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STANDARDS RESEARCH

Use Category for Preservative-Treated Wood in Northern Canada

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Executive Summary

During the past 30 years, assessments by Mychem Wood Protection Consultants Ltd. of untreated timber piles installed into permafrost in the Arctic and Northern Canada have shown that the piles can last for three or four decades. A recent research project in 2016 on over 170 creosote-treated sawn piles in Iqaluit revealed that despite not having a preservative retention, consistent with the current Canadian Standards Association (CSA) Wood Preservation standard CAN/CSA-O80-15, they were not decayed. They did meet the retention in the CAN/CSA-O80 standard, which was used when the piles were installed into the permafrost in 1958. This observation highlighted the fact that with time, various changes have been made to the standard retention during metrification and harmonization with US and global standards through the International Standard Organization during which the preservative retentions have increased. But more importantly, the influence of temperature on the potential for decay has never been considered. It was shown as far back as the 1930s that at temperatures around 10°C the activity of decay fungi decreased markedly. Significantly, the influence of the temperature was not considered during the most recent harmonization of CAN/CSA-O80-15, which introduced the Use Category (UC) concept.

A research project was designed to develop data on the performance of treated wood in regions in the Canadian Arctic and Northern Canada. Based on information from Mychem's previous research, together with input from technical staff of the Governments of the Northwest Territories and Nunavut, several buildings were identified which were constructed with piles drilled into permafrost. All were at least 20 years old and had a well-documented history. Four structures were selected that would provide information on round piles treated with creosote and on round and sawn piles treated with chromated copper arsenate (CCA), as well as a structural retaining wall, which incorporated CCA-treated large-dimension ('8 x 8') spruce timbers. The research project to undertake an assessment of the four structures was proposed by Mychem and supported by CSA, the Governments of the Northwest Territories and Nunavut, and the treated wood industry.

At each location, 25 timbers or piles were randomly selected, and bored twice to a depth of at least 30 mm. Two 12 mm diameter cores were removed and stored for analysis. The preservative penetration in each core was recorded and the two cores were cut to the required length for the assay according to CAN/CSA-O80-15. The results were compiled.

Previous research by Mychem in 2017 on creosote-treated Douglas-fir sawn piles recorded average creosote retentions of 131 kg/m^3 and 141 kg/m^3 for two buildings. After almost 60 years, all 175 piles were free of basidiomycete decay. In the current research, 25 creosote-treated round piles at Fort Resolution were all free of decay after 48 years of service. They had an average creosote retention of 208 kg/m^3 and an average penetration of 16 mm. Based on the excellent performance by both sets of piles for almost 50 years, it was recommended that the creosote retention for UC4.1 of 120 kg/m^3 be adopted as the retention for the UC4 Arctic and Northern Canada.

The treated wood, in the CCA-treated pine round piles at Deline, was all assessed as sound, based on the average 12 mm measurement using the 6-Joule Pilodyn™, which was identical to the reference readings on the same piles from sound timber. The average retention of the piles was 7.4 kg/m^3 and the average CCA penetration was 15 mm. The CCA content in the treated wood only, based on the standard assay but adjusting for the lower CCA penetration, was 8.9 kg/m^3. The '10 x 10' CCA-treated Douglas-fir sawn timber piles supporting the air terminal building at Baker Lake were all free of decay in the treated wood, with an average Pilodyn™ value of 14.7 mm. The average reference value was 14 mm. The retention using the CAN/CSA-O80-15 standard was very low at 2.7 kg/m^3. Based on the penetration data, the retention of the treated wood only was 4.9 kg/m^3. The 25 CCA-treated '8 x 8' spruce timbers in the retaining wall at Pond Inlet were all free of basidiomycete decay. This was reflected in the Pilodyn™ measurements, which were identical to reference values from sound timbers. One timber that was extremely wet had an elevated Pilodyn™

reading, indicating some loss of fiber quality. It also had one of the highest CCA retentions of 8.5 kg/m^3. The average retention based on the CAN/CSA-O80-15 methodology was 4.3 kg/m^3. Using the observed penetrations that were quite low, compared to those assumed in the standard, the actual preservative retention of the treated wood only was 7.3 kg/m^3.

In recommending preservative retentions for the proposed UC4 Arctic and Northern Canada, consideration was given to the retentions for creosote and CCA currently specified in UC3.2 and UC4.1. It was also considered that the proposed retention be selected from the same UC for both preservatives. Finally, it was recognized that a service life of at least 50 years should be assumed, and that this must consider the impact of climate change on the loss of permafrost over the 50-year period. Based on all of the creosote round and sawn pile data available, a retention of 120 kg/m^3 was proposed for the new UC4 Arctic and Northern Canada. After a similar evaluation of CCA-treated sawn wood and round wood data, it was recommended that a retention of 6.4 kg/m^3 be specified for treated wood in UC4 Arctic and Northern Canada.

Following the completion of the sample acquisition and analysis, a proposal was made to the CAN/CSA-O80-15 Technical Committee Annual Meeting in Toronto, on October 24, 2019, to introduce a UC4 Arctic and Northern Canada for application in regions where permafrost was affecting the design of buildings with treated timber piles and structural retaining walls. The proposal was unanimously supported by the Technical Committee.



The most common structural use for timber in the Arctic and Northern Canada where there is permafrost is as pilings to support buildings and as retaining walls to contain large-dimension timbers.

1.0 Introduction

During the last decade, the effect of climate change on the loss of Arctic sea ice has attracted global attention. Less attention has focused on other effects of global warming in the Arctic, which are equally important. One such issue is the lowering of permafrost as the soil surface warms [1], [2]. The melting of permafrost in coastal communities like Tuktoyaktuk has resulted in houses sliding into the sea, while also raising water levels [3], [4]. These effects combine to threaten the future of the town, which now must consider relocating to higher ground.

1.1 Infrastructure Development in the Arctic and Northern Canada

The most common structural use for timber in the Arctic and Northern Canada where there is permafrost is as pilings to support buildings and as retaining walls to contain large-dimension timbers. Typically, untreated wood piles have been previously inserted into holes drilled into the permafrost. This eliminates the effect of active-layer movement, which destabilizes structures built directly onto the surface. While this approach has proved successful over several decades of service life, the combination of bacterial and fungal decay due to thermal losses in spaces below the buildings has left many of the untreated piles in need of replacement. For small buildings, alternative support strategies using a steel frame or screw jacks on timber pads have been used. But for large structures, such as schools, medical clinics, and offices, the use of piles locked into the permafrost remains the principal support. The loss of permafrost, coupled with the previous use of untreated timber, has created an urgent need to replace the aging infrastructure.

In addition, there are initiatives to expand commercial activities in the Arctic. China has expressed interest in using the Northwest Passage to ship goods to Europe. Cruise ships now venture through the Northwest Passage, bringing much needed income for Indigenous communities. This has created a demand for facilities to allow the ships to dock, as well as for reception areas where passengers can spend time ashore and meet with local residents. In addition, plans to expand Arctic College campuses and broaden education opportunities for the Indigenous peoples of the Arctic and Northern Canada will create a need for new buildings in small communities. Thus, the need for a new infrastructure is critically important in the Arctic. Much of this infrastructure, made up of timber piles and structural timbers, should involve preservative-treated wood.

1.2 Wood Preservation

The treatment of timber for use in structures is standardized in Canada in the CAN/CSA-O80-15 *Wood Preservation* Standard [5]. CAN/CSA-O80.1-15 *Specification of Treated Wood* [5] recognizes different Use Categories (UC) for treated wood, ranging from UC1 for wood used indoors to UC5 for treated wood used in the marine environment. These Use Categories are defined by the degree in which products become wet and support decay. The UC that applies to treated wood

used in ground contact is UC4. In particular, UC4.2 covers treated wood piles and structural retaining walls comprised of treated, large-dimension timbers. This UC currently applies for all new and replacement infrastructure in the Arctic and Northern Canada where contact with the ground occurs. However, when considering the risk of decay of timber, no allowance has been made for the influence of temperature.

A number of authors have commented on the role of temperature on the activity of decay fungi. In 1933, Humphrey and Siggers [6] tested 56 types of wood-decay fungi and showed that at 12°C growth was either entirely inhibited or greatly reduced. For many fungal species, growth may be only 5 to 10% as fast as growth at optimal temperatures. This observation has been supported by Scheffer [7], who noted that decay is quite slow below 50°F (10°C) and is completely inhibited at temperatures near 32°F (0°C). Rayner and Boddy [8] stated that, generally, wood-decay fungi are mesophilic with a growth range within 0 to 45°C. They also noted that many basidiomycotina have cardinal temperatures in the region of 5, 25, and 40°C. Eaton and Hale [9] also commented that most wood-decay fungi are mesophilic and grow at temperatures ranging from 10 to 40°C. Cartwright and Findlay [10] focused mostly on the temperatures needed to kill fungi, but showed similar results in which growth significantly declined as temperatures declined and approached 10°C. It is clear that temperatures such as those found in the Arctic and Northern Canada for most of the year will severely inhibit fungal activity. However, this is not reflected in the UC defined in CAN/CSA-O80-15 [5].

In addition to the effects of temperature on wood decay, one must also consider the potential implications of wood preservative on the environment. When wood is pressure-treated, most preservatives will remain in the timber but small amounts are able to move with the available moisture into the wood. This is an important contribution to long-term performance, as it coats the surface of checks and splits, which would otherwise expose untreated wood. This provides a valuable remedial treatment to protect any exposed untreated wood during use. However, the potential for leaching of the preservative increases at very high preservative retentions where, during service, a small amount of the excess preservative can be lost from the treated wood. It is therefore important that the treatment of the timber used in the Arctic and Northern Canada reflects the needs of this region, considering both the effects of temperature on decay as well as the potential impacts of wood preservatives on the environment.

The purpose of this study is to assess decay in treated wood in regions containing permafrost in order to inform the parameters of a future UC4 for Arctic and Northern Canada. This new UC4 would seek to balance the lower risk of decay arising from the low temperatures present in regions containing permafrost with the important need to ensure long-term performance. It would be anticipated that such treated timber would provide a service life in excess of 50 years. In addition, the impact of climate change on the loss of permafrost over the next 50 years must be considered. The benefits from a specific UC4 for Arctic and Northern Canada would be the greater environmental stewardship by the treated wood industry (by minimizing the environmental impact of treated wood used in ground contact), coupled with extremely long service lives in uses such as building piles and structural retaining walls.

2.0 Methodology

2.1 Defining Criteria of a UC for Cold Climates

Several parameters must be considered when defining a new UC4 for Arctic and Northern Canada. The parameters of greatest relevance include temperature, structure type, climate change impacts, and preservative type.

2.1.1 Temperature

One consideration in developing a new UC for Arctic and Northern Canada is the boundaries in which such a UC would apply. Temperatures within communities close to the Arctic vary, as is demonstrated in the meteorology map published by the National Snow and Ice Data Center (NSIDC) [11]. It is therefore important to consider the impact of the temperature when defining a UC for Arctic and Northern Canada, which could be specified as those areas where permafrost is present.

2.1.2 Structure Type

One of the principal uses of treated wood in the Arctic and Northern Canada is for building foundations and structural retaining walls, which are several meters high and comprised of large-dimension timbers. The impact of permafrost on the design of such structures involving treated wood is defined by local building codes. Therefore, a UC4 would apply only to structural uses where permafrost is present, such as land piles and retaining walls.

2.1.3 Climate Change

Over time, global warming may have a significant impact on the loss of permafrost. It would be expected that a new UC for treated wood to be used for structural foundations and retaining walls would ensure a service life of at least 50 years. Such a requirement could impact the choice of preservative retentions recommended for a new UC4.

2.1.4 Preservative Type

To ensure ease of use of the new UC4, existing preservative retentions at lower decay hazards (e.g., UC3.2 and UC4.1) for the two preservatives widely accepted as reference preservatives will be considered. Fortunately, piles and other structures treated with creosote and chromated copper arsenate (CCA) are available in areas with permafrost and can be used to confirm the preservative retentions required.

2.2 General Methodological Considerations

2.2.1 Assessment of Preservative Content

In a normal assessment of the preservative content needed for a specific Use Category, sapwood samples fully treated with the preservative would be installed in a test site. Untreated sapwood samples would also be installed to provide a reference to the decay hazard. For the Arctic, where the decay hazard is much lower than other parts of North America, such a strategy is unworkable since several decades would be needed before the untreated wood would fail. Consequently, an alternative strategy was adopted using full-sized material already in service.

Piles and sawn timbers treated with one of the two reference preservatives, creosote or CCA, and which had been in service for at least two decades, were selected from available structures in regions of the Northwest Territories and Nunavut that had permafrost. The preservative retention measured according to the standard assay zones was determined, and the condition of the treated wood was assessed. However, the CAN/CSA-O80-15 [5] standard also specifies a minimum penetration requirement for treated wood. Since the material was unincised, (whereas incising is required in the current CAN/CSA-O80-15), the penetration of the preservative did not always meet that specified in the standard. It is possible to estimate the preservative content in only the treated portion of the timber by combining the retention using the standard assay zone with the measured preservative penetration. This approach is useful since the actual preservative content in the treated sapwood can be then equated to what may be required to protect the sapwood from decay. In the discussion of results, both the standard retention and the preservative retention in the treated wood only will be discussed where appropriate.

2.2.2 Evolution of Preservative Retention Values

An additional factor to consider is the increase in preservative retentions that have occurred since the first CAN/CSA-O80 standard [8] was accepted in 1954 (Table 1). The first of these occurred during the conversion from imperial to metric units. During the metric conversion, preservative retentions were rounded up to the nearest 5 kg/m^3. Further increases occurred during harmonization of the CAN/CSA-O80 with the American Wood Protection Association (AWPA) standards, which also were converted to a metric base. In 2008, the CSA Group agreed to harmonize the CAN/CSA-O80 with other wood preservation standards globally through the International Standards Organization. This introduced the Use Category System (UCS). The effects of all of these changes (Table 1) have resulted in creosote retention increasing from 128 kg/m^3 (ground contact round wood and sawn wood) in 1954, to the current retentions of 160 kg/m^3 (UC4.2 sawn wood) and 240 kg/m^3 (UC4.2 round wood). Likewise, the retention for CCA

has increased from 6.4 kg/m^3 for ground contact in all uses initially, to 8 kg/m^3 for sawn wood in ground contact and to 12 kg/m^3 for round wood in UC4.2. Data from treated wood in the period from 1954 to the mid-2000s will be used to analyze the performance of the timber treated to these lower retentions in the Arctic and Northern Canada.

2.3 Data Collection

2.3.1 Preparation for the Site Visits

After consultation with senior staff in the Governments of the Northwest Territories and Nunavut, structures containing significant quantities of preservative-treated wood with at least 20 years of service life were identified. The selection of sources of treated timber was then made based on a) service life and b) the need to collect data on both round and sawn timbers that have been treated with either of the widely used reference preservatives, creosote or CCA.

An important component was the assaying of the treated wood samples. Following discussions with industry representatives, the creosote assay was performed by the Southern Pine Inspection Bureau (SPIB) in the United States, which is accredited for the assay of creosote-treated wood. For the assay of the CCA-treated wood, each of the major CCA preservative suppliers in Canada (Viance, Timber Specialties, and Lonza Wood Protection) agreed to be responsible for assaying one source of treated wood cores.

2.3.2 Measurements Made on Site

During each site visit, a number of measurements were made. The moisture content of the treated wood in the ground line region for piles and close to the sampling points for the timbers in the retaining wall at Pond Inlet was measured with a resistance moisture meter (RDM^3 Wood Moisture Meter, Delmhorst Instrument Co., Towac, NJ 07082). The presence of biodegradation in the treated wood at the timber surface was assessed using a 6-Joule Pilodyn™ (Wood-Slimp, GmbH, Denmark). A photographic record of the piles and timbers was also made.

Table 1. *Creosote and CCA Retentions for Douglas-fir Treated Sawn and Round Wood in Ground Contact, in the CAN/CSA-O80 Wood Preservation Standards, 1954, 1979, 1997, and 2016*

		1954	1974	1997	2016 UC4.1	2016 UC4.2
CREOSOTE						
Sawn wood	Under 5″	10 pcf (160 kg/m^3)	10 pcf (160 kg/m^3)	160 kg/m^3	160 kg/m^3 Under 114 mm (4.5″)	160 kg/m^3
	Over 5″	8 pcf (128 kg/m^3)	8 pcf (128 kg/m^3)	128 kg/m^3	120 kg/m^3 Over 114 mm (4.5″)	160 kg/m^3
Round wood		8 pcf (128 kg/m^3)	8 pcf (128 kg/m^3)	8 pcf 128 kg/m^3	240 kg/m^3	240 kg/m^3
	For severe service conditions	10 pcf (160 kg/m^3)	10 pcf (160 kg/m^3)	10 pcf 160 kg/m^3	NA	NA
CCA						
Sawn wood	All dimensions		0.4 pcf (6.4 kg/m^3)	6.4 kg/m^3	6.4 kg/m^3	8 kg/m^3
Round wood			0.8 pcf (12.8 kg/m^3)	12 kg/m^3	12 kg/m^3	12 kg/m^3

NOTE: *pcf = pounds of preservative per cubic foot of wood.*
Creosote ***Blue:*** *by gauge or weight;* ***Orange:*** *by gauge, weight, or assay;* ***Grey:*** *by assay*
CCA ***Orange:*** *by gauge, weight, or assay;* ***Grey:*** *by assay;*
NA – This designation is not applicable since UC4.2 is for more severe conditions compared to those of UC4.1

2.3.2.1 Moisture content

The moisture content was measured with a resistance moisture meter at a depth of approximately 5 to 10 mm from the surface of the wood. The two pins of the meter were hammered into the wood to a depth of 10 mm and the moisture content of the treated wood was read from the digital display. The moisture content is based on the electrical conductivity of the treated wood.

2.3.2.2 Assessment of deterioration at the surface of the timber using the 6-Joule Pilodyn™

An important aspect of the research was to confirm that the treated wood at the surface of the timber had not deteriorated due to decay. The Pilodyn™ was selected for this purpose. The Pilodyn™ fired a stainless steel pin that was 60 mm long and 2.5 mm in diameter into the wood (Figure 1). The resistance of the fiber governs the penetration of the pin, which is read from the scale on the tool. The technique provides a relative measurement. Different wood species having different densities will provide different pin penetrations. For the research described here, the deterioration of the treated wood at the outer 40 mm of the timber was assessed. A number of studies have reported the use of the Pilodyn™ to assess decay [13]–[16]. Since the measurements are relative, reference measurements were also made on a number of the piles or timbers, where the wood was considered to be sound.

2.3.3 Sample Collection

The sampling of the treated wood was timed for late July and early August 2019, since this ensured that the frozen ground had thawed prior to the onsite sampling. Data were also included from a more comprehensive study of creosote-treated timber piles in Iqaluit, performed in 2017 for the Government of Nunavut [17]. Two structures in the Northwest Territories were sampled for preservative penetration and decay in wood piles. A further three structures in Nunavut were sampled for preservative penetration and decay in sawn wood.



Figure 1: *Assessment of Treated Wood Using a 6-Joule Pilodyn™*
(Reproduced with permission from Mychem Wood Protection Consultants Ltd.)

At each location where buildings were supported by piles, a review was made of all the piles and 25 were selected to be representative for those available. Any piles that had been machined were excluded from the selection, since this may have caused deterioration of unexposed untreated wood. Each round pile was drilled in two locations close to the ground line. Cores were removed to a depth of at least 40 mm. To protect the treated timber, an Impel™ boron rod (Sasco Products Limited, Dartmouth, NS) was inserted in each core hole before it was sealed with a plastic plug.

The removed cores were visually assessed for preservative penetration to ensure that the full depth of treated wood was recovered. In general, preservative penetrations were all less than 25 mm. For sawn timber piles, cores were removed from the adjacent faces of the piles. For timbers in the retaining wall at Pond Inlet, cores were removed along the length of a selected timber. To maximize the decay hazard from the exposed face, cores were collected close to the interface of two timbers where moss had collected. Each pair of cores was placed into a plastic sample container that was labelled and sealed.

2.3.3.1 Creosote-treated wood

Fort Resolution, NWT. Twenty-five piles were randomly selected from 159 round creosote-treated Douglas-fir piles drilled into the permafrost at the Deninu School, Fort Resolution (Figure 2). The school was constructed in 1971. Measurements were made of the pile moisture content and the quality of the treated wood using the 6-Joule Pilodyn™. Two 12 mm diameter cores were removed from each pile to a depth of ca. 40 mm. Upon returning to Vancouver, a photographic record was made of each pair of cores to illustrate the preservative penetration. The two cores were processed to provide the 0 to 25 mm assay zone and submitted to the SPIB for creosote analysis.

Iqaluit, Nunavut. In 2017, an assessment (Figures 3a and 3b) of 177 incised Douglas-fir sawn timber piles supporting Nunavut Arctic College and the Federal Warehouse in Iqaluit was conducted by Mychem for the Government of Nunavut [17]. These buildings were constructed in 1958. Some data from this previous collection have been included in this study. Unlike the current research, the piles in the previous research in 2017 were excavated. A laboratory assessment was also made of the untreated wood recovered from each pile beyond the outer, treated shell.

2.3.3.2 CCA-treated wood

Deline, NWT. Twenty-nine CCA-treated round piles supporting the Grand Father Ayah School at Deline (Figure 4) were identified from earlier building pile assessments conducted by Mychem. The school was built in 1984, using 231 untreated pine piles inserted into the permafrost. In 2006 after 22 years, these piles were found to be in poor condition due to decay, particularly in the outer sapwood. Typically, in areas with permafrost, the ground beneath the school easily flooded as water could not drain due to the permafrost. This would enhance the risk of decay. These treated pine piles support an extension to the school built in 1994. Discussions with the Government of the Northwest Territories staff confirmed that the CCA-treated piles were functioning well with no instability.



Figure 2: *Creosote-Treated Round Piles at Deninu School at Fort Resolution*



3a *(Reproduced with permission from Mychem Wood Protection Consultants Ltd.)*



3b *(Reproduced with permission from Mychem Wood Protection Consultants Ltd.)*

Figure 3: *Assessment of Creosote-Treated Douglas-fir Sawn Timber Piles at Nunavut Arctic College and the Federal Warehouse, Iqaluit. a) Federal Warehouse, b) Pile Sampling*

Measurements were made of the pile moisture content and the quality of the treated wood using the Pilodyn™. A photographic record of each pile was then made. Upon returning to Vancouver, a photographic record was made of each pair of cores to illustrate the preservative penetration. The core samples were then submitted for the assay by X-ray spectrometry.

Baker Lake, Nunavut. The air terminal building at Baker Lake was constructed in 1982 and is supported by 54 unincised, CCA-treated, '10 x 10' Douglas-fir timber piles, using a Greenland foundation (Figure 5). Twenty-five piles were selected for the sampling. Measurements were made of the pile moisture content and the quality of the treated wood using the Pilodyn™. Two 12 mm diameter cores were removed from each pile to a depth of ca. 30 mm. They were subsequently processed to a length of 0 to 16 mm and sent to a commercial laboratory for analysis.

Pond Inlet, Nunavut. A retaining wall at Ulaajuk School, Pond Inlet, was constructed in 1987 from unincised CCA-treated, '8 x 8' spruce timbers (Figure 6). The section of retaining wall is in excess of 40 m in length with a height ranging from 0.5 to 1.5 m. Twenty-five spruce timbers in the wall were each sampled in two places and cores were recovered for assay. Measurements were made of the timber moisture content and the quality of the treated wood using the Pilodyn™. The processed cores were then sent to a commercial laboratory for analysis.

2.4 Analytical Procedures of Creosote and CCA Cores

2.4.1 Processing of Samples for Analysis

At the end of the sampling at all of the locations, each core was visually assessed for preservative penetration based on the change in colour that can result from the preservative, and the result was recorded. For the CCA assessment in the field, no indicator was applied. Any anomalies were noted. When the samples had been returned to Vancouver, a second assay was conducted. Where the preservative penetration resulted in an unclear colour change in the cores, chrome azurol-S reagent was applied, as described in the AWPA A3-14 standard [18]. The two cores for each timber source were



Figure 4: *CCA-Treated Round Piles at the Grand Father Ayah School at Deline*



Figure 5: *CCA-Treated Douglas-fir Timber Piles in a Greenland Foundation at the Baker Lake Air Terminal Building*



Figure 6: *CCA-Treated Spruce Timber Structural Retaining Wall at Ulaajuk School, Pond Inlet*

then cut to the length required by the assay protocol. For sawn wood, the assay zone was 0 to 16 mm, while for round wood, the assay zone was 0 to 25 mm.

2.4.2 Analysis of the Cores

The processed cores from the creosote-treated round piles were sent to the SPIB where the two cores were combined for the assay. The creosote content was determined by using the AWPA A6-15 standard [19].

For samples collected from CCA-treated timber, the two cores were cut to the assay length, oven dried, ground to 30 mesh sawdust, and then combined for a single assay. The preservative content was measured by X-ray spectrometer analysis (AWPA A9-18) [20]. For the X-ray analysis, the wood density from the Table 3 CAN/CSA-O80.2-15 (in CAN/CSAO80-15) was used.

At each location where the wood species had not been specified in the available records, additional cores from untreated heartwood were collected and sent for wood identification to FPInnovations. The wood species were Douglas-fir for the round creosote-treated piles at Fort Resolution, lodgepole pine for the round CCA-treated piles at Deline, Douglas-fir for the CCA-treated sawn piles at Baker Lake, and spruce for the timbers in the retaining wall at Pond Inlet.

3 Results and Discussion

The retention data for the creosote and CCA piles and structural timbers sampled are presented here. In choosing a suggested preservative retention to consider for a new UC4 Arctic and Northern Canada, long-term performance must be balanced with minimizing the environmental impact. This requires a retention that would be effective should the permafrost thaw due to warming in the 50-year anticipated life of newly installed treated piles or structural retaining walls. For this reason, the preservative retentions in UC3.2 (creosote 96 kg/m^3 and CCA 4 kg/m^3) and UC4.1 (creosote 120 kg/m^3 and CCA 6.4 kg/m^3) are considered when evaluating the data.

3.1 Assessment of Creosote-Treated Round Piles – Fort Resolution, NWT

The data for the 25 creosote-treated Douglasfir round piles sampled at Fort Resolution are shown in Appendix 1 and summarized in Table 2. The average penetration for the 25 piles was 16 mm, which is slightly lower than the 19 mm required for creosote-treated round piles in CAN/CSA-O80-15 [5]. The average moisture content was 22%, which is low due to the creosote treatment. The average 6-Joule Pilodyn™ pin penetration value was 11.4 mm, while that of the reference reading on the same piles was 11.8 mm. It may therefore be concluded that no measurable degradation of the

Table 2. *Summarized Data for Creosote-Treated Round Piles at Fort Resolution*

	Average	SD
Moisture Content (%)	22	4
Pilodyn™ (mm)	11	1
Core 1 Penetration (mm)	16	6
Core 2 Penetration (mm)	16	7
Average Penetration (mm)	16	7
No. of Cores with Penetration ≤ 10 mm	15	
Retention (kg/m^3)	208	82
Retention – Treated Wood Only (kg/m^3)	307	150

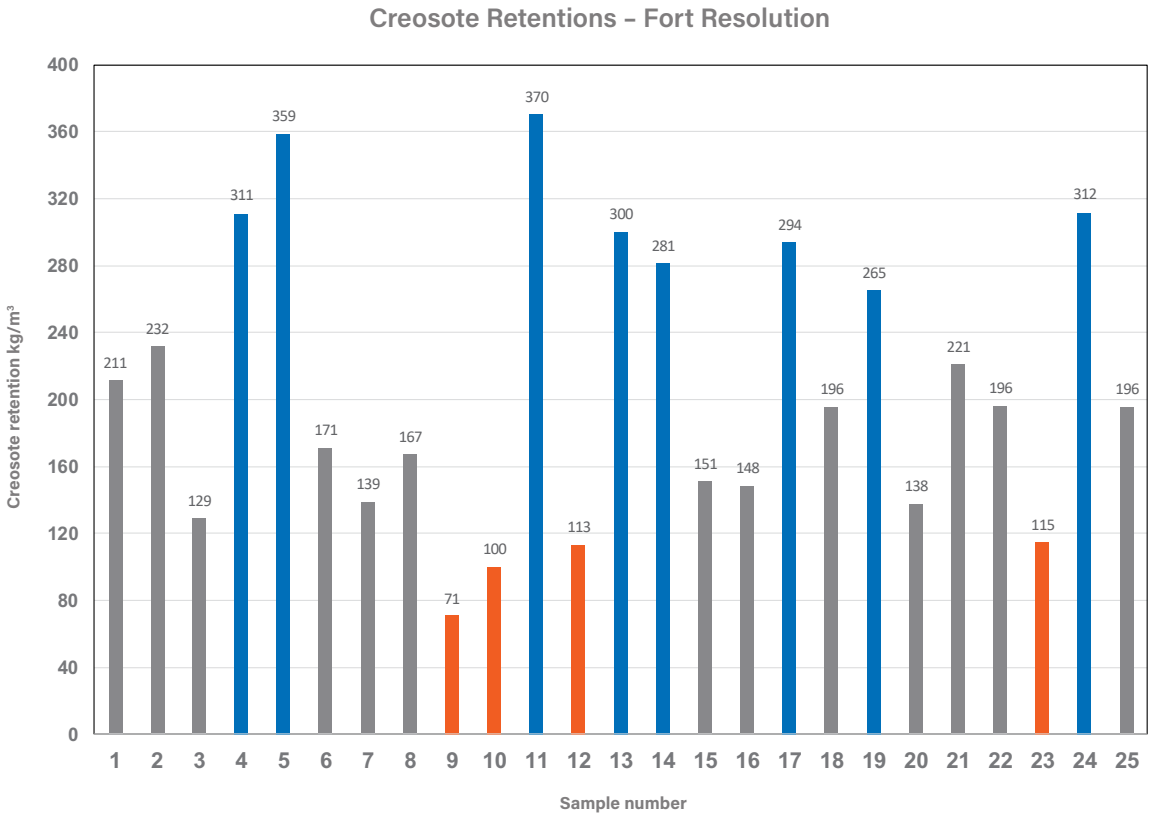
treated wood had occurred. For comparison with other Douglas-fir published data, normalization of the data to 30% moisture content would increase the average penetration by about 1.6 mm to 13 mm. This agrees well with published data [16].

The penetration of the creosote in the piles was highly variable. This may be expected since the piles were unincised. Of the 25 piles sampled, over almost one-third (8 piles/15 cores) had creosote penetration less than 10 mm.

The retention of the 25 piles was based on an assay of two cores from each pile. The average retention was 208 kg/m^3 (Table 2). Of the 25 piles, eight piles had creosote retentions exceeding the current CAN/CSA-O80 standard of 240 kg/m^3 (Figure 7). This reflects the good treatment of the piles in 1971. Considering the options discussed earlier, an additional 13 piles had creosote retentions exceeding the proposed retention for UC4 Arctic and Northern Canada of 120 kg/m^3 based on those in UC4.1. Three of the remaining piles had creosote retentions greater than 96 kg/m^3, which is the retention required for creosote timber to be used above ground in UC3.2. One pile retention was below 96 kg/m^3.

Based on this new data, the excellent performance of the piles after 48 years suggests that in UC4 Arctic and Northern Canada, a creosote retention of either 96 (from UC3.2) or 120 kg/m^3 (from UC4.1) would be suitable for both round and creosote-treated sawn timber in ground contact.

Figure 7: *Creosote Retentions for the 25 Samples from the Round Piles at Deninu School, Fort Resolution (Blue >240 kg/m^3; Grey >120 kg/m^3 <240 kg/m^3; Orange <120 kg/m^3)*



3.2 Creosote Sawn Piles at the Federal Warehouse and Nunavut Arctic College in Iqaluit, Nunavut

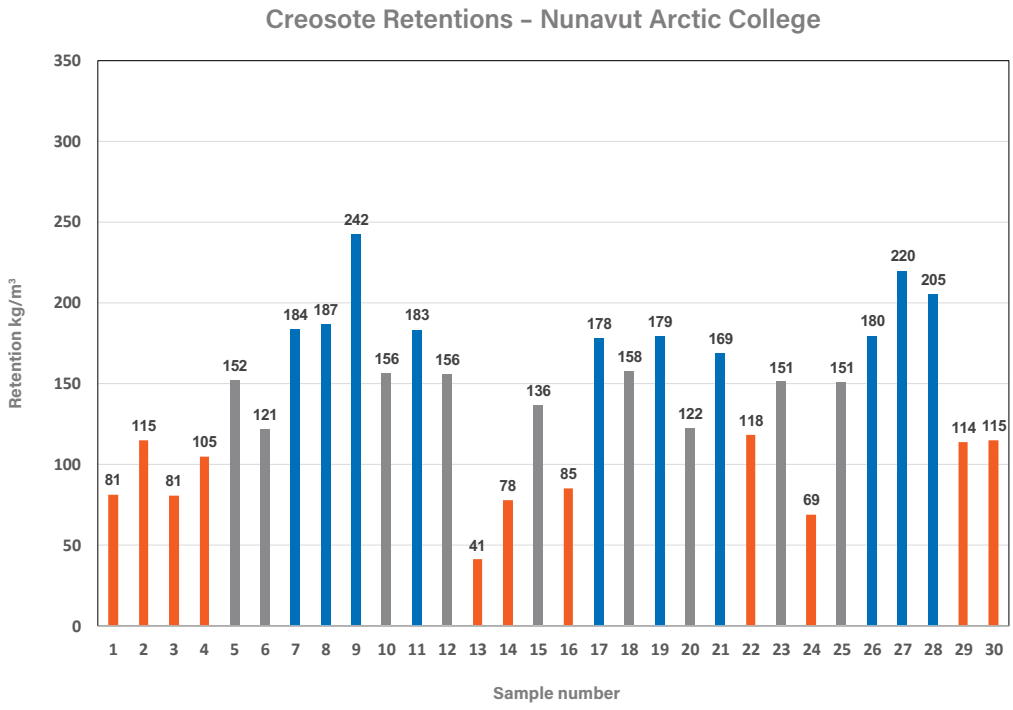
The results (Figure 8) showed that the average retention for the piles sampled for the Nunavut Arctic College was 131 kg/m^3. The average retention for the piles sampled beneath the Federal Warehouse was 141 kg/m^3. Both these values exceed the creosote retention required at the time of the installation in 1958, in the first edition of CAN/CSA-O80, published in 1954 [12]. However, neither meets the existing retention requirement in UC4.2 for the current edition of CAN/CSA-O80 [5] of 160 kg/m^3. During the assessment, additional cores 12 mm in diameter were removed to a depth of 75 mm from the original core holes. This enabled the soundness of the untreated wood to be determined by physical inspection. No basidiomycete decay could be detected.

The excellent condition of the piles after almost 60 years of service, even though the retentions do not meet those required for sawn piles in the current CAN/CSA-O80 standard, is consistent with the much lower decay hazard present in the Arctic and Northern Canada where permafrost is present close to the surface of the ground. Combining this data with that from the research conducted for CSA at Fort Resolution, and considering the impact of global warming on the loss of permafrost, it is recommended that the retention for the proposed new UC4 Arctic and Northern Canada be assigned from UC4.1 of 120 kg/m^3.

3.3 Assessment of CCA-Treated Round Timber Piles at Deline, NWT

The 29 CCA-treated piles installed as part of an extension to the Grand Father Ayah School were in excellent condition after 25 years (Appendix 2 and summarized

Figure 8: *Retention of Creosote-Treated Piles Supporting Nunavut Arctic College, Iqaluit (Blue >160 kg/m^3; Grey >120 kg/m^3 <160 kg/m^3; Orange <120 kg/m^3)*



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in Table 3). The average moisture content of the piles was 30%. The average 6-Joule Pilodyn™ pin penetration was 12 mm, while the average reference value was 12 mm. The two values are identical, which confirms that the treated wood is sound and has no fiber deterioration. All of the piles examined were visibly found to be in good condition with no evidence of decay.

Because the piles were unincised, the CCA penetration would be limited to the sapwood, which is usually known to be very permeable. The average CCA penetration was 15 mm, which is close to the CAN/CSA-O80 standard requirement of 19 mm. Indeed, 11 of the 25 piles (based on 22 cores) had CCA penetrations of 19 mm or more (Table 3).

The average CCA retention for the 25 piles sampled was 7.4 kg/m^3. This is significantly less than the 12 kg/m^3 required for preservative-treated round wood in ground contact in UC4.2. Only three piles had a CCA retention exceeding the UC4.2 retention requirement (Figure 9a). A further 12 piles had retentions exceeding the proposed CCA retention of 6.4 kg/m^3 for UC4 Arctic and Northern Canada. Nine piles had a CCA retention less than 4 kg/m^3 (Figure 9a).

Combining the CCA penetration measurement with the retention recorded for each pile using the standard assay, it was possible to estimate the CCA retention of the treated wood only. When this was done, the average retention increased slightly to 8.9 kg/m^3. Eighteen of the retentions for only the treated wood exceeded 6.4 kg/m^3 (Figure 9b), one of the proposed retentions for the UC4 Arctic and Northern Canada. Only an additional two piles had a retention that exceeded 4 kg/m^3.

3.4 Assessment of CCA-Treated Sawn Timber Piles at Baker Lake, Nunavut

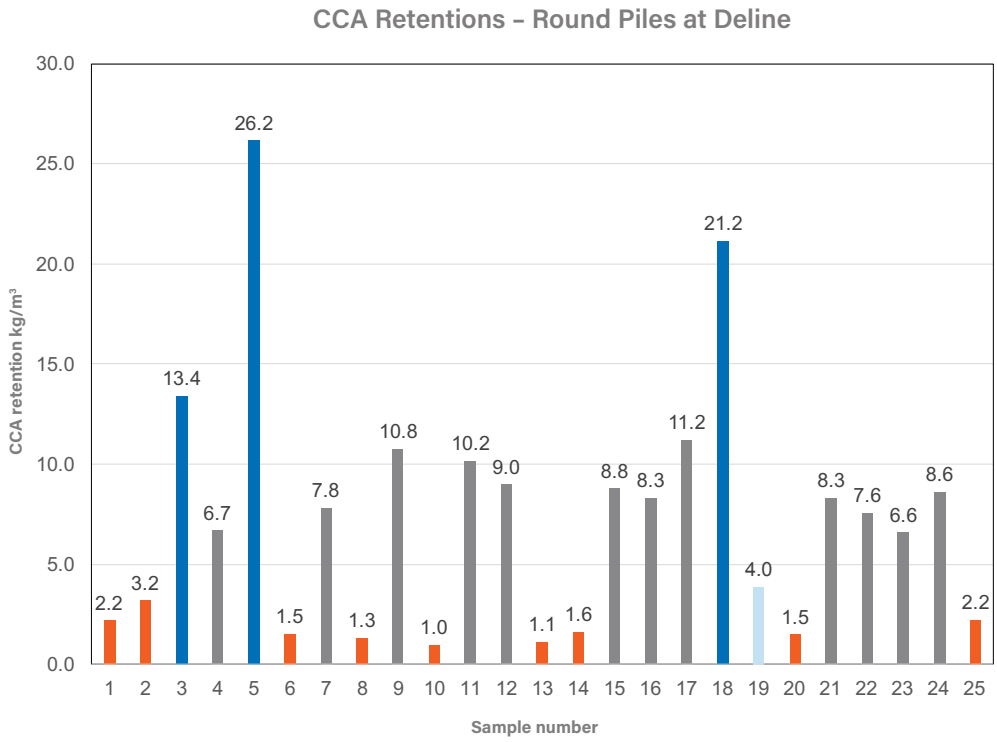
The condition of the treated wood in the piles at Baker Lake appeared to be excellent. This was confirmed by the 6-Joule Pilodyn™ data. The average pin penetration

Table 3. *Summarized Data for CCA-Treated Round Piles at Deline*

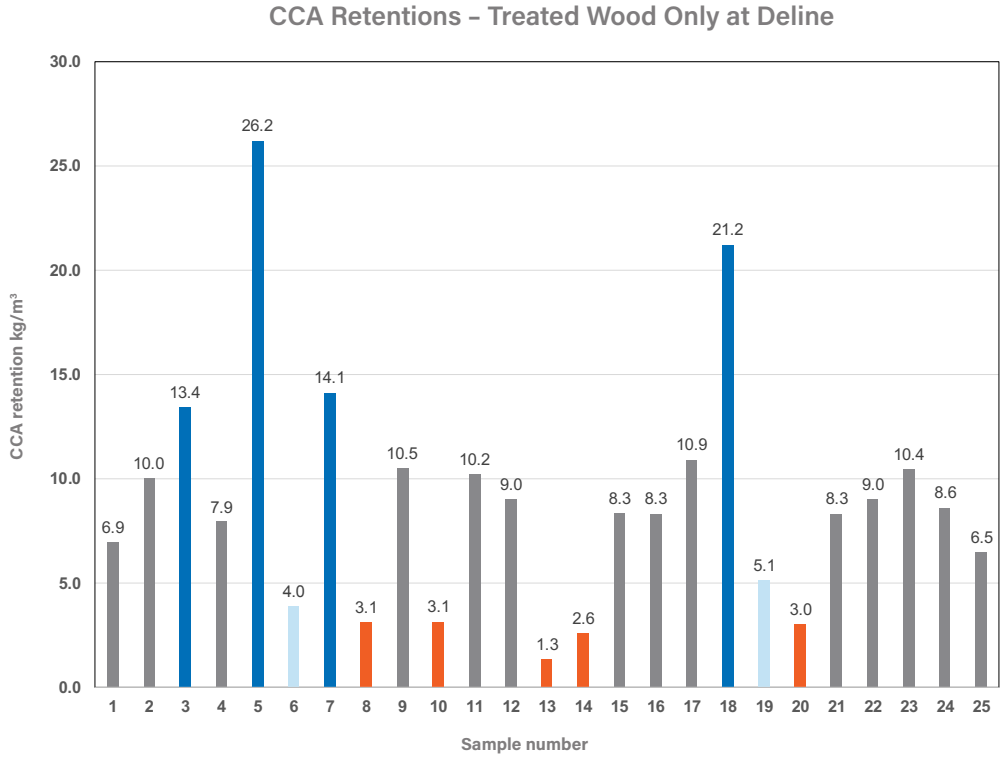
	Average	SD
Moisture Content (%)	30	7
Pilodyn™ (mm)	12	1
Core 1 Penetration (mm)	15	6
Core 2 Penetration (mm)	15	6
Average Penetration (mm)	15	6
No. of Cores with Penetration ≤ 10 mm	15	
Retention (kg/m^3)	7.4	6.2
Retention – Treated Wood Only (kg/m^3)	8.3	4.7

Figure 9: *The CCA Retentions for the 25 Round Piles Sampled at Deline. a) Standard CAN/CSA-O80 assay, and b) Treated Wood Only Using the Standard CAN/CSA-O80 Assay Zone and CCA Observed Penetration (Blue >12 kg/m³; Grey >6.4 kg/m³ <12 kg/m³; Light Blue >4 kg/m³ <6.4 kg/m³; Orange <4 kg/m³)*

9a



9b



was 14.7 mm, and values ranged from 12 to 15 mm, while reference measurements provided an average of 14 mm (Appendix 3 and summarized in Table 4). The average moisture content was 27%. The wood species is Douglas-fir. Typical Pilodyn™ measurements for mature Douglas-fir usually range from 12 to 14 mm [16]. This would suggest that the Douglas-fir used for the piles is relatively young with a lower density than mature Douglas-fir.

The CCA penetrations for the piles in this location were highly variable and strongly influenced by the presence of sapwood, as well as the cellular nature of the wood at the surface. The average CCA penetration was 7.9 mm with a standard deviation of 5.1 mm (Appendix 3 and summarized in Table 4). Twenty-two of the 50 cores had CCA penetrations <5 mm, while almost two-thirds of the cores had CCA penetrations of less than 10 mm.

The average CCA retention for the 25 piles sampled was exceedingly low at 2.7 kg/m^3 (Table 4). The high variability can be shown by the standard deviation of 1.8 kg/m^3. Of the 25 piles sampled, two had retentions exceeding 6.4 kg/m^3 required by UC4.1 (Figure 10a). A further three piles had CCA retentions exceeding the 4 kg/m^3 required by UC3.2. The remaining 20 piles had CCA retentions below 4 kg/m^3. While the retentions for these piles were very low, they showed no signs of decay. This reflects the lower decay hazard present in the Canadian Arctic and subarctic regions where permafrost is present.

Since the penetration data show many piles did not have the required 13 mm of penetration, a modified approach was made to the standard protocol for the lower penetration to allow the actual retention of the treated wood to be estimated. The average CCA retention for the treated wood only was 4.9 kg/m^3. Eight piles showed a CCA retention greater than 6.4 kg/m^3 in the treated wood only (Figure 10b). A further 11 assays were estimated to contain more than 4 kg/m^3 (Appendix 3).

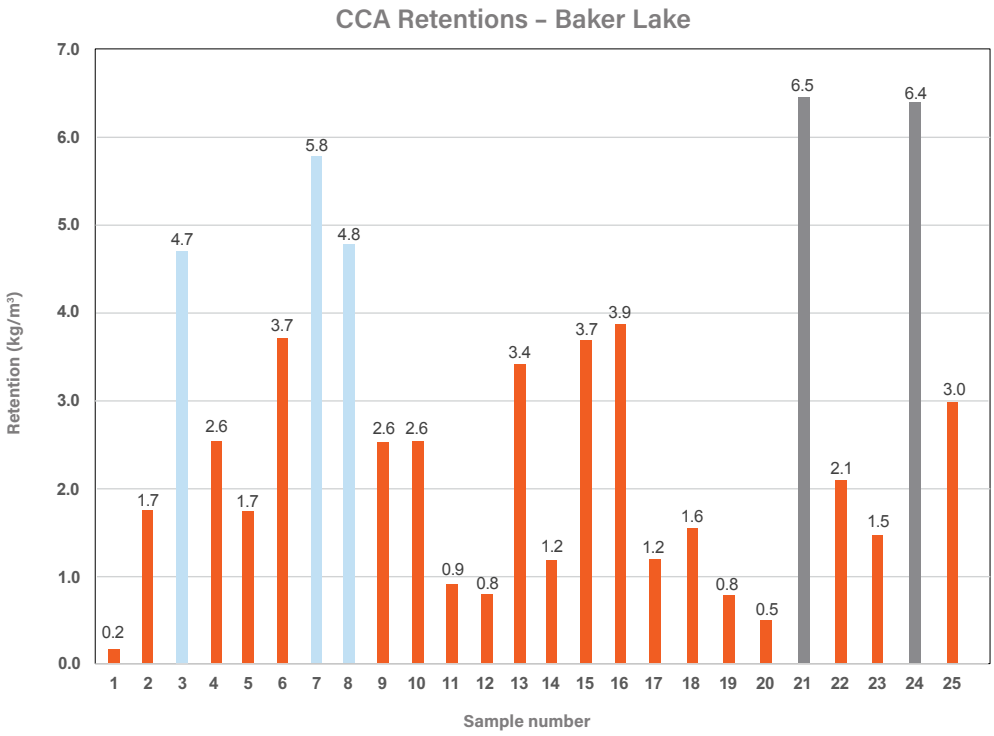
It may be concluded that, even when the standard assay was performed on the cores from the unincised piles, the CCA content was sufficient to protect the treated wood from decay under the cold conditions where permafrost is close to the surface. The data support a retention of 6.4 kg/m^3 or 4 kg/m^3 for treated wood to be used in UC4 Arctic and Northern Canada.

Table 4. *Summarized Data for CCA-Treated Round Piles at Baker Lake*

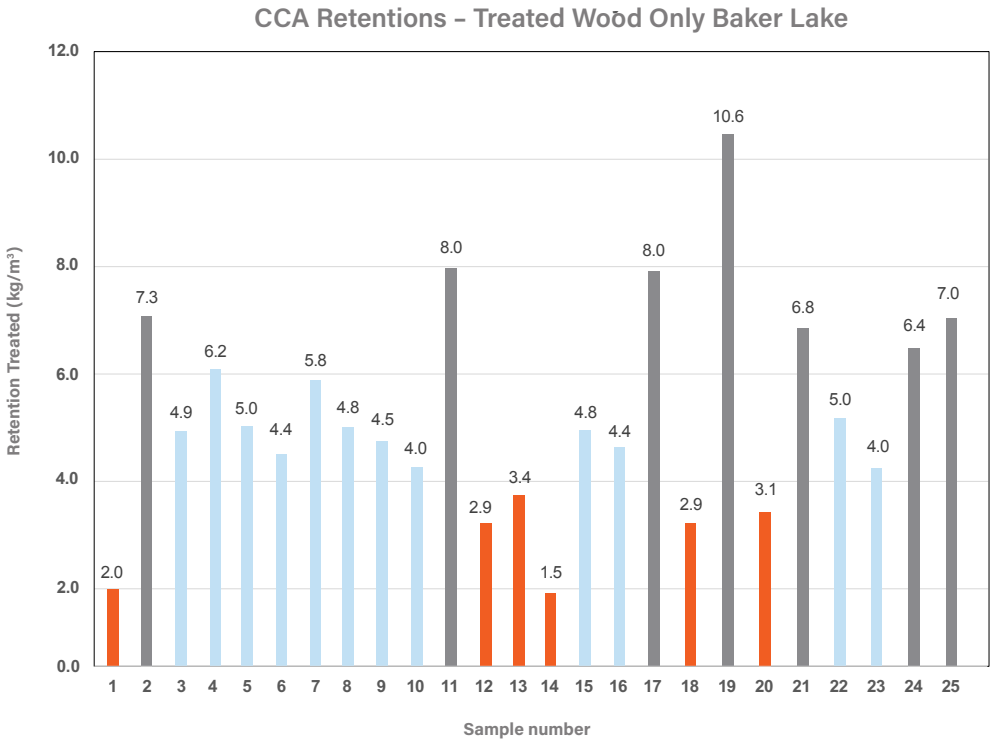
	Average	SD
Moisture Content (%)	27	4
Pilodyn™ (mm)	15	4
Core 1 Penetration (mm)	7	6
Core 2 Penetration (mm)	9	6
Average Penetration (mm)	8	5
No. of Cores with Penetration ≤ 5 mm	23	
No. of Cores with Penetration ≤ 10 mm	34	
Retention (kg/m^3)	2.7	1.8
Retention – Treated Wood Only (kg/m^3)	4.9	2.1

Figure 10: *CCA Retentions for the 25 Treated Sawn Timber Piles Sampled at the Baker Lake Airport Terminal Building. a) Standard CAN/CSA-O80 Assay, and b) Treated Wood Only Using the Standard CAN/CSA-O80 Assay Zone and CCA Observed Penetration (Grey >6.4 kg/m³; Light Blue >4 kg/m³ <6.4 kg/m³; Orange <4 kg/m³)*

10a



10b



3.5 Assessment of CCA-Treated Timber in a Structural Retaining Wall at Pond Inlet, Nunavut

The condition of the spruce timbers in the retaining wall at Pond Inlet was excellent. The average 6-Joule Pilodyn™ pin penetration of the timbers was 12.2 mm (SD 2.1 mm) (Appendix 4 and summarized in Table 5). The average reference pin penetration was also 12 mm (SD 2.0 mm). One timber had algal growth and a 6-Joule Pilodyn™ pin penetration of 20 mm, indicating that some loss of fiber quality had occurred.

The average moisture content of the timbers was 25% (SD 7.9%). The timber with algal growth had a moisture content of 60%. The enhanced moisture content only increases the pin penetration up to fiber saturation. Based on previous research by the author of this report and others [13], [14], the difference in the pin penetration due to moisture differences above fiber saturation are negligible. Smith and Morrell [16] have suggested that the pin penetration in a Pilodyn™ increases approximately 0.19 mm for each percent increase in the moisture content up to 30%. The enhanced penetration due to moisture increases to the fiber saturation would be approximately 1 mm. Thus, the remaining ca. 7 mm enhanced pin penetration must be due to bacterial and fungal deterioration. However, no visible evidence of basidiomycete decay was observed.

The average CCA retention for the 25 timbers was 4.3 kg/m^3, which is approximately 50% of that required for timbers in UC4.2. Nevertheless, the timbers have performed well. The one suspect timber that appeared to be extremely wet may have some bacterial deterioration. Five timbers had a CCA retention exceeding 6.4 kg/m^3 (Figure 11a). An additional eight timbers had a retention exceeding 4 kg/m^3. The remaining 12 timbers had retentions less than 4 kg/m^3. Despite the low retentions, the treated timbers have performed well under the Arctic conditions for 32 years.

The CCA penetration is generally poor, as might be expected from spruce, a well-known refractory species. While the overall average penetration was 9.3 mm, only seven timbers had an average penetration of the two cores meeting the 13 mm requirement of CAN/CSA-O80. Twenty-nine of the 50 cores (two cores per timber) had penetrations less than 10 mm, with 22 of the cores having CCA penetrations less than or equal to 5 mm (Table 5). CCA penetration depended largely on the presence of sapwood.

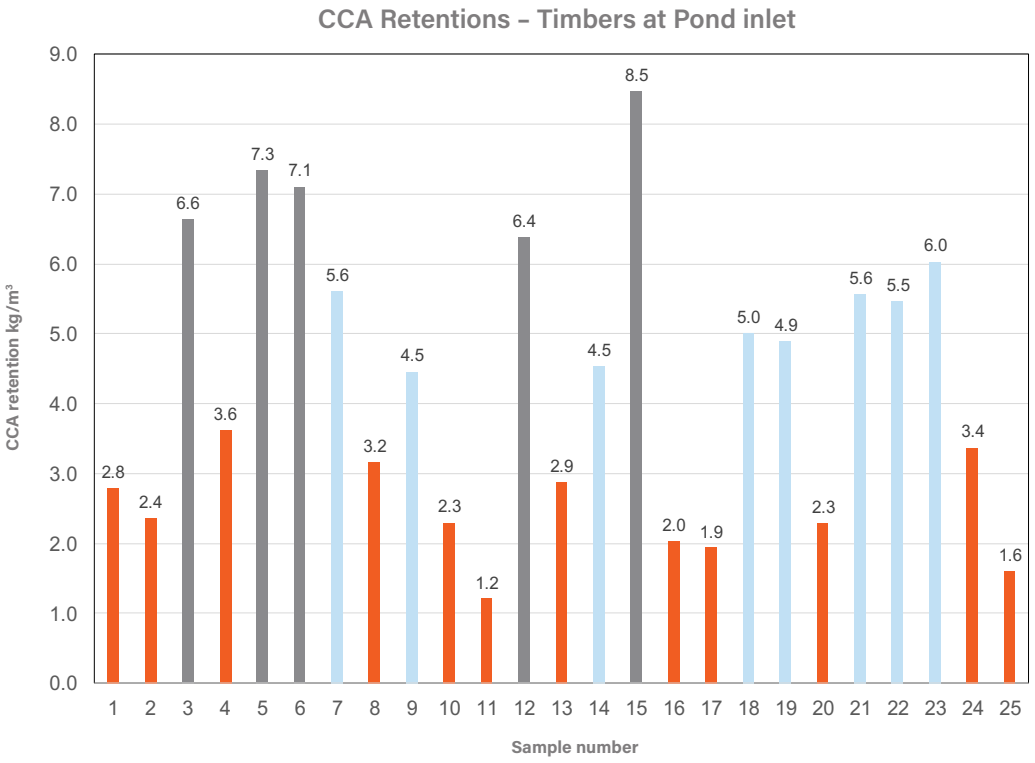
The CCA retention in the treated wood can also be determined using the average CCA penetration and the standard assay. When this is done, the average CCA retention in the treated wood only was 7.3 kg/m^3. Fourteen of the timbers had an average retention of the treated wood only of greater than 6.4 kg/m^3 (Figure 11b), while only three timbers had a retention less than 4 kg/m^3.

Table 5. *Summarized Data for CCA-Treated Timbers from the Structural Retaining Wall at Ulaajuk School, Pond Inlet*

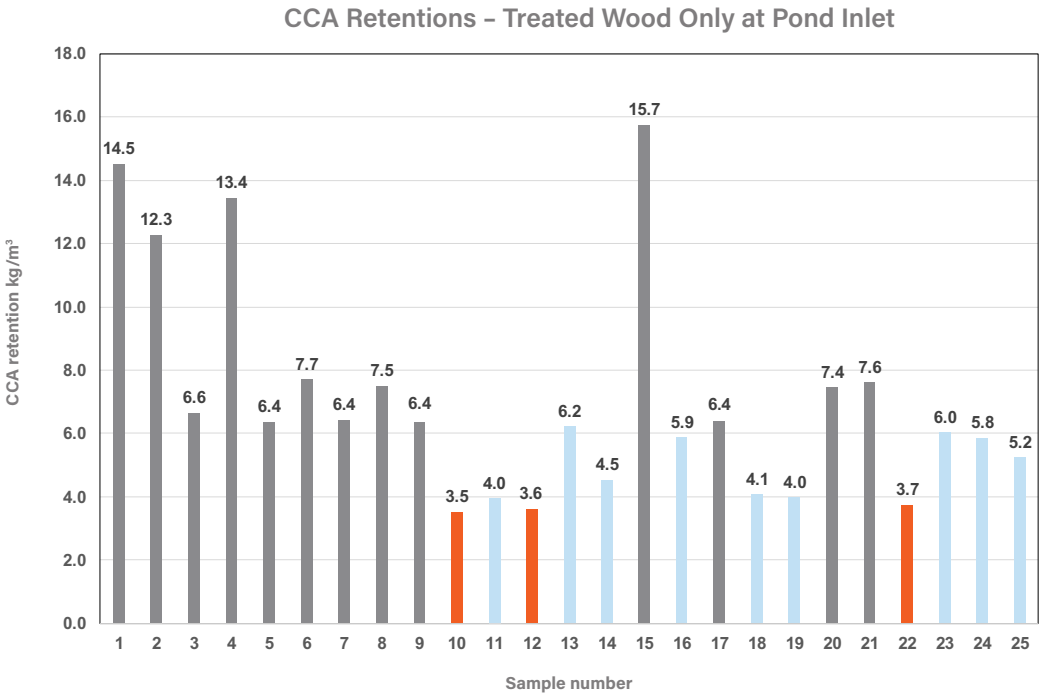
	Average	SD
Moisture Content (%)	25	8
Pilodyn™ (mm)	12	2
Core 1 Penetration (mm)	9	7
Core 2 Penetration (mm)	9	6
Average Penetration (mm)	9	6
No. of Cores with Penetration ≤ 5 mm	22	
No. of Cores with Penetration ≤ 10 mm	32	
Retention (kg/m^3)	4.3	2
Retention – Treated Wood Only (kg/m^3)	7.0	3.4

Figure 11: *The CCA Retentions for the 25 ('10 x 10') Timbers in the Retaining Wall Assessed at the Ulaajuk Primary School, Pond Inlet. a) Standard CAN/CSA-O80 Assay, and b) Treated Wood Only Using the Standard CAN/CSA-O80 Assay Zone and CCA Observed Penetration (Grey >6.4 kg/m³; Light Blue >4 kg/m³ <6.4 kg/m³; Orange <4 kg/m³)*

11a



11b



Based on all of the CCA data on sawn wood and round wood, a retention of 6.4 kg/m^3 of CCA for the proposed new UC4 Arctic and Northern Canada would be the most appropriate retention to recommend. While many of the timbers or piles have lower CCA retentions, the influence of a lower temperature in the Arctic and Northern Canada suggests that a much lower retention than those specified in CAN/CSA-O80 UC4.2 can provide an acceptable service life. However, applying the criteria of a long service life (greater than 50 years) and loss of permafrost due to global warming, a conservative approach is recommended. It is proposed to use the current retentions for UC4.1 of creosote 120 kg/m^3 and CCA 6.4 kg/m^3 for all timbers (round and sawn) for the proposed new UC4 Arctic and Northern Canada.

4.0 Conclusions

Core samples were collected from four structures in regions of the Canadian Arctic and Northern Canada with permafrost. Earlier research had shown that creosote-treated sawn Douglas-fir piles had provided over 60 years of service life, even though the preservative retention did not achieve that required by the current edition of CAN/CSA-O80-15 [5]. The results, however, did comply with the CAN/CSA-O80 standard developed in 1954 [8], which was in force at the time of construction. This focused attention on the needs of decay fungi with respect to temperature. Since the 1930s, research has been published that clearly showed that as temperatures lowered, decay slowed dramatically until it ceased when temperatures approached freezing. The objective of the current research was to develop data to support a lower preservative retention than is currently listed in UC4.2 for preservative-treated timber used in ground contact in regions with permafrost.

Core samples were collected from round foundation piles in Fort Resolution and Deline, sawn timber piles at the air terminal building at Baker Lake, and also at a structural retaining wall at a school in Pond Inlet. The lack of incising of all timbers resulted in low preservative penetrations and low preservative retentions compared to the current edition of CAN/CSA-O80-15 [5]. Nevertheless, all of the timbers were free from basidiomycete decay. Assessments of the treated wood using a 6-Joule Pilodyn™ confirmed the integrity of the treated wood in all four structures. The data from the earlier research at Iqaluit, combined with the new data from the Deninu School at Fort Resolution, support a creosote retention of 120 kg/m^3 for the new UC4 Arctic and Northern Canada. The new data from the round CCA-treated piles at the Father Ayah School at Deline, the CCA-treated Douglas-fir sawn timber piles at Baker Lake, and the '8 x 8' spruce timber structural retaining wall at Pond Inlet all support the adoption of a CCA retention of 6.4 kg/m^3 for preservative-treated wood used in structural applications in regions where permafrost is affecting foundation construction.

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Creosote: Gord Gilmet, Technical Manager, Ruetgers Canada Inc.

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7 Appendices

Appendix 1

Data from Assessment at Fort Resolution

ID		PILES AT FORT RESOLUTION					PENETRATION		AVERAGE PENETRATION	RETENTION	TREATED WOOD
			MC	PILODYN™							
No.	Row	Column	%	mm	Core 1	Core 2	mm		mm	kg/m³	kg/m³
1	1	2	20	12	Good	Good	7	8	7.5	211	535
2		1	25	11	Good	Good	6	7	6.5	232	678
3		3	15	11	Good	Good	23	25	24	129	102
4		4	28	11	Good	Good	15	14	14.5	311	408
5		5	30	10	Good	Good	24	25	24.5	359	278
6		6	19	12	Good	Good	24	26	25	171	130
7		7	18	12	Good	Good	15	12	13.5	139	196
8		8	23	11	Good	Good	11	8	9.5	167	335
9		9	19	10	Good	Good	19	19	19	71	71
10		10	19	12	Good	Good	5	5	5	100	381
11		11	30	12	Good	Good	20	19	19.5	370	361
12	2	10	20	13	Good	Good	19	19	19	113	113
13		9	25	14	Good	Good	15	16	15.5	300	368
14		8	25	12	Good	Good	8	10	9	281	593
15		7	20	11	Good	Good	21	19	20	151	144
16		6	19	11	Good	Good	24	25	24.5	148	115
17		5	25	11	Good	Good	21	23	22	294	254
18		4	18	10	Good	Good	24	25	24.5	196	152
19		3	20	10	Good	Good	15	15	15	265	336
20		2	17	12	Good	Good	9	10	9.5	138	275
21		1	20	11	Good	Good	20	26	23	221	183
22	3	3	19	10	Good	Good	12	14	13	196	287
23		4	19	13	Good	Good	9	6	7.5	115	291
24		5	29	12	Good	Good	20	25	22.5	312	263
25		6	28	122	Good	Good	7	8	7.5	196	496
Average			22.0	11.4			15.7	16.4	16.0	208	294
Std. Dev.			4.3	1.0			6.4	7.1	6.7	82	157

Appendix 2

Data from Assessment at Deline

ID		PILES AT DELINE					PENETRATION		AVERAGE PENETRATION	RETENTION	TREATED WOOD
			MC	PILODYN™							
No.	Row	Column	%	mm	Core 1	Core 2	mm		mm	kg/m³	kg/m³
1	A	5	27	12	Good	Good	6	6	6	2.2	6.9
2		4	28	13	Good	Good	6	6	6	3.2	10.0
3		3	23	11	Good	Good	25	20	22.5	13.4	13.4
4		2	25	10	Good	Good	15	17	16	6.7	7.9
5		1	25	14	Good	Good	24	22	23	26.2	26.2
6	B	1	26	11	Good	Good	7	8	7.5	1.5	3.9
7		2	28	11	Good	Good	11	10	10.5	7.8	14.1
8		3	28	12	Good	Good	7	9	8	1.3	3.1
9		4	27	12	Good	Good	19	20	19.5	10.8	10.5
10		5	25	11	Good	Good	5	7	6	1.0	3.1
11	C	5	27	12	Good	Good	20	19	19.5	10.2	10.2
12		4	28	13	Good	Good	19	19	19	9.0	9.0
13	D	4	29	12	Good	Good	17	15	16	1.1	1.3
14	E	4	28	12	Good	Good	12	12	12	1.6	2.6
15	F	4	29	11	Good	Good	21	19	20	8.8	8.3
16		3	28	10	Good	Good	19	22	20.5	8.3	8.3
17		2	29	10	Good	Good	19	20	19.5	11.2	10.9
18		1	28	10	Good	Good	22	23	22.5	21.2	21.2
19	E	1	28	11	Good	Good	14	15	14.5	3.9	5.1
20		2	30	12	Good	Good	9	10	9.5	1.5	3.0
21		3	28	12	Good	Good	23	25	24	8.3	8.3
22	D	3	45	12	Good	Good	15	17	16	7.6	9.0
23	C	3	50	13	Good	Good	13	11	12	6.6	10.4
24	D	2	50	14	Good	Good	20	23	21.5	8.6	8.6
25	C	2	40	12	Good	Good	6	7	6.5	2.2	6.5
Average			30	12			15.7	15.3	16.0	7.4	8.9
Std. Dev.			7	1			6.4	6.1	6.7	6.2	5.6

Appendix 3

Data from Assessment at Baker Lake

ID		PILES AT BAKER LAKE ATB					PENETRATION		AVERAGE PENETRATION	RETENTION	TREATED WOOD
			MC	PILODYN™							
No.	Row	Column	%	mm	Core 1	Core 2	mm		mm	kg/m³	kg/m³
1	1	A	43	35	Damaged	Good	1	1	1.5	0.2	2.0
2	2		25	14	Good	Good	3	3	3	1.7	7.3
3	3		24	14	Good	Good	11	14	12.5	4.7	4.9
4	4		28	14	Good	Good	1	10	5.5	2.6	6.2
5	5		26	13	Good	Good	7	2	4.5	1.7	5.0
6	6		24	14	Good	Good	9	13	11	3.7	4.4
7	1	B	28	14	Good	Good	15	17	16	5.8	5.8
8	2		24	12	Good	Good	20	16	18	4.8	4.8
9	3		28	13	Good	Good	1	14	7.5	2.6	4.5
10	4		26	14	Good	Good	2	15	8.5	2.6	4.0
11	5		28	14	Good	Good	2	1	1.5	0.9	8.0
12	6		24	14	Good	Good	5	2	3.5	0.8	2.9
13	1	C	25	13	Good	Good	16	10	13	3.4	3.4
14	2		29	14	Good	Good	2	20	11	1.2	1.5
15	3		26	14	Good	Good	10	10	10	3.7	4.8
16	4		24	13	Good	Good	18	5	11.5	3.9	4.4
17	5		24	14	Good	Good	3	1	2	1.2	8.0
18	5	D	25	15	Good	Good	7	7	7	1.6	2.9
19	5	E	30	13	Good	Good	1	1	1	0.8	10.6
20	5	F	29	15	Good	Good	1	3	2	0.5	3.1
21	5	G	27	13	Good	Good	12	13	12.5	6.5	6.8
22	5	H	28	14	Good	Good	1	10	5.5	2.1	5.0
23	4	H	28	14	Good	Good	2	8	5	1.5	4.0
24	4	G	28	14	Good	Good	18	18	18	6.4	6.4
25	4	D	27	16	Good	Good	6	5	5.5	3.0	7.0
Average			27.1	14.7			7.0	8.8	7.9	2.7	5.1
Std. Dev.			3.7	4.2			6.2	5.9	5.1	1.8	2.1

Appendix 4

Data from Assessment at Pond Inlet

ID	POND INLET SCHOOL					PENETRATION		AVERAGE PENETRATION	RETENTION	TREATED WOOD
	MC	PILODYN™								
No.	%	mm		Core 1	Core 2	mm		mm	kg/m³	kg/m³
1	25	12		Good	Good	2	3	2.5	2.8	14.5
2	28	14		Good	Good	2	3	2.5	2.4	12.3
3	18	12		Good	Good	8	18	13	6.6	6.6
4	18	12		Good	Good	4	3	3.5	3.6	13.4
5	20	13		Good	Good	20	10	15	7.3	7.3
6	24	14		Good	Good	20	4	12	7.1	7.7
7	22	13		Good	Good	3	20	11.5	5.6	6.3
8	20	14		Good	Good	2	9	5.5	3.2	7.5
9	23	12		Good	Good	5	13	9	4.5	6.4
10	28	13		Good	Good	10	7	8.5	2.3	3.5
11	22	12		Good	Good	5	3	4	1.2	3.9
12	24	10		Good	Good	26	20	23	6.4	6.4
13	21	10		Good	Good	7	5	6	2.9	6.2
14	23	11		Good	Good	12	14	13	4.5	4.5
15	60	20	17	Fibre Separated		8	6	7	8.5	15.7
16	28	12		Good	Good	5	4	4.5	2.0	5.9
17	26	11		Good	Good	3	5	4	1.9	6.3
18	19	13		Good	Good	15	17	16	5.0	5.0
19	26	12		Good	Good	12	20	16	4.9	4.9
20	24	12		Good	Good	5	3	4	2.3	7.4
21	26	11		Good	Good	12	7	9.5	5.6	7.6
22	25	9		Good	Good	24	14	19	5.5	5.5
23	24	10		Good	Good	12	14	13	6.0	6.0
24	28	12		Good	Good	10	5	7.5	3.4	5.8
25	26	10		Good	Good	5	3	4	1.6	5.2
Average	25.2	12.2				9.5	9.2	9.3	4.3	7.31
Std. Dev.	7.9	2.1				6.9	6.2	5.6	2.0	3.2

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