# Timber pile foundations in Longyearbyen:

## a guidance for simple and preliminary assessment

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This booklet is made as result of the “Pelefundamenter og klimaendringer” project (“Pile foundations and climate change”) supported by the Svalbard Environmental Protection Fund (project reference number: 14S95579). The present booklet is made primarily for prospective buyers or owners of real estate in Longyearbyen. It can be also useful for other readers interested in the topic.

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## Scope of the booklet

**Assessment of foundations may be performed as a part of the extended thorough evaluation of the building/house ("boligsalgsrapport"), which includes the state evaluation ("tilstandsvurdering") and value evaluation ("verditakst"). Need in assessment of a building can be caused by number of reasons. The following reasons are among the main ([1, 2]):**

- When need in price estimate of a building arises (for instance, at change of an owner).
- If errors in design/construction became known.
- The type of use of the building is altered.
- Visual damage provides doubts in structural safety, inadequate serviceability and usability.
- The structure has experienced exceptional incidents or loads, which might have damaged the structure.
- When the remaining lifetime (determined from the beginning of exploitation for original design of structure), or after the previous assessment, has expired.

**The goal of the booklet is to provide information for basic assessment of conditions of timber pile foundations in Longyearbyen. It is supposed, that the information from the booklet will be used primarily by prospective buyers of real estate or by the owners of such properties. The following aspects are presented in the booklet:**

- List of simple procedures for assessment of current state of timber pile foundations.
- Simple measures aimed to improve (if required) the situation concerning rotting process of timber foundations.
- Short discussion on effects of projected climate change on timber pile foundations in Longyearbyen.

The scope of the booklet is the timber pile foundations. Foundations made from other materials, for instance, concrete piles or various steel piles, concrete shallow foundations are not considered in this booklet.

Assessment of conditions of timber foundations can be an element of an overall assessment of the conditions of a structure. Several standards and guidelines does exist at national and international level, some documents cover timber structures in particular (for instance, [3, 4]).

## Some environmental conditions related to foundations in Svalbard

Svalbard is located within a continuous permafrost zone, [5]. *Permafrost*, or perennially frozen ground, is defined as “ground (soil or rock and included ice and organic material) that remains at or below 0 °C for at least two consecutive years”, [6]. In other words, *permafrost* is not a type of soil, but it’s a thermal state. Moisture in the form of water or ice may or may not be present in the *permafrost*, [7]. The top layer of the ground in permafrost regions is defined as the *active layer*. Temperature fluctuates above and below 0 °C in this layer during the year, [7]. Permafrost is located below this layer. Interested reader can find thorough review of permafrost in Svalbard, including climatic background and engineering challenges in [8].

# Some information on foundations of living buildings in Longyearbyen

## *Settlements of foundations in permafrost conditions*

Foundations are one of the key elements of buildings and structures. The main role of foundations is to transfer loads from the upper structure to the ground. In general, foundations in permafrost conditions are designed for a given time period during which settlements of foundation shall be within a specified range. In other words, some settlements may be, and usually are, permitted within the life period of a foundation. Requirements to settlements can be dependent on type of the building. Requirements to allowable settlements of foundations of the capital public buildings are usually more strict than for the residential buildings. Public buildings are usually designed for longer life period.

Settlements and movements of foundation members in permafrost conditions may take place due to several reasons: i) creep of frozen ground containing ice due to loads from building and other loads; ii) thaw or underlying permafrost containing ice; iii) action of frost heave; iv) action of slope processes. All these, and other reasons shall be taken into considerations during the design of a building.

Practically, excessive settlements are known to happen. They may take place due to errors in design, construction and maintenance. Professional geotechnical expertise may be required to identify factor(s) causing the settlements. Also, it is often difficult to differentiate effects of climate warming from other factors which may affect a structure on permafrost, [9].

Uneven settlements usually (but not always!) do not present immediate treat to human life. For instance, in some cases, excessive settlements of the building have taken place. However, a danger to human life due to collapse of a building or its elements may be absent, and existing issues (some inclination of flooring for instance) does not preclude significantly exploitation of the building. It is difficult to estimate without proper engineering calculations if a building located on damaged foundation may collapse. Closure of a building with excessive settlements may be done as a precaution measure.

## *Rotting of timber pile foundations and other timber elements in permafrost conditions and in cold climate*

Many old, and, especially historical buildings in Longyearbyen were built with limited or absent (compare to the present time) engineering considerations regarding the permafrost conditions. Use of impregnated timber for foundations of old and historical structures was not reported up to date in Svalbard. Review of historical buildings in Longyearbyen is provided in [10].

In some cases, rotting of timber piles and subsequent breakup of a pile may look like an excessive settlement. Latest construction norms ([11]) require to use impregnated timber piles in order to avoid rotting process. This requirement did not exist in the past as it was believed that cold temperatures preclude a rotting process. It was, however, found ([12]) that decay of timber structures and buildings definitely has taken place in Svalbard, despite the cold climate. The study showed that floors, ceilings, crawl spaces, areas affected by leakages were the parts most affected by rot. Study of timber trestles (taubanebukker) at Hiorthhamn ([13]) has shown that large variation of rotting extent in timber elements. It was recommended ([13]) to utilize the rot drill technique for detection of rotting as the majority of rot damages were undetectable using visual inspection or traditional survey methods.

## *Goals of simple assessment of timber foundations*

Simple and preliminary assessment of timber pile foundations can be performed in order to obtain an opinion on conditions of foundation of a given building. The main goals of such assessment are the following:

- To check conditions of timber piles in regard of rotting process.
- To check settlements of the building and/or separate piles.
- To check integrity of foundation system (presence of raptures of foundation elements and excessive displacements of separate piles).

List of simple procedures for assessment of the current state of timber pile foundations
Several procedures may be utilized in order to check different indicators, which may point to certain issues concerning the foundations. One shall bear in mind that some subjectivity may be involved in the procedures suggested below, hence conclusions shall be derived with care. Sufficient number of revealed issues (if any) may indicate a need to contact a professional consultant company for further evaluation of foundation conditions.

It is suggested to perform assessment in three steps:

- Step 1. Desk study.
- Step 2. Visual inspection of the upper structure.
- Step 3. Inspection of foundation (upper part).

Check points and/or indicators at each step and corresponding possible concerns related to foundations are summarized in Table 1-Table 3. It can be recommended to check several piles of a building according to “check points” of the Step 3. The number of piles shall be sufficient to draw meaningful conclusion on conditions of a foundation system.

**TABLE 1.** **Step 1 - List of procedures for assessment of current state of timber pile foundations in Longyearbyen.**

| Step | Check points and/or indicators | Indicators of possible concerns related to foundations |
|---|---|---|
| **Step 1. Desk study**<br>Existing documentation should be collected at this step, including, but not limited to: (i) description and drawings presenting structural design, (ii) and approval documents should be collected, (iii) other documentation, for instance, reports on renovation/interactions in the structure. Notes on actual length of piles are of particular interest.<br><br>Drawings of structural design can be used at later stages as a "map" to follow. Approval documents could be helpful to trace previous interventions in the structure.<br><br>Documentation may be provided by the owner of a building. Local authorities may provide documentation for public buildings. | Date of construction of the building. | The older a building is, the higher the chances may be that foundation fabric is affected by rot.<br><br>Buildings are usually designed for a specific time period (design time period). One may expect appearance of excessive settlements of foundations in permafrost when their age exceeds the design life period. It is assumed that such settlements may take place due to creep in frozen ground, no issues with rot are directly involved in this case. |
| | Previous interventions in the construction of the building (after the construction):<br>• The foundations system.<br>• Bearing elements of upper structure.<br>• Non load-bearing elements such as (but not limited to): wall paneling, flooring, etc. | Possible renovation of foundation system, or/and other bearing/non load-bearing elements may hide issues (existed or still existing) related to foundations. One cannot, however exclude, that issues are solved as result of intervention in foundation system. |

**TABLE 2. Step 2 – List of procedures for assessment of current state of timber pile foundations in Longyearbyen.**

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| **Step 2. Visual and instrumental inspection of the upper structure.** | Cracks in bearing elements such as horizontal, vertical and oblique beams. Note that these elements can be hidden behind paneling or other decorative elements.<br><br>Cracks on concrete/brick walls supported by timber piles. | Defects (as cracks, etc.) and deformations (as inclinations of facade elements or flooring), issues with opening of windows and doors of the upper structure may signalise presence of uneven settlements of foundations caused by either, pile damage (rupture) or settlement of piles. |
| | Inclination or bending of the roof ridge, bottom sill, balcony railing, window line, wall skirt (Figure 1). All such facade elements shall be straight (Figure 2).<br><br>First impression on inclination of the facade elements can be obtained after visual inspection. As a second step, levelling of facade elements with laser leveller can be performed.<br><br>It is assumed that facade elements (as window line) were originally in level, deviation from horizontal position signalise settlements.<br><br>This method is limited for use at facades of a building. Settlements of internal piles cannot be assessed with this method.<br>Levelling with laser leveller was used to make assessment of many foundations in Longyearbyen, ([14]). | |
| | Inspection of doors and windows. It shall be possible to open and close doors and windows with normal resistance. | |
| | Inclined flooring in interior of the building. Allowable inclinations of flooring are defined in [15]. | |

**TABLE 3. Step 3 – List of procedures for assessment of current state of timber pile foundations in Longyearbyen.**

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|---|---|---|
| **Step 3. Inspection of foundation (upper part).**<br><br>This section is largely based on recommendations presented in section "2.4.3. Defects and damage survey", [2]. | Inclination of piles of buildings situated on slope terrain (Figure 3). | Deviation from vertical position for number of piles may indicate action of slope processes as solifluction[1] on foundation system. Inclination of piles may signalize the insufficient resistance of foundation system to action from slope processes. |
| | Detection of missing (possibly by empty mortises) or new foundation members and supportive elements as oblique beams. | Missing foundation members might have been removed due to damage caused by overloading.<br><br>Incorporation of new members can be needed for strengthening of original construction for some reason (when loads appear to be higher than foreseen, and/or rotting processes unexpectedly took place). |

1 Solifluction is slow downslope flow of saturated unfrozen earth materials, ([6]). Solifluction is a typical slope process in slope terrain in Longyearbyen.

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|---|---|---|
| | Visual detection of indicators of mechanical damage of piles or other members of foundation system (as oblique or horizontal beams), such as:<br>• Complete failures: a pile/an element has a rupture affecting the whole cross section (Figure 4).<br>• Structural distress as cracks or failures of joints.<br><br>One should, however, bear in mind that drying fissures hardly affect the load-carrying capacity when they are parallel to the beam/column axis (see Figure 5), but they can be decisive when they deviate from this direction, [16]. | Indicators of mechanical damage, in general, signalise the overloading of a foundation member (the member can be intact or rotten at some degree).<br><br>Structural distress of horizontal and oblique members may indicate overloading due to slope processes (solifluction). |
| | Visual detection of areas of fire or biological damage (Figure 6). | Areas affected by fire or decay have decreased (up to absent) strength. |
| | Physical inspection of foundation fabric. Visually intact areas can experience decay of both, outer layers and of central part of an element. One can recommend to check timber quality above and below ground surface. It is most convenient to perform such operation in late summer/early autumn when it is possible to dig on the whole depth of the active layer as it reaches maximum thickness in the end of summer season.<br><br>The following procedures may be used for assessment of timber quality:<br>• Penetration resistance (destructive method). A technical equipment or penknife can be used. A knife freely penetrates into fully rotten part of a pile. One may however expect difficulties in penetration of a knife through intact outer layer into rotten (if any) inner part of a pile (Figure 7).<br>• Drill resistance (destructive method). Differences in resistance when drilling into sound wood, and when a drill passes through a crack or void, or when drilling into decayed wood can be registered [17, 18]. In other words, resistance when drilling through rotten part decreases compared to intact parts. | Timber members affected by decay are characterised by decreased strength. |

| | | |
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| | This method is developed for using professional equipment, and investigation with shall be performed by professionals.<br>An attempt may be given to use a hand electrical drill equipped with an auger in order to perform similar operation.<br>• Tapping or sounding. Tapping using hammer can be used to obtain a reference to the inner conditions of a wood element [4]. The sound which comes when beating on the wood may signalise presence of serious damage due to decay of material. Locations of hollow parts can be also obtained.<br>• Investigations with various professional techniques (ultrasound techniques, core drilling, etc.). | |

**Note:**

The following information should be taken into account when one performs survey of timber pile foundations. It is known from practical experience that ground conditions around a timber pile may affect the rotting rates. In particular, it may be considered that timber decay is less active (within the active layer) when a pile is surrounded by fine-grained material (as clay), rather than coarse material (as sand). If a pile is surrounded by sand material, then decay may take place at some depth below the ground surface. It is also known, that either, dry or wet conditions around the pile element are preferred. One should avoid a situation when a pile is exposed alternately to dry or wet conditions, i.e. conditions of changing ground water levels. Changes of ground water levels lead to oxygen exchange which leads to intensification of rotting process.

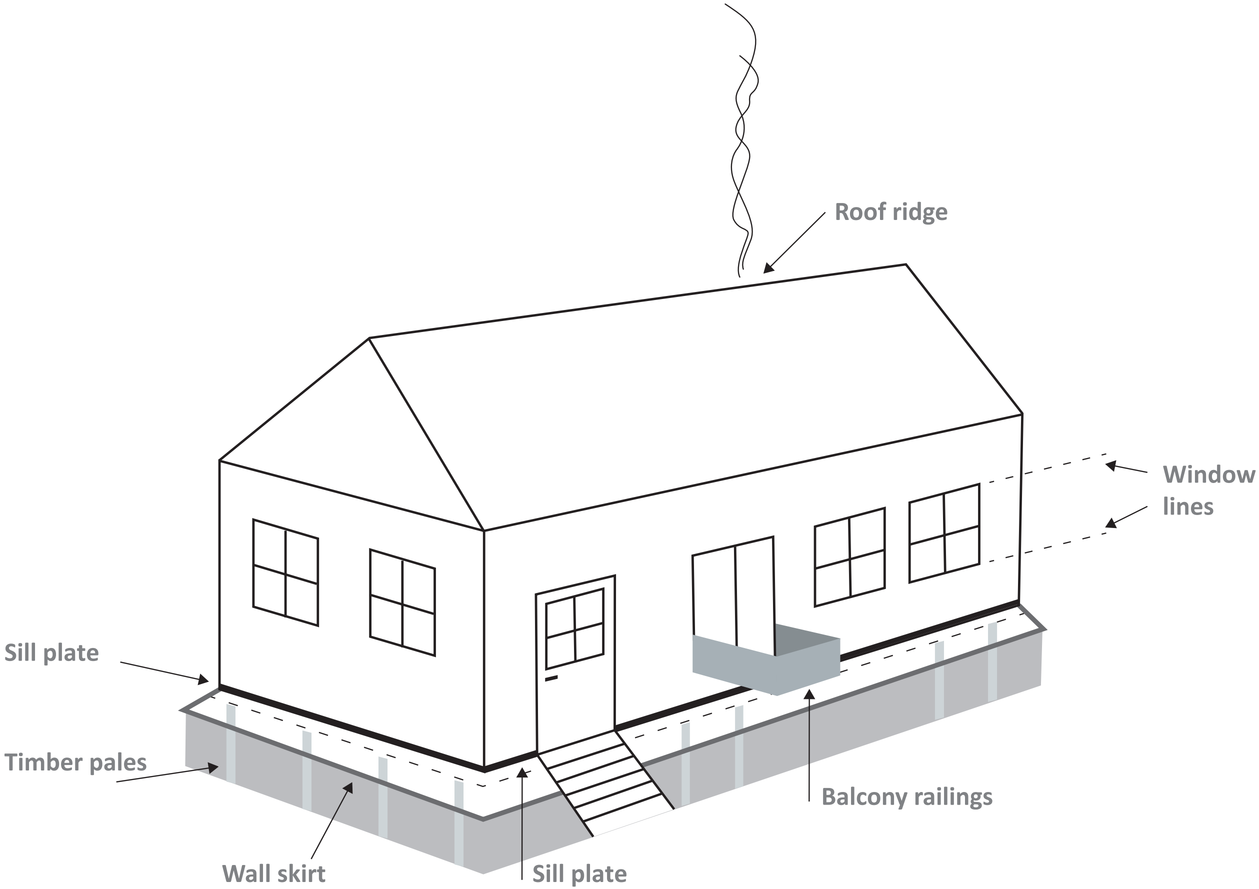


Figure 1. Typical facade elements, geometry of which shall be controlled during visual inspection (Figure: Sinitsyn A., SINTEF).

Figure 2. Example of deformed wall skirt (Photo: Sinitsyn A., SINTEF).

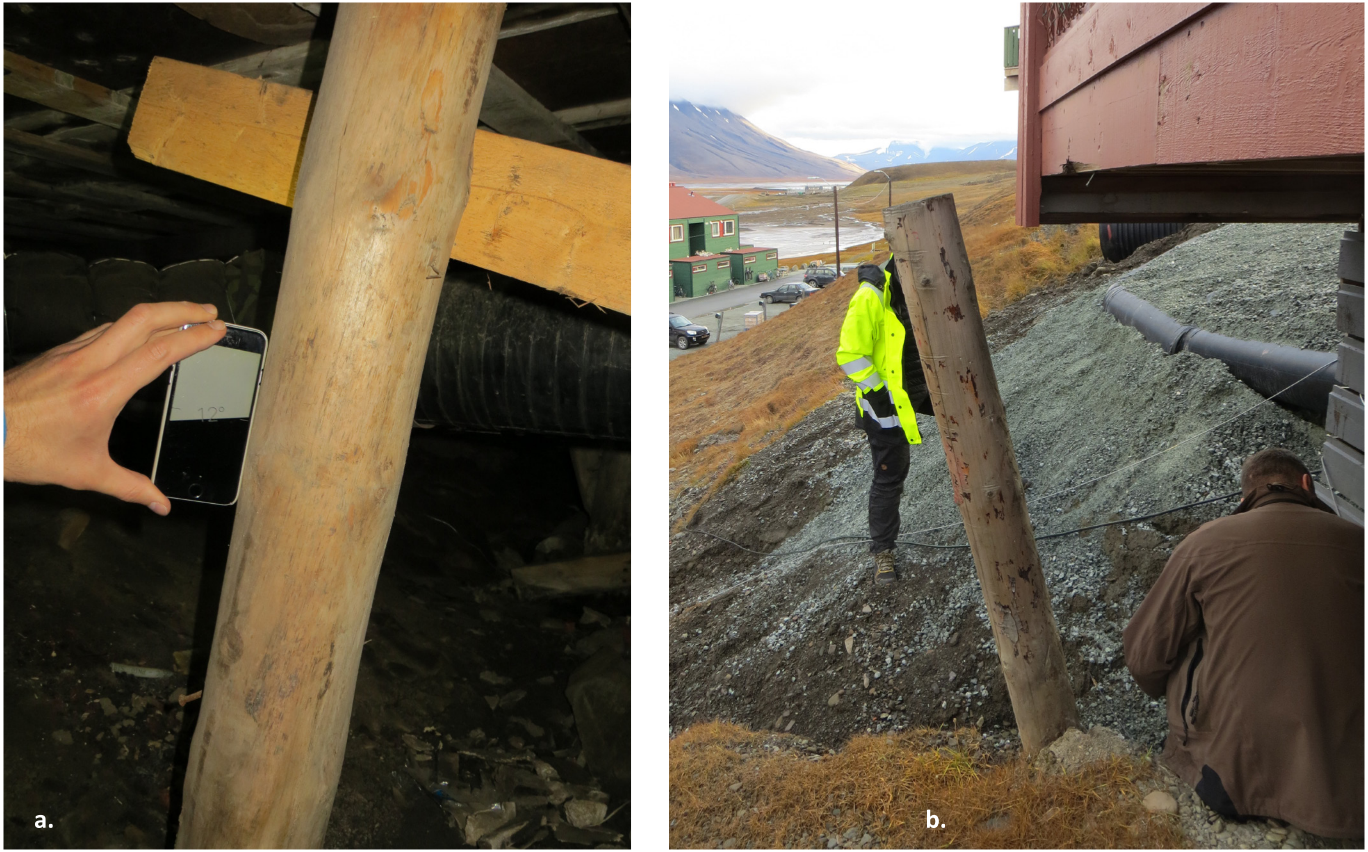


Figure 3 (a, b). Inclined piles (12º) at buildings located on slope terrain in Longyearbyen (Photo: Sinitsyn A., SINTEF)

Figure 4. Rupture of a foundation member (Picture: SWECO).

Figure 5. Example of drying fissures hardly affect the load-carrying capacity which are parallel to the column axis (Photo: Sinitsyn A., SINTEF).


Figure 6. Visual detection of rotten pile elements (Photo: Sinitsyn A., SINTEF).



Figure 7 (a-c). Contact inspection of foundation fabric by penknife (Photo: Sinitsyn A., SINTEF).

# Simple measures for improvement of ground conditions in order to retard the decay processes of timber foundations in Longyearbyen

**The following measures may be suggested to prevent as much as possible the decay of timber pile foundations:**

1. For relatively new foundations, constructed from non-impregnated timber, it can be recommended to impregnate the piles within the active layer. One should perform such operation in late summer, when active layer reaches it's maximal depth and hence is easy to dig. It can be recommended to dig into the permafrost, i.e. somewhat deeper than the depth of active layer.
2. For pile foundations, which are partly rotten from outside, it can be recommended to remove the outer decayed layer of wood, and to impregnate undamaged wood. In such cases it is recommended to contact a professional consultant for evaluation of the remaining load-bearing capacity of the pile.
3. To provide as dry as possible ground conditions around the piles. This can be achieved by proper drainage of surface water around the building and by the drainage of ground water in active layer. Situation of standing water on the ground surrounding piles shall be avoided as much as possible. The following means could be implemented:

a. Micro drainage around foundations.

b. Water collection from the roof with controlled further transportation of water (via drainage ditch, pipe and channel drains).

c. Catchment, transportation/drainage of surface and ground water around the building.

d. Snow management around the building can facilitate minimal snow accumulation, and hence to avoid drainage issues during the melt season.

4. To provide sufficient ventilation of the crawl space beneath the building. Ventilation shall be sufficient to provide removal of i) loss of heat from the building, and ii) moisture in the air due to evaporation of water from the ground. This can be achieved by proper spacing between the planks (if any are used) in the wall skirt and by sufficient height of the crawl space.

# Assessment of climate change effect

Svalbard Archipelago has experienced warming during 20th century, especially in the last three decades [19]. Future climate projections suggest significant air warming, increase of precipitation, and increasing storm frequency [20-22]. The latest, observations for July 2016 at Svalbard airport show air temperatures and precipitations at values of much higher than normal ([23]). Moreover, the last July was the single warmest month ever recorded ([24]).

Projected air warming and increased precipitation may lead to challenges during exploitation of timber pile foundations. Typical thickness of active layer of undisturbed ground with high water content in Longyearbyen is approximately 1 m ([25]) at present time. Estimations of the active layer thickness for 2050, obtained by simple calculation and input data (using conservative approach) from empirical downscaling, show that active layer may increase in the range of 10-20 cm by 2050. Predictions based on modelling show significant warming of permafrost in Svalbard and increase of active layer thickness ([26]) in 21st century. Hence, one may assume that longer parts of piles (located within the active layer) will be exposed to conditions favourable for rotting, and bearing capacity of piles will decrease due to warmer permafrost.

Projected longer periods of warmer and wetter conditions will be more favourable for rotting of timber elements, higher rates of rotting of untreated timber elements should be expected. Hence proper protection of piles shall be provided, especially within the active layer.

One should expect that the old buildings will be more sensitive to climate change because they are constructed on either shallow untreated timber foundations or untreated timber piles. In both cases, owners of such buildings are especially encouraged to check conditions of the foundations.

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