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Assessment of the quality and lifetime of wooden pile foundations

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Assessment of the quality and lifetime of wooden pile foundations

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ABSTRACT

The development of wooden pile foundations started centuries ago and enable man to build and live in strategic and fertile areas. Although the building methods, the building materials and the building regulations chanced especially over the last decades, worldwide wooden pile foundations still fulfil their function to support above ground constructions of which many belong to our cultural heritage. In the Netherlands wooden foundations are a national bench mark and Amsterdam is often regarded as the City on wooden piles. The pile population in service is estimated on 25 million and as they are carrying many ordinary family houses and water building constructions their importance is far above building history. The behaviour of wood in the soil and the special threats for pile foundations asked for an adapted method in order to assess the actual and future status of these underground constructions. This paper describes a method quantifying the actual and future stability taking in to account the special behaviour of wood in constructions in the ground. This method was developed in the last decades in the Netherlands by a multidisciplinary group of researchers.

Keywords: bacteria, decay, foundations, inspection

1. INTRODUCTION

For centuries wooden foundations were used to support buildings in areas with weak soils. Despite their instability, estuaries, riverbeds and some of the peat lands were attractive living habitats because of their strategic position. The first settlements with small and light houses relay on soil improvements with closely spaced short piles. The dimensions and the weight of the buildings increased in time and asked for other construction of foundations with higher bearing capacity. Presently wooden pile foundations can be seen all over the world supporting many historical constructions like the old city centre of Venice near the Adriatic sea and river Po, the Indian Taj Mahal built in 1631, the 370 years old Royal Palace on the Dam square in Amsterdam and a huge number of common constructions (e.g. family houses in several Western Dutch cities, in high populated Asian areas like Tokyo and Nagasaki; industrial buildings like the Speicher city of Hamburg or a sugar factory in Leeuwarden). Also many civil engineering constructions obtain their stability from wooden piling and are common in many harbour areas as quay walls, bridge heads and locks e.g. Boston near the Atlantic ocean and the river Charles, Rotterdam in the Dutch Rheine and Meuse delta. Beside the mentioned areas a substantial number of wooden foundation constructions were used near the Baltic sea e.g. Copenhagen, Stockholm, Saint Petersburg near river Neva, Helsinki near river Vantaa, Gdansk near the Vistula River complex (Aldrich and Lambrechts 1986, Ceccato and Simonini 2013, Christin 2013, Janse 2000, Klaassen et all 2005, Lionetto et all. 2014, Makoto Kimura personal communication 2014, Zhussupbekov, personal communication, 2013).

In the last century building regulations have been developed in order to increase proven safety of constructions. For foundations this lead to an increase of the load bearing capacity resulting in a more common use of concrete piles and longer piles. As the early wooden pile foundations constructions were developed on the basis of experience, they often thought not to fulfil the actual requirements causing discussions when the actual status has to be evaluated. In the Netherlands in the last decades the number of wooden foundation constructions that were replaced increased. This was caused by the large problems that appeared from the nineties of last century onwards with the stability of houses in the cities of Haarlem, Dordrecht and Zaandam, which mostly pine foundation piles are about 100 years old. Information on the actual stability of the construction was needed to enable the development of sustainable restauration or renovation building strategies. Until now thousands of wooden piles were investigated resulting in a rapidly increase of knowledge on the foundation itself and on deterioration processes occurring in the Dutch situation. Untreated pine or spruce are the main species used as piles with head diameters of 10 – 30 cm and lengths varying between 4 and 18 meters. The foundation construction is always located under the ground water table (Klaassen 2014, Klaassen and Creemers 2012).
This paper summarizes the main causes of settlement of constructions standing on wooden piles and the Dutch research method on how to assess the actual and future stability is explained.

2. MAIN DETERIORATION PROCESSES

It is estimated that in the Netherlands approximately 25 million wooden piles are still functioning within foundation constructions. Approximately halve of all these pile support civil engineering constructions and the other half are under buildings. Their ages vary between 600 and 50 years but most constructions are 80 to 120 years old. In the last 20 years over 10.000 piles were inspected and the wood quality of about 6000 piles was determined (Klaassen 2014). From all this work four main causes for foundation problems were recognized.
The first one is an inappropriate foundation construction where the cohesion of the construction is lost because of insufficient connection between the individual wooden elements and or an insufficient connection between the foundation construction and the upper construction. Furthermore the position of the piles can be inappropriate: they are not fully concentrically positioned under the building walls or they even are positioned outside the building walls.
Negative skin friction is the second cause that results in too high settlements. In the Netherlands, not earlier than 1940 this extra load was recognized and taken in to account in the design of the foundation construction. In older constructions, especially there were the street level was elevated by extra sand layers, the soil bearing capacity for the foundation construction appeared too low, resulting in settlements of 2 - 3 mm/year during many years. If the settlement was uniform for the building as a whole, the building was maintained but street level adaptations were necessary. In other cases massive reparations were needed. One should realise that settlements because of negative skin friction are long lasting processes that generally decrease in time. However settlements can increase again due to lowering groundwater table (climate change), extra elevation or temporary water extractions.
The third cause is a too low groundwater table which enables fungi to become active and deteriorate the upper foundation timber. The Netherlands are a patchwork of polders, each with its own water management. To establish a specific ground water level one has to deal with a variety of concerns e.g. dry streets as general starting point; the variety of different ground floor levels of buildings within one area where as a submerge foundation for one owner can result in a wet cellar for another owner; farmers are favourite to a low ground water table in order to increase their crop growth; unexpected circumstances like broken sewerage systems, evaporating trees and increasing drought because of climate change; the creation of polders results in a general trend that the height of the street level in the west of the Netherlands is decreasing because of soil layers compression as a result of lower groundwater tables.

The Final and fourth cause is wood decay under water by bacterial activity. In contrast to fungal decay, bacterial decay is not restricted to the upper part of the foundation construction while it is active along the whole pile axes and is not related to drought but is strongly related to the quality of the wood (Klaassen 2008, Klaassen and Creemers 2012).

Bacterial wood decay

Main type of bacterial wood decay occurring in foundation piles is caused by erosion bacteria. The patterns of bacterial wood decay are described not earlier than 30 years ago by Daniel & Nilsson (1986). In the decades followed, the process of decay was studied and the first isolations of the degrading species were done in the beginning of this century (Björdal & Nilsson 2008). Where fungal decay is caused by single species, bacterial decay is caused by a consortium of species. A chain where each species rely on adjacent species. Active bacterial decay is established only when the species intermix and as the species are immobile they rely on external sources to move them. In wooden foundation piles this external source is water movement in the wood and therefore most permeable wood structures are most sensitive for erosion bacterial wood decay. These bacteria are common in all kinds of (wet) soils and are active in poor environments (e.g. less or no oxygen, limited amount of nitrogen), there where fungal growth is difficult. They infect the wooden elements from the outside and enter the wood with streaming water. Their wood degrading velocity is slow e.g in one year they can severe degrade a wood layer of maximum 1 mm. The mean severely degrading velocity in spruce piles is 0,18 mm and in pine piles is 0,32 mm (Klaassen 2014). As wood degrading bacteria rely on water transport they are active in the sapwood only. The heartwood of most timber species is water tight which reduces the bacteria activity in the wood until almost zero.

Where fungal decay occurs at the pile head only, bacteria degrade piles over their full length. Klaassen and Overeem (2012) show on a limited number of about 50 piles that the degree of bacterial decay varies between the pile head and tip. In most cases the degree of bacterial decay is most severe at the pile head but more research on extracted piles should be done for a better understanding of the processes that causes a decay gradient over the pile axes. For the time being in the assessment of wooden piles it is assumed that the degree of bacterial decay at the pile tip is half of that at the pile head.

The degree of decay can be describe on the basis of the anatomical degrading patterns and Klaassen (2008) showed a high correlation between the moisture content of bacterial degraded water saturated softwood and the compression strength. His model to estimate compression strength from the moisture content has a R^2 of 0.78. The possibility to estimate compression strength provides an additional tool in the assessment of wooden foundation construction.

3. DUTCH METHOD TO QUANTIFY THE STABILITY OF THE FOUNDATION CONSTRUCTION

Significance

Because of the deterioration processes the quality, and also the load carrying capacity, of all wooden foundations will decrease in time. As its present and future impact on the stability of the construction varies tremendously, a quality classification is needed, which indicate the present quality and future expectations, at least when the ownership will change and before construction, renovation and restauration building activities start. On basis of the method described in this paper a quality assessment can be made.

Test hammer

The method presented here, relies strongly on a test hammer. This is an apparatus that shoots a needle (5 mm in round diameter and 50 mm length) into the wood. The velocity of the needle is determined on 5,05 (±0,11) m/s and the weight of the needle block is 460 (± 39) g. The execution of the measurements with the test hammer are easy and quick, also in a watery environment like a foundation pit. This enables the researcher to achieve several measurements of each of the wooden elements of the foundation construction (Fig. 1).

Figure 1. Test hamer

The test hammer is developed to indicated the thickness of the soft shell, which is the outermost layer of a wooden element that is severely degraded wood by bacteria (Fig 2). It is assumed that bacteria degrade wooden elements homogeneous from outside towards the inside.

Table 1: Penetration depth determine with a test hammer at 3-4 different locations around the heads of 30 pine pile. Data are extracted from Klaassen and Vosslamber (2002).

pile	N	mean [mm]	std	std/mean	pile	N	mean [mm]	std	std/mean
1	3	7,33	2,31	0,31	16	4	23,50	3,42	0,15
2	4	13,50	3,00	0,22	17	4	30,00	1,63	0,05
3	4	13,50	2,52	0,19	18	4	20,00	1,63	0,08
4	4	10,50	4,43	0,42	19	3	29,33	6,11	0,21
5	4	10,50	1,91	0,18	20	4	16,50	5,74	0,35
6	4	10,50	1,91	0,18	21	4	3,00	2,00	0,67
7	4	13,00	2,00	0,15	22	4	26,50	4,12	0,16
8	4	15,00	2,58	0,17	23	4	18,50	2,52	0,14
9	4	16,00	2,83	0,18	24	4	16,50	1,91	0,12
10	4	33,50	3,42	0,10	25	4	23,50	3,00	0,13
11	4	27,00	6,22	0,23	26	4	14,50	5,97	0,41
12	4	35,00	6,00	0,17	27	4	13,00	4,16	0,32
13	4	33,00	3,46	0,10	28	4	25,00	8,41	0,34
14	4	22,50	1,00	0,04	29	4	22,50	1,91	0,09
15	4	21,50	1,00	0,05	30	4	18,50	2,52	0,14

Many unpublished data are available on the variety of the thickness of the weak shell around wooden piles. Table 1 is included as an example of this variety (Klaassen and Vosslamber 2002) and show for 30 pile heads the mean values of 3-4 measurements with a test hammer. Also the standard deviation and variance (ratio between the standard deviation and the mean values) are given. The mean values of the thickness of the weak shell ranges from 3 mm (sound or almost sound wood) until 35 mm. In 65% of all piles the variance is 20% or less, and in only 10% of all piles it is more than 40%. These data support the assumption that bacteria degrade the outer most layer in a homogeneous way. The variation found, depends on the structure of the stem, especially in stems with an asymmetric pith. Reaction wood (with other strength properties than regular growth wood) as well as the sapwood width (the area which is sensitive for bacterial decay) will cause differences in the thickness of the weak shell (see Fig. 3).

Figure 2. Three pile heads with a soft shell by bacteria decay, for each pile the app. diameter and thickness of the soft shell are given. A: wet broken pine pile head (14 cm / 5 cm); B: wet sawn cross surface pine pile head (18 cm / 6 cm); C: dry cross surface pine pile head (20 cm / 1,5 cm)

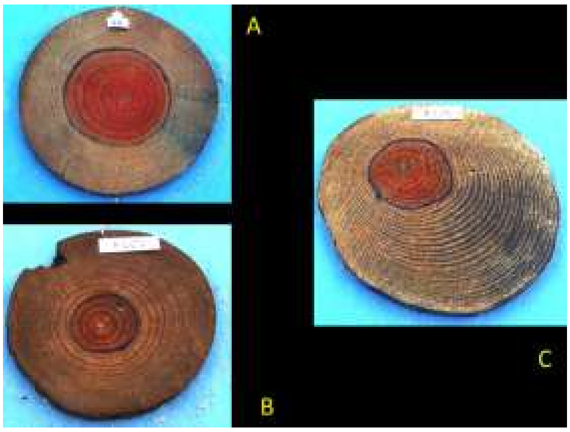

Figure 3. Example of variation in wood structure in pine pile heads of app. 16 cm in diameter. A and B show differences in sapwood width and C shows a asymmetric pith and compression wood at the right side

As the weak shell lost more than 80% of its strength the pen of the test hammer always fully penetrates this layer. In situations where the bacterial decay is not active, there is a sharp boundary from the weak shell towards the sound, strong timber. The penetration depth of the pen is in this situation always ±5mm around this boundary. However, in situations where the bacterial decay is active, there is a gradual increase in strength from the weak shell until the sound timber. In this situation, the penetration depth of the pen is less accurate. Not only the severely degraded wood is penetrated but also a part of the wood where the degree of decay is less. So the penetration depth of the pen is in these situations can be deeper than the depth of the initial bacterial decay in the pile.

Therefore the interpretation of the measurements with the test hammer should always be done in combination with the wood research of the increment core which makes the gradient of decay visible.

Figure 4. Extracted piles to be inspected and measured over their full length

Figure 5. Example of the impact of bacterial decay on a pile (original diameter 130 mm, after 75 years in service and decay, the sound diameter was 35 mm only)

Although the test hammer gives a relative good estimation of the weak shell at the pile head, there are much more uncertainties over the weak shell along the length of the piles. Without demolition it is not possible to inspect the piles over their full length (Fig 4 and 5). That is why an estimation has to be made on the basis of the information gathered in the foundation pith (core sample analysis and measurements with the test hammer).

Data collection

In order to classify the quality of the wooden foundation, data has to be collected. A first step is to gather general information on the construction e.g. age, construction details, maintenance and reparations carried out. The second step is to gather information from the construction above the foundation. Mortar joints in brickwork are originally constructed as a straight and horizontal line. Deviations in this line indicate differences in settlements since the erection of the building and together with the appearance of cracks, skew angle measurements on floors and façades, indications of problems with the foundation construction can be found. A third step is to get an indication of the actual settlement. Sometimes monitoring bolts are available on the building and by regular levelling absolute yearly settlement can be calculated. Alternative an estimation of the total settlement can be obtained by comparison of building level, e.g. actual ground floor level, with actual street level. A fourth step is obtaining information on the ground water table and soil constitution. If no reliable information is available, additional well pipes should be inserted and monitored. Finally on the basis of all gathered information the most logical location in terms of settlement and stability is chosen for making a foundation inspection pit where at least three pile heads are uncovered over a length of approximately 50 cm. In the pit the groundwater is lowered and the brickwork as well as the foundation timber is cleaned. A visual inspection is done on the brickwork, the soil layers and the timber. The position and the dimensions of all visual foundation elements are determined and with a standardised test hammer (Fig. 1) the thickness of the soft shell of all elements is measured on at least three positions; the mean soft shell thickness is then determined as the average of these three measurements. With an increment borer a core with a diameter of approximate 10 mm is taken from each pile approximately 15 cm below the pile head (see Fig. 6). The cores are used to determine the timber species, the amount of sapwood, tree age, wood quality, moisture content, type and degree of decay as well as estimation of the compression strength is made radially along the pile diameter. The method of analysis is described by Klaassen (2008). The reduction of the strength of the pile by taken increment cores is negligible. The relation between the area of the core (10 mm wide, from bark to pith) and the pile diameter gives the maximum reduction and for common piles diameter (140-300 mm) is this < 4%. In thinner piles (until 60 mm in diameter) the effect increases until 10%. As almost the complete load on the core hole is absorbed by the surrounding timber the strength lost is only a fraction of that calculated on the bases of the sound cross section area ratio.

Figure 6. Increment borer (diameter 10 mm)

Sound pile head diameter

The collected data are combined in order to make a reliable estimation of the stability of the construction. First the sound pile diameter near the head is determined. In the absence of fungal decay the mean thickness of the soft shell can be used. It is assumed that not more than 5 mm below the mean soft shell thickness the timber remains its fully strength. The sound pile head diameter is therefore calculated according to Eq. 1. As the mean soft shell can be an over-evaluation of the thickness of the degraded wood, results from the core analyses can be used to improve the calculation of the sound diameter. If the depth of severe bacterial wood decay is less than the mean soft shell thickness, than Eq. 2 can be used.

$$d = D - 2(s+5) \tag{1}$$
$$d = D - 2s \tag{2}$$

D = original pile head diameter [mm]
d = sound pile head diameter [mm]
s = mean soft shell thickness [mm]

Geotechnical pile bearing capacity

From the sounding graphic the geotechnical pile bearing capacity can be calculated according to the Dutch National Annex to NEN-EN 9997-1+C1 (Eurocode 7). In general the load bearing capacity of the pile tip is 70 till 90% of total bearing capacity. 10 till 30% is due to positive skin fraction, activated in the load carrying soil layer. The tip diameter is calculated on the basis of the pile head diameter using a mean taper value of 7,5mm/m[1] (F3O commission 2013). Although bacterial decay is present at the tip of piles that were in service for several decades, it is assumed that it has no influence on the geotechnical bearing capacity. This assumption is based on the experience that extracted piles with bacterial decay never show shear failure or removal of the degraded wood near the pile tip. Moreover the compression and shear strength, even of severely degraded wood, is still higher than that of any of the soil layers.

The bearing capacity of the timber pile

The load bearing capacity of the timber pile should be calculated at that point over the pile length where the load is at maximum. The length of wooden foundation piles is adapted to the depth of the stable sand layer. The constitution of the weak soil penetrated by the piles consist of a variety of peat and or clay layers each with their own weakness and stability. The compression of the weak soil layers and increasing sand fill (in order to adjust the street level) , creates an extra load at the upper pile part, the so-called negative skin friction load. At the lower part of the pile the soil layers contribute to the bearing capacity, the so-called positive skin fraction. On the bases of the sounding graphic the position in the pile can be determined where the negative skin friction changes towards a positive skin fraction. This is the position in pile with the highest load, the so- called neutral point (see Fig. 7).

$$\boldsymbol{d_{neutral} = D - 7,5l \; - \frac{D-d}{2}\left(1 + \frac{L-l}{L}\right)} \tag{3}$$

D = original pile head diameter [mm]
d = sound pile head diameter [mm]
$d_{neutral}$ = sound pile diameter at neutral point [mm]
L=pile length [m]
l=distance between pile head and neutral point [m]

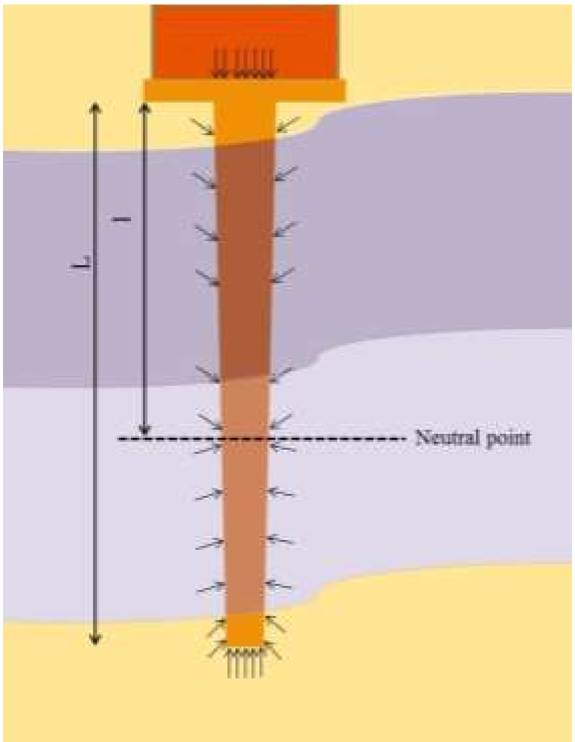

Figure 7. Location of the neutral point in a timber pile in service (sand layers are yellow, weak layers purple, orientation of the load on the pile is given by arrows)

At the neutral point the sound pile diameter is calculated using Eq. 3 that take in to account the taper value and the gradient of bacterial decay over the pile length.
The design bearing capacity of the timber pile can now by calculated according to Eq. 4.

$$F_d = \frac{\pi}{4} d_{neutral}^2 . f_{c,d} \qquad (4)$$

$d_{neutral}$ = sound pile diameter at neutral point [mm]
F_d = the design bearing capacity of the timber pile [N]
$f_{c0,d}$ = design value compression strength parallel to the fibre direction of water saturated sound wood [N/mm²]
$f_{c90,d}$= design value compression strength perpendicular to the grain direction of water saturated wood [N/mm²]

For masonry buildings the load combination with only permanent loading is generally determining and $f_{c,d}$ should, according to the Dutch National Annex to NEN-EN 1995-1-1 (Eurocode 5), be taken as $f_{c,d}$ = 10,8 N/mm^2. For light weight structures, e.g. timber frame, the load combination with both permanent and life loads is determining and $f_{c,d}$ should, according to the Dutch National Annex to NEN-EN 1995-1-1 (Eurocode 5), be taken as $f_{c,d}$ = 12,6 N/mm^2. In both cases a system factor k_{sys} = 1,1 is taken into account assuming that at least three piles are supporting the structure and that the structure is able to redistribute loads among these piles.

In the method for the determination of the design load carrying capacity in compression of the timber pile as described above, zero contribution of degraded part of the pile cross section is assumed. Therefor an alternative method could be used which takes a certain load carrying capacity of the degraded part into account. Since the timber response loaded in compression is ductile the reduced strength of the less stiff degraded part also contributes to the load carrying capacity as indicate in Fig. 8. In the case of Fig. 8, assuming a uniform sound part and a uniformly degraded part, the design load carrying capacity can, assuming that a strain of ε_g is reached, be calculated according to Eq. 5.

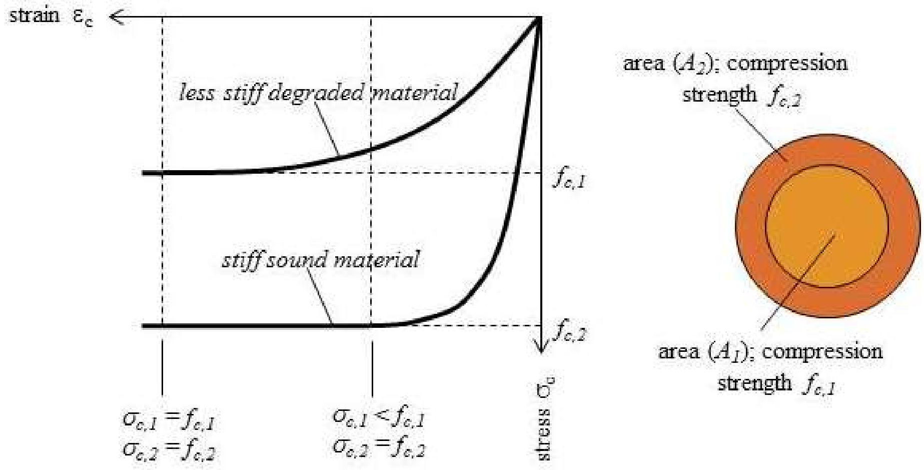

Figure 8. Effect of ductile behaviour (wood loaded in compression)

The determination of the compression strength of the degraded wood is described in Klaassen (2008) where a (strong) correlation between the wood moisture content and the compression strength is shown. A similar relation is found by Lantinga (2015). Consequently, the wood moisture content of the core taken with the increment borer mentioned earlier has to be determined over its length in order to determine the variation in compression strength over the pile cross section (in the example of Fig. 8, where the cross section is divided into two sections, f_{c1} and f_{c2} have to be determined).

$$F_d = A_1 . f_{c,1} + A_2 . f_{c,2} \tag{5}$$

A_1 =cross section area of the sound wood [mm^2]
A_2 =cross section area of the degraded wood [mm^2]
F_d = the design bearing capacity of the timber pile [N]
$f_{c,1}$ = fc0,d [N/mm^2]
$f_{c,2}$ = design compression strength parallel to the grain of the degraded wood [N/mm^2]

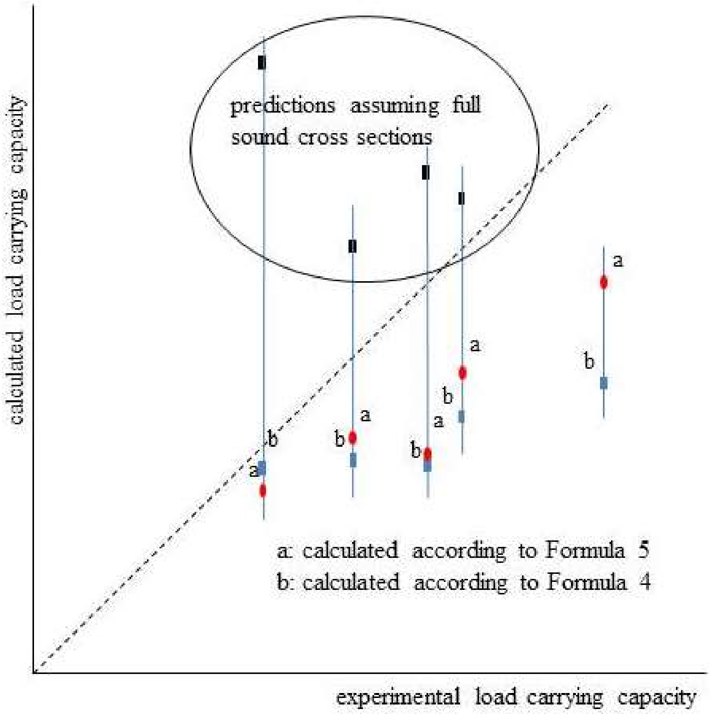

Figure 9. Differences in in load carrying capacity, using Eq. 4 and Eq. 5.

As an example, Lantinga (2015) calculated the predicted load carrying capacity according to both Eq. 4 and 5 for extracted piles, which were in service for more than 100 years, the results are (qualitative) shown in Fig. 9.

The perpendicular to the grain wood bearing capacity
At the upper part of the foundation construction the pile load is transferred to the horizontal timber elements as shown in Fig. 10.

Figure 10. Two examples of common Dutch foundation constructions: two piles connected by a beam, covert by horizontal planks on which the bricks are situated. Both planks and beams are loaded perpendicular to the grain.

The compression stress perpendicular to the grain equals the compression stress parallel to the grain in the sound part of the pile head. The compression strength perpendicular to the grain exceeds, due to load spreading, the pure strength for which values can be found in NEN EN 338 (e.g. for strength class C24, NEN EN 338 lists $f_{c,90,k}$ = 2,5 N/mm^2). Furthermore, the strength values in NEN EN 338 are determined on a strain limitation which is not applicable for foundations; this is a second reason that the design strength for compression perpendicular to the grain to be applied in foundations exceeds the values used in other structural design applications. The load carrying capacity for perpendicular to the grain loading is calculated according to Eq. 6 and 7 (in which $f_{c,90,d}$ = 4,5 N/mm^2).

$$D_{horizontalbeam} = D - 2(s - 10) \tag{6}$$

$$F_d = \frac{\pi}{4} D^2_{horizontalbeam} \cdot f_{c,90,d} \tag{7}$$

$$D_{horizontalbeam} = D - 2s \tag{8}$$

D = original pile head diameter [mm]
$D_{horizontal\ beam}$ = load transfer diameter of the horizontal beam [mm]
F_d = the design bearing capacity of the timber pile [N]
$F_{c90,d}$ = design value compression strength perpendicular to the grain direction of water saturated wood [N/mm²]
s = mean soft shell thickness [mm]

The determination of the load carrying capacity perpendicular to the grain (Eq. 7) as presented here is only applicable for a thickness of the horizontal element larger than 40 mm). In cases when the unaffected wood thickness is less than 40 millimetres, the reduction of 10 mm on the penetration depth can be neglected and Eq. 8 instead of Eq. 6 can be used.

Assessment
After all data are collected and the calculations are carried out, the quality of the pile foundation can be assessed. Therefor three checks need to be carried out:

1. The foundation construction must be able to transfer the loads from the construction in a proper way to the piles. This check is in fact a visual judgement. None of the wooden components of the foundation construction may be broken of heavily deformed and the piles must be located under the brickwork of the walls;

2. The geotechnical pile bearing capacity must be sufficient for the loads from the construction according to Dutch National Annex to NEN-EN 1997-1+C1 (Eurocode 7);
The bearing capacity of the timber of the piles and the horizontal elements must be sufficient, and the lowest value obtained by Eq.s 4/5 and 6 (pile and horizontal element) is taken into account.

It is clear that if one of these tests fails or settlements are too high (e.g. > 3mm/year) or unequal causing distortion in the building, reparation measurements are necessary. On the other hand it is clear that if calculations show that the bearing capacity for a building is sufficient and no or minor settlements occur, the foundation can be classified as stable. If in addition the bacterial wood decay is not active and the environmental conditions are stable, a future classification for a five years period is possible. If the environmental conditions are re-evaluated every five years prolonged classifications are possible for more than two decades. If the results are less clear and the bearing capacity of the building showed intermediary values and moderated (< 3 mm/year) but homogeneous settlements the judgement to intervene on the quality of the foundation is done on the basis of a combination of the parameters described, sometimes in combination with yearly evaluation on the settlement based on levelling the monitoring bolts (see F3O 2013).

4. CONCLUSION

Assessing the quality of old wooden pile foundations asks for a special approach as they are designed and built in times when design by calculation of the stability was not common use. Regulations for existing buildings do not offer the possibilities to take into account the specific timber properties (water saturated, partly degraded construction timber) and its interaction with the soil. The importance of many, sometimes very old, historical buildings justifies the use of a special judgement approach that enables a durable maintenance and avoid unnecessary demolition or replacement of wooden pile foundations which are found worldwide in areas with weak soil.

The method described in this paper offers the possibility to get reliable information on the quality of wooden pile foundation constructions. It is based on objective measurements, takes into account the special behaviour of wood in the soil and its practical and financial efficient, The outcome is important for safeguarding these constructions and can prohibit unexpected collapse or unnecessary disruptions.

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