&STB=T
[Accessed 27 May 2011].

Cobouw,2011. *Grondstof prijzen.* Nederlands Bouwkosten Instituut, Doetinchem, The Netherlands.

Crossman, M., & Simm J., 2004. *Manual on the use of timber in coastal and river engineering*. London: Thomas Telfort Publishing.

CUR, 2003, CUR report, 213 Hout in de GWW-sector "duurzaam detailleren in hout" Stichting CURNET, The Netherlands, Gouda

CUR, 2005, CUR report 166 Damwandconstructies (4th print, part 1 and 2) Stichting CURNET, The Netherlands, Gouda

Data sheet Accoya, 2010. *Dimensions of Accoya® wood*. Arnhem: Accsys Technologies.

*DIN 52189 (*Deutsches Institut für Normung)*,* 1981. Prüfung von Holz; Schlagbiegeversuch; Bestimmung der. Bruchschlagarbeit, Germany: Berlin.

Dubbelaar. J. 2011. Geschiktheid Accoya voor KOMO /BRL 2905 and CE marking [phone] (Personal communication, 14 May 2011)

DWW wijzer (Ministerie van verkeer en waterstaat, The Netherlands) 93, 1999a. *construeren met houten damwand* [Online].
Available at: http://english.verkeerenwaterstaat.nl/kennisplein/3/6/366467/DWWwijzer93.pdf
[Accessed 25 April 2011].

DWW wijzer (Ministerie van verkeer en waterstaat, The Netherlands) 91, 1999b. *Mariene borders in hout.* [Online].
Available at: http://english.verkeerenwaterstaat.nl/kennisplein/3/6/366465/DWWwijzer91.pdf
[Accessed 27 April 2011].

Environment Agency, 1999. *Waterway bank protection: a guide to erosion assessment and management.*
Environment agency, Bristol, United Kindom

EU FLEGT 2011, FLEGT Voluntary Partnership Agreements (VPAs)
Available at: http://ec.europa.eu/environment/forests/flegt.htm
[Accessed at: 20 may 2011]

Franken, R., Kragt, F., & Kuiper, R., 2004. Water in de Nota Ruimte; ruimte voor water?. *H_2O,* 11-2004, pp.1-4.

Herik , Van den, 2011, Usage and construction of pilling structures for shore protection, constructor in hydraulic engineering, Sliedrecht, The Netherlands [phone] (Personal communication, 19 May 2011)

Homan, W.J. & Bongers, H.P.M., 2004. *Influence of up-scaling processes on degree and gradient of acetylation in spruce and beech.* Presentation given at the Final Conference of COST Action E22, Estoril, Portugal.

Klüppel, A Militz1 H., Cragg,S., Mail, C., 2010. *Resistance of Modified Wood to Marine Borers Conference on Wood Modification 2010*. Europe.

Koenen, I., 2011. Doorbraak innovatief aanbesteden. Cobouw, 30 June. p.1.

Kraan, M (European Conference of Ministers of Transport), 2002. *The inland waterways of tomorrow on the European continent*. France, Paris, 30 January 2002.

Kuilen, J.W.G van de., COST E53, 2008. *The use of timber in hydraulic structures*. Delft, The Netherlands 29-30 October 2008. The Netherlands, Delft.
Available at: http://www.coste53.net/downloads/Delft/Presentations/COSTE53-Conference_Delft_van_de_Kuilen.pdf
[Accessed at: 06-May-2011]

Leusen, van B., 1975. *Kleine waterbouwkundige constructies*. Culemborg, The Netherlands: Educaboek B.V.

Maas. G.P., 2011. *Comparison of quay wall designs in concrete, steel, wood and composites with regard to the CO2-emission and the Life Cycle Analysis*. Delft: Delft University of Technology.

Masdar, 2011. *Accoya*. The Fuiture Build tm.com :an initiative of Masdar.
Availeble at: http://www.thefuturebuild.com/titan-wood-bv-accsys-technologies/accoya/product.html
[Accessed 8 June 2011].

Mumm (Management Unit of North Sea Mathematical Models), 2011. *North Sea facts*. The Management Unit of the North Sea Mathematical Models and the Scheldt estuary, Brussels, Belgium.
Available at: http://www.mumm.ac.be/EN/NorthSea/facts.php
[Accessed 5 July-2011].

Muss, H., & Purse, L., 2009. Greenhouse Gas Emissions Assesement for Accoya® Wood. *Camco Global, Sheffield, United Kingdom*, [Online].
Available at:
http://www.accoya.com/pdf/Greenhouse_Gase_Emisssions_Assessment_Accoya.pdf
[Accessed 24 April 2011].

NEN, 2011, *Wat is een norm?*.normen instituut Nederland.
Available at: http://www.nen.nl/web/Normen-ontwikkelen/Wat-is-een-norm.htm
[Accessed 14 June 2011].

Oldenburger, J. & van den Briel, J., 2009. *Het juiste hout op de juiste plaats.* [Online].
Available at: http://www.probos.nl/home/pdf/RapportHetjuistehoutopdejuisteplaats_mei2009.pdf
[Accessed 22 June 2011].

Oliver, R., & Donker, B., 2010. Levelling the playing field. *ITTO Technical series #36.*

Owen, J., 2006. World's Forests Rebounding, Study Suggests, *National Geographic News*. [Online] (Updated 13 November 2006).
Available at: http://news.nationalgeographic.com/news/2006/11/061113-forests.html
[Accessed 9 May 2011].

Probos, 2010. Duurzaam Bosbeheer & Legaliteit. *Infoblad FLEGT,* 12, 2010.

Page, D., Hedley, M., & Waals, van der, J., 2011. The durability of Accoya radiate pine sapwood(results from ground contact tests after six years exposure). *SCION next generation biomaterials.* Rosorua, New Zealand. March 2011.
Available at: www.accoya.com/wp-content/uploads/2011/05/scion-6.pdf
[Accessed 5 May 2011].

Regulation (EU) No. 995/2010 of the European Parliament and of the council of 20 October 2010 (Laying down the obligations of operators who place timber and timber products on the market). (Official journal of the European Union) (1. 295/23). Belgium; Brussel.

RWS & NWP,2011. *Rijkswaterstaat en Nederlands water partnership*. [Online].
Available at:
http://www.waterland.net/index.cfm/site/Water%20in%20the%20Netherlands/pageid/E3B3B416-FB4E-0AB8-2FB6E2B271F1BD6E/index.cfm
[Accessed 10 May 2011]

SHR, 2006b. Sterkteclassificering van geacetyleerd Radiata Pine(Strength classes ranking of acetylated Radiata Pine). *Report code 6.104*. SHR Timber Research. The Netherlands: Wageningen.

SHR, 2006c. Janka hardness of Accoya® wood. *Report code 6.352*. SHR Timber Research. The Netherlands: Wageningen.

SHR, 2006d. (d.d. 30 oktober 2006). Corrosie van verbindingsmiddelen in geacetyleerd Radiata Pine. SHR Timber Research, the Netherlands, Wageningen.

SHR, 2006e. (d.d 23 may 2006) toxicity acetylated wood, SHR Timber Research. The Netherlands: Wageningen.
Available at: http://www.accoya.com/wp-content/uploads/2011/05/Nontoxic.pdf
[Accessed 9 June 2011].

SHR, 2007. Durability of acetylated Radiata Pine – investigation of the resistance against brown-, white- and soft rot fungi. *Report code 6.244-3.* SHR Timber Research. The Netherlands: Wageningen.

SHR, 2006a. Impact bending strength of Accoya® wood. *Report code 6.353*. SHR Timber Research. The Netherlands: Wageningen.

SKH, 2010. (d.d 13 July 2010) Komo product certificate Modified timber Accoya® Wood. The Netherlands, Wageningen.
Available at: http://www.accoya.com/wp-content/uploads/2011/05/KOMO-product-certificate.pdf
[Accessed 7 April 2011].

Smith, S.T., 2007. *A cost-benefit analysis of creosote-treated wood vs. non-treated wood materials.*
Available at: http://creosotecouncil.org/pdf/CCIII_Cost-BenefitAnalysis.pdf
[Accessed 13 July2011].

Stiho Utrecht, 2011. *Price range Plato, Norway spruce, and Accoya for GWW as sheet pilling.*[Phone] (Personal communication, 28 July 2011).

Timber trader, 2011. *Price range for Most used hardwood species used in GWW*.. [Email] (Personal communication, 11 April 2011).

Titan Wood, 2006 (d.d 16 November 2006). Titan Wood Research report 200601; *Machine ability of Accoya*. Titan Wood, the Netherlands, Arnhem

Titan Wood, 2007 (d.d 30 May 2007). Titan wood research overview tm, Reaction with metals. Titan Wood, Arnhem, The Netherlands.

Titan Wood, 2010 (d.d 9 July 2010). Technical Summary; Health and safety considations and environmental impact. Accoya® wood and the acetylation process. Titan Wood, Arnhem, the Netherlands.

Titan Wood, n.d., Accoya® guarantee certificate. Titan Wood, Arnhem, The Netherlands. Available at:
www.westgatejoinery.co.uk%2FAccoya%2520Guarantee%2520Certificate.pdf&rct=j&q=accoya%20guarantee&ei=U3RJTrG9AoaeOr26yPUH&usg=AFQjCNHQtawLPi-pudItROo1qdOp8KTXLw&sig2=FKovh3VKUAew9R31JeQULQ&cad=rja
[Accessed 8 July 2011].

Tjeerdsma B.F., Boonstra, M. and Jorrisen, A. (2007). Accetylated wood in exterior and heavy load-bearing constructions: building of two timber traffic bridges of acetylated Radiata pine. *Proceeding of the Third European Conference on wood Modification.*

Twist & de Wit, 2011.*Gepland oever beschoeiings project door waterschap Stichtse Rijnlanden, materiaal keuze en motivatie, mogelijkheden van Accoya.* [interview] (Personal communication, 16 May 2011)

Van den Dobbelsteen, A., & Alberts, K., 2001. *Milieueffecten van bouwmaterialen (Duurzaam omgaan met grondstoffen).*
Available at: http://www.wegwijzerduurzaambouwen.be/pdf/174.pdf
[Accessed 13 July 2011]

VHN, 2011. Verduurzaamd Hout Nederland. *Indicaties van de natuurlijke duurzaamheid, De levensduurindicatie bij permanente blootstelling aan vocht uit de grond of aan zoetwater.*[Online]
Available at: http://www.vhn.org/output/NEN350.htm
[Accsessed 5 April 2011]

VROM 1991. Tweede structuur schema verkeer en vervoer 1991. *Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer 1991* [Online].
Available at: http://www.rijksoverheid.nl/documenten-en-publicaties/kamerstukken/2009/11/14/tweede-structuurschema-verkeer-en-vervoer-1991.html
[Accessed 7 April 2011]

VROM, 2010. Criteria voor duurzaam inkopen van Waterbouwkundige Constructies 2010. *Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer 2010*, [Online]. 1.5. Available at:
http://www.pianoo.nl/pv_obj_cache/pv_obj_id_3225076447B92D25EC3E02BB856B79F95D240300/filename/criteriadocumentwaterbouwkundigeconstructiesv15.pdf
[Accessed 26 April 2011]

VROM, 2011. Factsheet Monitor Duurzaam Inkopen 2010. *Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer 2011*, [Online]. 3,

Available at: http://www.rijksoverheid.nl/onderwerpen/duurzaam-inkopen/documenten-en-publicaties/publicaties-pb51/factsheet-monitor-duurzaam-inkopen-2010.html
[Accessed 26 April 2011].

VROM, 2011. Duurzaamheids beleid rijksoverheid. *Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer 2011,* [Online].
Available at: http://www.rijksoverheid.nl/onderwerpen/duurzaam-inkopen#ref-vrom
[Accessed 17 May 2011].

Wassink, J.T., 1984. Berichten: Waarom Tropisch Hout? Vroeger, nu, straks. *Stichting Bos en Hout Bos en hout*, [Online]. 2,
Available at: http://www.probos.nl/home/bosbericht_bestanden/bosenhoutberichten1983-02.pdf
[Accessed 1 April 2011].

Wellink, A., & Ravenhorst, G.J.P., 2008. *Applications and quality requirements for (tropical) hardwoods. Conferenece COST E53*, 29-30 October 2008. The Netherlands: Delft.

Weis, P. J. S., Weis, A., Greenberg & T.J. Nosker, 1992. *Toxicity of construction materials in the marine environment*. Arch Environ. Contam. Toxicol 22: 99-106.

Wiselius, S.I. ed., 2010. *Houtvademecum 10th version.* Centrum Hout Almere, The Netherlands: SDU.

Appendix 1 Main used timber species

Short description of main used timber species in Dutch civil waterworks applications:

For the most used timber species the main properties are given below. Since in civil waterworks the wood is wet, the reduction of the bending strength and modulus of elasticity are given from dry (circa 12% wood moisture content) to wet (green) conditions.

Ekki, *Azobe*, (*Lophira alata*)
Sourced from; West and Central Africa

Ekki is a strong and wear resistant durable timber species that offers resistance against marine borers, which make it suitable for civil waterworks applications. The durability class is I/II and a typical strength class is D70. Ekki is used to make applications such as; lock gates, bridges and sheet pilling. The availability in long lengths and in almost any dimension combined with a good durability are the advantages of Ekki.

Mechanical Properties**:**

Moisture content (%)	Bending strength (kg/cm^2)		Modulus of elasticity(MOE) (1000 kg/cm^2)		Weight Kg/m^3	Shrinkage % (1)		Hardness N (1)	
								surface area	Along side
Green	1049	38 %	143	17,2 %	1009	Rad	Tang		
12%	1692		174		945	3.8	6.0	19.200	17.000

Source: text: Wiselius, 2010 data: thewoodexplorer, 2011, (1) wiselius, 2010

Basrolocus, (*Dicorynia guianensis Amsh.*)
Sourced from; Surinam, French Guiana, Guyana, Brasil

Basrolocus is often used for poles, because of its high amount of silica content giving it resistance against marine borers and strength. Basrolocus is available in long lengths (24 meter) and offers high abrasion resistance combined with a durability class of I/II and a typical strength class is C22 old new D18.

Mechanical Properties**:**

Moisture content (%)	Bending strength (kg/cm^2)		Modulus of elasticity (MOE) (1000 kg/cm^2)		Weight Kg/m^3	Shrinkage % (1)		Hardness N (1)	
								Surface area	Alon g side
Green	823	34,4 %	137	14,4 %	785	Rad	Tang		
12%	1254		160		608	2.5	4.3	10.400	8.400

Source: text: Wiselius, 2010 data: thewoodexplorer, 2011, (1) wiselius, 2010

Red Angelim, *Angelim vermelho, (Dinizia excelsa Ducke*)
Sourced from; Brazil, French Guiana, Guyana

Red angelim has an unpleasant odour in the green condition and can leave colour marks on clothing which makes it unsuitable for sitting areas(stool). This timber is known to be good available and is used for bridges, harbour construction and sheet piling. With a durability class of I and a typically strength class is D50.

Mechanical Properties**:**

Moisture content (%)	Bending strength (kg/cm^2)		Modulus of elasticity (MOE) (1000 kg/cm^2)		Weight Kg/m^3	Shrinkage % (1)		Hardness N (1)	
								Surface area	Along side
Green	1197	28 %	177	11,5 %	1169	Rad 2.1	Tang 4.0		
12%	1660		200		817			14.300	13.500

Source: text: Wiselius, 2010 data: thewoodexplorer, 2011, (1) wiselius, 2010

Norway spruce, *Noors vuren,* (*Picea abies*)
Sourced from; Eastern Europe, Western Europe

Spruce is used for structural parts under the fresh water level, because the risk for decay is here the lowest, caused by the low amount of oxygen. Sometimes it is also used for quick repairs of waterworks constructions, because the typical durability class for spruce is IV and the relative low price if compared with tropical hardwoods. Preservative treated wood is previously also often applied as with CCA treated spruce but this usage is now mainly prohibited in contact with water because of European and Dutch legislation. Heat treated spruce is also used because of its improved durability. Spruce has a typical strength class of C18/ C24.

Mechanical Properties**:**

Moisture content (%)	Bending strength (kg/cm^2)		Modulus of elasticity (MOE) (1000 kg/cm^2)		Weight Kg/m^3	Shrinkage % (1)		Hardness N (1)	
								Surface area	Along side
Green	372	58 %	78	20,5 %	520-1100	Rad 1.9	Tang 4.5		
12%	641		98		464			2650	1570

Source: text: Wiselius, 2010 data: thewoodexplorer, 2011, (1) wiselius, 2010

For more timber species,available with FSC certificate and usable in civil waterworks constructions see the following pdf developed by FSC Nederland;
http://www.fsc.nl/documents/docs/publications/matrix_FSC-gecertificeerd_hout_oktober07.pdf
Or at the website; houtdatabase, developed by Probos in cooperation with RWS and Centrum hout: http://www.houtdatabase.nl/?q=hout/gww

Tabel A1.2 Basic properties of most used timber species and alternatives Accoya and Plato

timber species			cross grain	mass in kg	shrinkage	wet - 12%	hardness	durability class	strength class	durability	class borers	price €/m³ *	years guarar
English	Dutch	Latin		at 12% MC	rad	tang.	kN						
required			option	750(tropical)									
angelim vermelho	angelim vermelho	Dinizia excelsea Ducke	yes	1000	2,1	4	13,5	1	D40	1	D	1000,- NAT	N
ekki	azobe	Lophira alata Banks ex Gaertn.f.	yes	1060	3,8	6	17	1	D70	1a2	D	700 à 850,-	N
basrolocus	basrolocus	Dicoynia guianensis Amsh.	yes	730	2,5	4,3	8,4	2	D18	2	D		N
greenhart	demara Groenhart	Chlorocardium rodiei Rohwer	yes	1000	3,4	3,9	11,1	1	D60	1	D		N
douglas fir	douglas	Pseudotsuga menziessii	straight	500	2	4,1	2,9	4	C18-C22	3a4	N	650,-	N
okan	okan	Cylicodiscus gabunensis Harms.	yes	920	3	3,5	12,3	1	D50	1	D	700 à 850,-	N
missanda	tali	Erythrophleum ivorense A. Chev	yes	900	1,3	2,3	12,9	1	D40	1	M	800 à 900,-	N
oak	eiken	Quercus robur / patreae	straight	710	1,8	4,7	5	2	C20/C24	2a3	M		N
Norway spruce	vuren	Picea abies	no	460	2	5	1,7	4	C24	4	N	500,-	N
Plato® vuren	Plato vuren	Picea abies	no	380	1	1,8	1,9	2	*C18	1a3	N	850 a 950,-	15
Accoya®	Accoya	Pinus radiata	no	510	0,7	1,5	4,1	1	*C20/C24	1	M	900 à 1300,-	25

timber species	what is the timber species used for?					
	Poles	Heavy poles /	Sheet piling	Bridges	Shoring Scots	Decks	Walings
angelim vermelho	X	X	X	X	X	X	X
ekki	X	X	X	X	X	X	X
basrolocus	X	X		X			
greenhart							
douglas fir	X		X	X	X		X
okan							
missanda							
oak	X	X	X	X	X		X
Norway spruce	X		X	X	X		X
Plato® vuren	x		x			x	
Accoya®	x		x	x		x	

Explanation symbols

Name cell	Borers	Durability against marine borers (salt water)	Hardness	Movement
Explanation	D	durable	Kilo Newton	In percentage
	M	Less durable		
	N	Not durable		

* Prices are indications for GWW, given by timber traders, they can vary by requested dimensions and quantity.accoya = Bluyssen, 2011 , Stiho, 2011, Timbertrader, 2011.

Data Source: Wiselius, 2010, Thewoodexplorer, 2011, houtdatabase.nl,2011

Appendix 2 Requirements for timber&Accoya's properties

Table 1. Requirements for timber sused in cil waterworks constructions and Accoya.

	Required Advised	Required/ advised	Accoya
Usage in civil water EN460	R	Durability class 1, 2 or 3	Durability class 1
Usage in sluices, duckdalfs, (Cur, 2003)	A	Hardness 8kN	Hardness 4.1 kN
Usage in „big" structures in rivers and big canals.	A	Hardness 6KN	Hardness 4.1 kN
Usage of softwoods	A	Strength class C16/C18	Expected: C18/C24
For duckdalf and fender wood	A	Cross grain	Straight grains
Non toxicity	R	Non Toxicity of material	Non Toxic
Dimensional stability	R	Dimensional stable	Very dimensional stable

Table 2. Available dimensions Accoya wood.

Thickness	Width	Length (+10cm)	Quality (1)
25	100, 125, 150*, 175,200 mm	2.4, 3.0 ,3.6, 4.2 4.8 meter	A1, A2,A3,B
32	100, 125, 150*, 175,200 mm	2.4, 3.0 ,3.6, 4.2, 4.8 meter	A1, A2,A3,B
38	100, 125, 150*, 175,200 mm	2.4, 3.0 ,3.6, 4.2, 4.8 meter	A1, A2,A3,B
50	100, 125, 150*, 175,200 mm	2.4, 3.0 ,3.6, 4.2, 4.8 meter	A1, A2,A3,B
63	100, 125, 150*, 175,200 mm	2.4, 3.0 ,3.6, 4.2, 4.8 meter	A1, A2,A3,B
75	100, 125, 150*, 175,200 mm	2.4, 3.0 ,3.6, 4.2, 4.8 meter	A1, A2,A3,B
100*	100, 125, 150*	2.4, 3.0 ,3.6, 4.2, 4.8 meter	A1, A2,A3,B
Finger jointed			
50	100, 125, 150	6.0 meter	KOMO A
63	100, 125, 150	6.0 meter	KOMO A
75	100, 125, 150	6.0 meter	KOMO A
100	100, 125, 150	6.0 meter	KOMO A

* the sizes 100 mm thickness and all other sizes than 150 mm width are provisionary.
(1) The standard Quality grades of Accoya wood in short:
A1: 4 sides primarily clear
A2: 3 sides primarily clear
A3: 1 side primarily clear
B : Both faces with a limited number of defects
KOMO® A is done according the BRL"s 2902, 1704 and 0801.

Table 3. Quality requirements BRL 2905/02 compared to Accoya grading terms.

	BRL 2905/02 Class B	BRL 2905/02 Class C	Accoya® grade B	Accoya® Grade A1 <50mm thick	Accoya® Grade A3 >50mm thick
Growth rings	5mm *	No requirement	No req.	No req.	No req.
Resin pockets	No requirement	No requirement	20 mm	Up to 3 : 8mm wide, 50mm long	Up to 6: 10 mm wide, 100mm long
Heart, sealed in	Allowed	Allowed	100 mm (singly)	Up to 3: 8mm	Up to 6: 15mm
Lose knots	Not allowed	Not allowed	20 mm	Not allowed	Not allowed
Checks					
• Hair checks	Allowed	Allowed	Allowed	No spec	No spec
• Length checks	Max depth 1/3d	Max depth 1/3d	Unrestricted*	L. 20 mm	Max 3, 1mm wide
• End checks (splits)	No longer than width of timber	No longer than width of timber	Unrestricted*	No longer than width of board, not exceeding 200mm	Up to twice width board
Distortion per 2m.					
• Sheet pilling thick					
bow	4mm	8mm	10-25mm*		
crook	2mm	4mm	2-10mm*		
twist	2mm	4mm	3-10mm*		
hollow	2mm	2mm	1 mm		
• Other applications					
curve	4mm	8mm	10-25mm*		
crook	4mm	4mm“	2-10mm*		
twist	4mm	4mm	3-10mm*		
hollow	2mm	4mm	1 mm		
• Wane Sheet pilling	None	From the bottom over a length of max. 250mm, small wane allowed	Up to 18mm width and depth, 50% of equivalent, slightly more for a short distance.		
• Wane Other applications	On 1 rib max. 0,2 x timber width resp. thickness	unless good fitting of tongue and groove remains intact. On 2 ribs max. 0,3 x timber width resp. thickness	Up to 18mm width and depth, 50% of equivalent, slightly more for a short distance.		

*Grading terms do not qualify with KOMO BRL 2905 (European softwood in civil waterworks) for Accoya wood when grading according grading qualifications for Accoya wood .

Appendix 3. The Internet Survey

Parties enrolled for Internet Survey.

Governments :

Rijkswaterstaat
Waterschap Noorderzijlvest (Groningen, Friesland en Drenthe)
Wetterskip Fryslân (Friesland en Groningen)
Waterschap Blija Buitendijks (Friesland)
Waterschap Hunze en Aa's (Groningen en Drenthe)
Waterschap Reest en Wieden (Drenthe en Overijssel)
Waterschap Velt en Vecht (Drenthe en Overijssel)
Waterschap Groot Salland (Overijssel)
Waterschap Regge en Dinkel (Overijssel)
Waterschap Veluwe (Gelderland)
Waterschap Rijn en IJssel (Gelderland en Overijssel)
Waterschap Vallei en Eem (Utrecht en Gelderland)
Hoogheemraadschap De Stichtse Rijnlanden (Utrecht en Zuid-Holland)
Hoogheemraadschap Amstel, Gooi en Vecht (Noord-Holland, Utrecht en Zuid Holland)
Hoogheemraadschap Hollands Noorderkwartier (Noord-Holland)
Hoogheemraadschap van Rijnland (Zuid-Holland en Noord-Holland)
Hoogheemraadschap van Delfland (Zuid-Holland)
Hoogheemraadschap van Schieland en de Krimpenerwaard (Zuid-Holland)
Waterschap Rivierenland (Gelderland, Zuid-Holland, Noord-Brabant en Utrecht)
Waterschap Hollandse Delta (Zuid-Holland)
Waterschap Scheldestromen (Zeeland)
Waterschap Brabantse Delta (Noord-Brabant)
Waterschap De Dommel (Noord-Brabant)
Waterschap Aa en Maas (Noord-Brabant)
Waterschap Peel en Maasvallei (Limburg)
Waterschap Roer en Overmaas (Limburg)
Waterschap Zuiderzeeland (Flevoland)
Provincie noord-Holland

Non-governmental parties:

Greenpeace
Milieu defensive

Translation:

*waterschap = Dutch water board

* Provincie = Provence

Questions & results, Summary Report – May 29, 2011
door Overheden

Survey: Materiaal keuze voor civiele waterwerken

Q1. Wat voor materialen hebben de voorkeur binnen uw afdeling bij civiele waterwerken?

Material	Total Score[1]	Overall Rank
Beton	74	1
Hout	64	2
Metaal	54	3
Plastic/rubber	32	5
Ander material	39	4

Total Respondents: 19

[1] Score is a weighted calculation. Items ranked first are valued higher than the following ranks, the score is the sum of all weighted rank counts.

Ander(e) materia(a)l(en)
kunststof gerecycled[1], composiet/kunststof[1],
natuurlijke materialen (bijvoorbeeld rietoevers) [1], Breuksteen[1]

[1]Materials added by servant

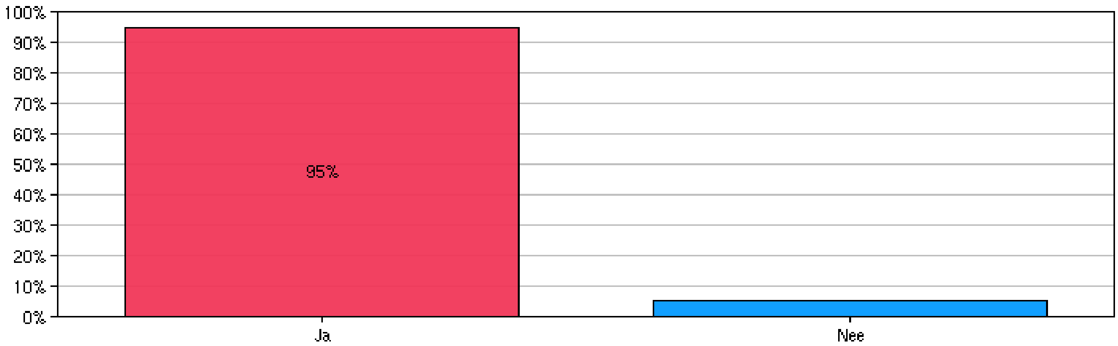
Q2. Hoe belangrijk vind u een bepaalde criteria?

	Mate van belang van (1) laag tot (5) hoog.
Prijs Average Rank 3.58	Count: 19 Min: 2 / Max: 5
Duurzaamheid levensduur (Hoe lang gaat een materiaal mee) Average Rank 4.58	Count: 19 Min: 4 / Max: 5
Duurzaamheid milieu (Milieu belasting, verkrijgen / eenmaal geplaatst) Average Rank 4.37	Count: 19 Min: 3 / Max: 5
Bewezen krachten, nut / nut door de jaren heen. Average Rank 4.11	Count: 19 Min: 3 / Max: 5
Bekendheid leverancier Average Rank 2.47	Count: 19 Min: 1 / Max: 4
Certificaat Cradle 2 Cradle. Average Rank 2.79	Count: 19 Min: 1 / Max: 4
Certificaten duurzaamheid (EU ecolabel) ((hout)(FSC, PEFC)) Average Rank 4.37	Count: 19 Min: 2 / Max: 5

Q3. Welk advies gebruikt u in belangrijke mate bij de materiaal keuze voor civiele waterwerken?

	Mate van belang van laag tot hoog.
Eigen kennis Average Rank 4.32	Count: 19 Min: 3 / Max: 5
Advies rapporten Average Rank 3.21	Count: 19 Min: 1 / Max: 4
Onafhankelijk advies bureau Average Rank 3.16	Count: 19 Min: 1 / Max: 5
Toeleverancier / Houthandel Average Rank 2.68	Count: 19 Min: 1 / Max: 4
FSC Nederland Average Rank 3.05	Count: 19 Min: 1 / Max: 5

Q4. Schrijft of gebruikt uw organisatie hout (voor) bij civiele waterwerken?



Value	Count	Percent %
Ja	18	94.7%
Nee	1	5.3%

Statistics	
Total Responses	19

Q5. Welke houtsoorten worden het meest geadviseerd / gebruikt binnen uw organisatie voor civiele waterwerken?

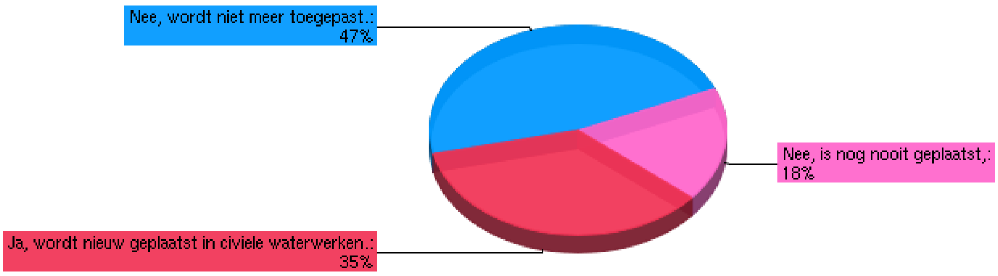
	veel gebruikt	geregeld gebruikt	weinig tot niet gebruikt	niet van gehoord / niet gebruikt	Total
Angelim vermelho	**5.9%** 1	**29.4%** 5	**41.2%** 7	**23.5%** 4	**100%** 17
Azobe	**23.5%** 4	**64.7%** 11	**11.8%** 2	**0.0%** 0	**100%** 17
Basrolocus	**0.0%** 0	**23.5%** 4	**47.1%** 8	**29.4%** 5	**100%** 17
Cloeziana	**5.9%** 1	**11.8%** 2	**23.5%** 4	**58.8%** 10	**100%** 17
Groenhart / IPE	**0.0%** 0	**0.0%** 0	**41.2%** 7	**58.8%** 10	**100%** 17
Okan	**0.0%** 0	**5.9%** 1	**17.6%** 3	**76.5%** 13	**100%** 17
Tali	**0.0%** 0	**0.0%** 0	**17.6%** 3	**82.4%** 14	**100%** 17

Q6. Zijn er andere houtsoorten die uw organisatie veel gebruikt?

	Handels naam andere veel gebruikte houtsoort.	Count
Naam andere veel gebruikte houtsoort	Eiken,[1]	1
Naam andere veel gebruikte houtsoort	Vuren[1]	3
Naam andere veel gebruikte houtsoort	Robinia pseudo acacia[1]	5
Naam andere veel gebruikte houtsoort	Kastanje[1]	5
Naam andere veel gebruikte houtsoort	Geïmpregneerd hout[1]	1
Naam andere veel gebruikte houtsoort	Grenen[1]	3
Naam andere veel gebruikte houtsoort	Lariks[1]	1

[1]Timber species added by servant

Q7. Past uw organisatie verduurzaamd / gemodificeerd hout toe in civiele waterwerken?



Value	Count	Percent %
Ja, wordt nieuw geplaatst als civiele waterwerken	6	35.3%
Nee, wordt niet meer toegepast	8	47.1%
Nee, is nog nooit geplaatst,	3	17.6%

Statistics	
Total Responses	17

Q8. Soort van toegepaste verduurzaming / modificatie?

	Veel toegepast	Weinig toegepast	Niet toegepast	Total
ACQ	**0.0%** 0	**21.4%** 3	**78.6%** 11	**100%** 14
WOLMANISEREN (CCA)	**14.3%** 2	**14.3%** 2	**71.4%** 10	**100%** 14
CREOSOTEREN (Creosoot olie)	**0.0%** 0	**0.0%** 0	**100.0%** 14	**100%** 14
DIFFUSEC / AQUA wood	**0.0%** 0	**21.4%** 3	**78.6%** 11	**100%** 14
Thermische modificatie (o.a. Plato, Lambowood) Stellac)	**0.0%** 0	**35.7%** 5	**64.3%** 9	**100%** 14
Chemische modificatie (o.a. Accoya, Nobelwood)	**0.0%** 0	**21.4%** 3	**78.6%** 11	**100%** 14

Q9. Worden er andere soorten van verduurzaming / modificatie toegepast door uw organisatie?

	Veel gebruikt / toegepast	Weinig gebruikt / toegepast	Total
Soort verduurzaming / modificatie	**00.0%** nvt	**00.0%** nvt	**100%** 0

Q10. Hartelijk dank voor uw medewerking

	Hoe vond u?
De vragen Average Rank 3.17	Count: 18 Min: 2 / Max: 5
Tijdsduur Average Rank 3.61	Count: 18 Min: 2 / Max: 5

Questions & results, Summary Report – JUN 15, 2011

Non-governmental parties:

Survey: Usage of Wood in Civil Waterworks Applications

Q1. What material does your party prefer to be used in civil waterworks applications.

Item	Total Score[1]	Overall Rank
Other material (name in question below)	9	1
Wood	9	2
Concrete	3	3
Plastic	2	4
Metal	1	5

Total Respondents:

[1] Score is a weighted calculation. Items ranked first are valued higher than the following ranks, the score is the sum of all weighted rank counts.

Q2. Name of "Other" material

Count	Response
1	recycled material
1	recycled plastics

Q3. What kind of timber do you prefer to be used in civil waterworks?

	least preferred <------> most preferred
Tropical timber Average Rank 1.00	• Count: 2 • Min: 1 / Max: 1
Certified tropical timber (according TPAC) Average Rank 3.50	• Count: 2 • Min: 3 / Max: 4
Certified non tropical timber (according TPAC) Average Rank 2.50	• Count: 2 • Min: 1 / Max: 4
Modified non tropical timber (Thermo, Chemical) Average Rank 3.00	• Count: 2 • Min: 1 / Max: 5
Preserved timber (water borne , tar-oil) Average Rank 1.00	• Count: 2 • Min: 1 / Max: 1
Timber composites (wood-plastics) Average Rank 2.00	• Count: 2 • Min: 1 / Max: 3
other (name in question below) Average Rank 3.00	• Count: 2 • Min: 1 / Max:

Q4. Name of "other" in question 3?

Count	Response
1	Modified non tropical timber (according TPAC)

Q5. What certification scheme for (tropical) timber do you prefer?

	least preferred <---------> most preferred
PEFC Average Rank1.50	• Count: 2 • Min: 1 / Max: 2
FSC Average Rank 5.00	• Count: 2 • Min: 5 / Max: 5
PEFC & FSC tropical timber (the same) Average Rank1.00	• Count: 2 • Min: 1 / Max: 1 • StdDev:0.00
PEFC & FSC non tropical timber (the same) Average Rank 3.00	• Count: 2 • Min: 3 / Max: 3
Other Average Rank1.00	• Count: 2 • Min: 1 / Max: 1

Q6. Could you please motivate your answer?

Count	Response
1	FSC is the highest standard there is, and therefore the best available option. PEFC has some good standards in some countries, but under the same umbrella there are countries with a standard that do not meet criteria for sustainable forest management. (in de indeling zitten dubbelingen, dus is het niet mogelijk om een goed lijstje te maken. Voorkeur voor FSC, dan PEFC. Het gelijkstellen van FSC en PEFC en alleen verschil maken tussen tropical en non-tropical, kan wat mij betreft niet)
1	on your former Q recognition of TPAC: we still do but depends on the outcome of MTCS whether we will keep on recogniszing it. On this Q: FSC is still the only solid certification system, PEFC in countries in Europe has still problems but could be a second option but problem with PEFC is that it also has endorsed schemes outside EU

Q7. What kind of Modification process and certificates is/are preferred for timber in civil waterworks applications? (durability class 1=high, 4 =low)

	least preferred <-----> most preferred
Thermo wood (durability class 2-3) (Plato) Average Rank 4.00	• Count: 2 • Min: 4 / Max: 4
Acetylated wood (durability class 1) (Accoya) Average Rank 4.50	• Count: 2 • Min: 4 / Max: 5
Cradle to cradle "gold" certificate for the product Average Rank 2.50	• Count: 2 • Min: 1 / Max: 4
FSC / PEFC certificate for the product Average Rank 4.00	• Count: 2 • Min: 4 / Max: 4 • StdDev:0.00
Dubo Keur certificate for the product Average Rank 1.00	• Count: 2 • Min: 1 / Max: 1
Combination product (twin wood); certified modified wood where needed and certified softwood there where possible. Average Rank 6.50	• Count: 2 • Min: 6 / Max: 7

Q8. opinion on wood composites?

Count	Response
1	good development, about the amounts don't really have an opinion on that, but in general, the more recycled the better
1	When done from recycled materials of which the timber is certified, is the best option.

Q9. Thank you for your cooperation.

	What is your score for:
The Questions Average Rank 3.00	• Count: 1 • Min: 3 / Max: 3
Duration Average Rank 4.00	• Count: 1 • Min: 4 / Max: 4

Note: This was a selection of the questions.