THE INSPECTION AND TESTING OF EXISTING FOUNDATIONS TO ASSESS THEIR SUITABLITY FOR REUSE AND EXTENDED USE, NATIONAL STATE OF PRACTICE IN THE NETHERLANDS

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ABSTRACT

In the Netherlands, there are more than 8 million residential buildings. Around half have been built before the 1970s. The foundation of these structures consists mostly of timber piles or shallow foundations. The Dutch knowledge center for existing foundation problems and solutions, KCAF, has estimated that the foundations of about 1 million current structures are sensitive to damage (KCAF, 2022), the degree of the which varies from minor (small cracks) to severe damage (large differential settlements, collapse). Natural degradation of materials with the catalyzing effect due to climate change, soil subsidence, additional (pile) load, and water management policy choices are the main causes of these growing foundation problems. The related costs of the reinforcement and replacement of current foundations (to prevent severe damage) are expected up to be as much as 60 billion Euro until 2050 (Deltares/ TNO, 2021). The reuse and extended use of current foundations is more urgent than ever. This is not only relevant to save costs and to prevent unsafe conditions, but also to reduce the CO_2 footprint related to the reinforcement and replacement of current foundations as much as possible. A correct and ambiguous foundation assessment is essential to this process. This paper describes the current Dutch approach of foundation assessments and classification, based on different available (Dutch) codes and guidelines, including the updated KCAF guideline 'Inspection and assessment of existing foundations' (KCAF, 2022).

Keywords: inspection and testing of existing foundations, reuse and extended use of foundations, national state of practice in the Netherlands, KCAF, Dutch guidelines and codes.

INTRODUCTION

The soft soil conditions in large parts of the Netherlands have always presented a challenge to the Dutch. Throughout the centuries, the Dutch have used timber piles to support their buildings and other structures, like the historical buildings at the harbour 'Veerhaven' in Rotterdam (fig. 1).

Fig. 1. Historical buildings at the harbour 'Veerhaven' in Rotterdam (Profittlich).

The Dutch knowledge center for existing foundation problems and solutions, KCAF, has estimated that the foundations of about 1 million current structures built before the 1970s are sensitive to damage (KCAF, 2022). This varies from minor (small cracks) to severe damage (large differential settlements, collapse). Natural degradation of materials with the catalyzing effect due to climate change, soil subsidence, additional (pile) load, and water management policy choices are the main causes of these growing foundation problems. The related costs to the reinforcement and replacement of current foundations (to prevent severe damage) are expected to cost up to 60 billion Euro until 2050 (Deltares/ TNO, 2021). The reuse and extended use of current foundations is more urgent than ever. This is not only relevant to save costs and to prevent unsafe conditions, but also to reduce our CO_2 footprint related to the reinforcement and replacement of current foundations as much as possible. A correct and ambiguous foundation assessment is essential to this process.

Since the 1970s, concrete and steel pipe piles are mostly used in the Netherlands for piled foundations. These piles are less sensitive to degradation and damage (if designed and installed correctly) and not part of the foundation assessments of existing piles as considered in this paper (and the current guidelines).

HISTORY

In the last few decades, the assessment of existing foundations has been professionalized in the Netherlands. In 2003, the Dutch Ministry of Housing published the first protocol on this topic (VROM, 2003). This protocol on the inspection of (only) timber piles was composed by the industry (like Fugro), research institutes and (local) government. Information about the inspection of timber piles in the protocol was very brief and not always ambiguous. Also due to additional research and developments, this protocol has been updated several times including the assessment of shallow foundations.

In 2022, the KCAF published the latest update of this protocol titled ‘Funderingen onder gebouwen; onderzoek en beoordeling funderingen op staal en op houten palen’ (in English: ‘Assessment of timber and shallow foundations’). This recent guideline is the result of combining the 2012 and 2016 guidelines (F3O, 2012 and 2016) titled ‘Onderzoek en beoordeling houten palen onder gebouwen’ (in English: ‘Inspection and assessment of timber foundation piles of buildings’) and ‘Onderzoek en beoordeling van funderingen op staal’ (in English: ‘Inspection and assessments of shallow foundations’). See also figure 2. Unfortunately, these guidelines were, until now, not available in the English language.

The recent KCAF guideline is applicable from 1 January 2023. The guideline replaces all the earlier published guidelines and includes the assessment of shallow foundations. Furthermore, the guideline has been extended with new measurement techniques, like satellite deformation measurements and façade scan techniques to detect cracks and differential settlements. Also, the classification has been updated and other improvements have been processed. The guideline is the result of cooperation among several organisations that are involved in foundation assessments including major clients like housing associations and (local) government. That is why it is expected that this guideline will be well supported in the field and highly regarded by clients and competent authorities (like the earlier published guidelines).

Fig. 2. Dutch guidelines (F3O) and code NEN8707 (NEN).

In addition to the guideline(s), there exists another more formal document that is related to foundation assessments in the Netherlands. This is the Dutch NEN8707 'Assessment of an existing structure in case of reconstruction and disapproval – Geotechnical constructions' issued in 2018. This code describes the assessment of all geotechnical construction including foundations of embankments and (anchored) quay walls. The assessment of foundations is similar to the guidelines, but with less detailed information. And the classifications are more simplified and mainly focused on the (differential) settlements and settlement rates. This code is part of a series of codes and has been appointed by the Dutch Ministry from 1 January 2021. Together with the recent KCAF guideline they form the basis for the assessment of existing foundations related to reuse and extended use in the Netherlands.

DUTCH APPROACH OF FOUNDATION ASSESSMENTS

The Dutch approach of the assessment of existing foundations according to the available regulations consists mainly of three phases:

1. Desktop study, visual technical inspection and several measurements;
2. Foundation inspection;
3. Foundation classification

Phase 1 consists of the following steps:

- Examination of available public and private data about the site history, area, structure, foundation, settlement rate(s), soil and ground water level conditions.
- Technical visual inspection inside and outside the building, related to foundation issues, where cracks are assessed by the classification as shown in table 1.
- Levelling/ elevation measurements inside and outside the structure, and where differential settlements are assessed by the classification as shown in table 2.
- Deformation settlement measurements, and where the settlement rate is assessed by the classification as shown in table 3.

Table 1. Classification of cracks

Width of cracks	Description of cracks
<0.5 mm	Very small
0.5 to 1 mm	Small
1 to 3 mm	Moderate
>3 mm	Large

Table 2. Classification of differential deformations

Rotation	Description
<1:300	Negligable
1:300 to 1:200	Low
1:200 to 1:100	Moderate
1:100 to 1:75	High
>1:75	Very high

Table 3. Settlement behavior

Settlement (mm/year)	Description
To 0.5 mm	Negligable
0.5 to 2 mm	Low
2 to 3 mm	Moderate
3 to 4 mm	High
>4 mm	Very high

The results of phase 1 of the foundation assessment will lead to a first estimation of the current quality of the foundation and maybe classification (phase 3). If the results are not that ambiguous, additional information about the foundation is necessary (phase 2). Phase 2 consists of the inspection of the foundation at one or more representative location(s). The location choice is dependent on the (worst) results of (differential) settlements and cracks, but is also dependent on the accessibility of the foundation.

Before the foundation inspection can be executed, a contractor has to create a safe, dry and accessible workplace to inspect the foundation. Normally, timber piles are installed below the water table to prevent degradation by fungi. That means that the contractor has to lower the water table locally and temporarily, and stabilize the excavation pit to prevent an unsafe situation due to collapse. See also picture 3.

This inspection aims to describe the (wooden) elements that are part of the foundations, and their condition, including at a minimum:

- Pile diameters;
- Distances between the piles;
- Position of the piles measured at right angle relative to the outer face of horizontal posts or the masonry, respectively;
- Horizontal posts: size, angle relative to longitudinal axis of foundation wall, projecting part (its length) and, in case of strong deformation or if broken, its aberration from the horizontal plane;
- Wooden beams in longitudinal direction (including boards): size;
- Sliding board: size;
- Steps in masonry and concrete – their height and depth;
- The degree to which the pile heads have been crushed. In cases where the piles haven been directly incorporated in a concrete foundation beam, the height over which the piles have been crushed should be ascertained;
- Position of the foundation element relative to a recognizable element of the structure, visible above ground level (e.g., a wall between two premises or its corner);

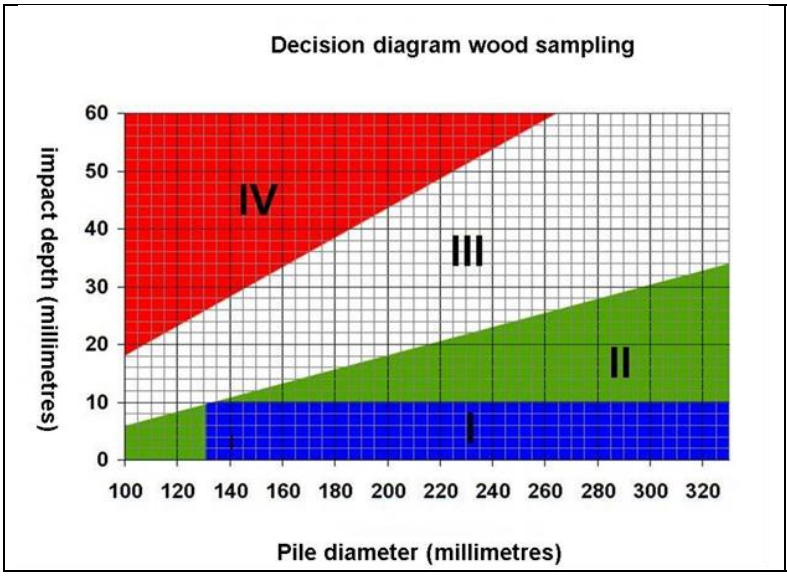
- Level below ground level of the elements, also to a formal reference level. The position of the highest element of the wooden foundations must be recorded.

Moreover, a general description can be given of the following aspects:

- Visible deterioration of the wood;
- Discoloration of wooden elements;
- Deformation of longitudinal beams and boards;
- Degree of pinching on horizontal beams;
- Occurrence of piles having intruded into horizontal beams;
- Deformation of horizontal beams in between the piles;
- Broken horizontal beams;
- Sundry details such as presence of masonry arches and an unequal level of the upper face of the timber foundations.

Fig. 3. Foundation inspection including wood sampling (Fugro).

It is also recommended to measure the thickness of the soft shell of the timber piles and wooden elements. This measurement can be executed by a (small) impact hammer. The results of this measurement will inform us the rate of degradation and which parts can't contribute to specific bearing capacity. Part of the foundation inspection can be wood sampling according to figure 4. The necessity is dependent on the pile diameter and thickness of the soft shell of the timber piles. This figure is not applicable for concrete or steel pipe piles.



Area I: These combinations of pile diameter and impact test results are considered to indicate that deterioration, if any, does not affect the performance of the construction. It is not necessary to sample the wood.
Area II: These combinations of pile diameter and impact test results indicate that a restricted deterioration is present. A limited/ minor effect on the performance of the construction may exist. Sampling the wood is necessary only when the cause of deterioration has to be determined and a prediction must be made of how this will develop over time.
Area III: Wood samples enabling further research have to be taken to help determine the remaining strength of the pile for these combinations of diameter and impact test results.
Area IV: These combinations of pile diameter and impact test results indicate major deterioration relative to the pile diameter. Remaining pile strength is insufficient. Sampling the wood makes sense only when the cause of deterioration has to be ascertained. Piles can't be reused.

Fig. 4. Decision diagram of wood sampling (F3O/KCAF).

FOUNDATION CLASSIFICATION

The goal of the assessment is a reliable prediction of the performance of the foundations as an entity in the future. Many municipal authorities are using a classification system including terms of maintenance within the framework of judging the state of timber foundations.

Table 4 is a standard classification according the KCAF guideline and based on all the mentioned steps as part of the foundation assessment with a focus at the (differential) settlements, and, if available, the results of the foundation inspection. The classification is the final step (step 3) of the foundation assessment and should always be formulated by a foundation expert. Only an expert with sufficient experience is able to analyse and combine all the results of step 1 and 2 to a final statement. Based on this statement the asset owner is able to reuse the foundation without compromises to safety.

Table 4. Classification according KCAF guideline

Classification	Description
Sufficient	Hardly any (additional) crack formation or (additional) lean (rotation, tilt) is expected within the next 25 years. Increasing the (pile) load is possible after calculations have underpinned this possibility.
Fair	Minor (additional) differences in settlement are expected within the next 25 years. Additional measurements and monitoring are necessary to get more insight in the foundation quality.
Intermediate	Additional differences in settlements are expected within the next 15 years. Additional differential settlements and crack formation are possible. Increasing the (pile) load is not possible.
Insufficient	Differential settlement can be expected, leading to (structural) damage to the construction. Foundation renovation within 5 years is necessary.
Poor	Due to differential settlement and (construction) damage, foundation renovation is directly necessary to prevent safety issues.

The classifications sufficient, fair and intermediate are only valid for 5 years when there are no substantial changes in the environment, like a decrease in groundwater levels or an increase of pile load. The classification is only valid until reinforcement or replacement of the foundation piles has been taken place.

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