Performance of Treated Wood in the Arctic

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ABSTRACT

During the last five years there has been a significant increase in interest in Canada in the Arctic, with research on the Franklin exploration of the mid19th century searching for the North West Passage, which coupled with the impact of Global warming on the loss of sea ice has rendered the North West Passage now navigable during the summer months. Building with wood in the Arctic has proved extremely effective even with untreated timbers. However, significant improvement in service life of structural components can be made with moderate preservative retentions. Evidence suggests that the Use Category System greatly overestimates the biological hazard faced by building timbers in the Arctic. Since the Arctic is a sensitive environment for the use of chemicals it is suggested that the UCS in Canada be modified for timbers to be used in the Arctic. Global warming has resulted in a lowering of the permafrost increasing the depth of the active layer. Since fundamental building strategies in delta areas of the Arctic have depended on fastening piles into the permafrost, data is needed in order to predict the depths needed for long term building life. Alternative strategies have been developed which seek to either permanently freeze the active layer, or replace the active layer with a thermally inert insulating material, and which can therefore form a base for building construction. The emergence of new building technologies and materials, requires assessment for their use under Arctic conditions. It is recommended that a data base on treated timber performance in the Arctic is developed, to support future treated wood use in the Arctic.

Keywords: Wood buildings, Arctic, Global warming, Franklin, UCS

1. INTRODUCTION

1.1 Standardisation

In 2007 the International Standardization Organization (ISO) developed a new approach to defining the standardisation of treated wood. Previously the standards governing the production and distribution of treated wood had been based on a results type specification. In the USA the American Wood Protection Association (AWPA) had since its formation in 1904, provided the detailed conditioning, preparation, and treatment characteristics for treated wood for a wide variety of end-uses. Key elements, were the results of the treatment as defined by the chemical penetration and retention as a core element in the standard. In Canada the approach was based on the AWPA approach, with special attention to Canadian wood species. Up until the 1980's the wood treating industry's largest market was the industrial use of treated wood, by such groups as the utility companies, railways, and government departments such as Ministry of Highways. The industry users had professional engineers and scientists who were familiar with the AWPA and CSA standards and helped with their development.

However, by the 1980's the market for treated wood had changed. It had grown tremendously, and almost all of the new growth was in the residential market, such that by 1990's the market distribution in North America was about 80% residential and 20 % industrial. However, the residential users were not present during standard development and largely did not understand the wood preserving standards in the USA (AWPA) and Canada [Canadian Standards Association (CSA) 080 Wood Preservation Association]. It was hoped that the new approach developed by ISO would be more widely understood and implemented. This new approach sought to define different biological hazards based mainly on the influence of moisture, and to a lesser degree on insects. Five Use Categories (UCS) were identified, ranging from extremely low (1) indoor not exposed to moisture to most severe (5) - exposed directly in sea water. Some UCS categories are subdivided, e.g. 3A timber above ground protected from rain (e.g. wooden windows) and 3B timber above ground exposed to direct rain action (e.g. decking).

1.2 Historical perspective

During the Cold War in the late 1950's Canada and the USA, jointly under the North American Aerospace Defence Command (NORAD), created a Distant Early Warning (DEW) radar system across northern Canada and positioned air protection units in the Canadian Arctic. An air defence system was built and in Canada was centred at Inuvik, NWT and Iqaluit, Nunavut. To support the construction and manning of the Dew Line, small communities expanded and a large number of buildings were constructed. In the North West Territories, due to the lack of surface rock and the large expanse of delta regions, most were constructed by driving piling into the permafrost to support the buildings. This enabled the builders to overcome the problems due to the movement of the "active layer". The large majority of these round timber piles were untreated. They were comprised of spruce, larch, Douglas-fir and jack pine. In a few cases creosote treated timbers were used, particularly for larger structures. By 1993 with the closing of most of the facilities related to the DEW line, most of the structures were transferred to local Inuit. However, the untreated piles of many of the structures were already experiencing advanced decay by brown rot and in some cases bacterial decay.

Mychem has been involved in assessing timber piling in the North West Territories (NWT) since 1990 with structures in all major communities in the Territories being assessed. These have included schools, gyms, clinics, housing complexes, Power generating stations, airports, local community halls, the utilidor system at Inuvik, RCMP buildings, commercial and industrial buildings, and buildings used by the Arctic College. In almost all structures some decay was evident in the piles. The decay varied widely, with some piles appearing almost sound, but most often some decay was present, ranging from almost totally rotten to surface bacterial decay. This is not surprising since untreated piles in most of Canada would have a service life of about 5 to 7 years, so that 30 plus years represents a significant extension in the service life. Recently Mychem was requested to assess the piles supporting a warehouse and dormitory buildings constructed around 1958 in Iqaluit, Nunavut. The sawn Douglas-fir piles were creosote treated using the CSA 080 standard of 1954.

With the increasing technology related to satellite communication, the lives of the Inuit have changed markedly. Perhaps the most recent example being the geological exploration for diamonds and other valuable minerals, centred on Yellowknife. However, a more profound change is also taking place due to global warming. This has created several significant changes in the Arctic, as was recently highlighted by temperatures at the North Pole being above freezing in mid-winter (Samenow, 2018). A consequence of the warming is the lowering of the permafrost which creates problems for building construction. Some aspects of this will be discussed later. The second major change is in the loss of sea ice. One of the first to venture in search of the fabled North West Passage Sir Martin Frobisher made three voyages to the Arctic in 1574, 1577 and 1578. However, perhaps the most famous explorer associated with the Arctic is Sir John Franklin, who disappeared during his expedition to search for the North West Passage in 1845 when his ships the Erebus and the Terror, became frozen in the sea ice.

In 2010 Parks Canada using side scanning sonar which requires ice free water, were able to locate HMS Investigator which was dispatched to find out what had happened to the Franklin expedition, and itself became trapped in the sea ice off Banks Island. The researchers were able to locate and identify many artefacts from the expedition left by the men when they abandoned their ship and walked to nearby Melville Island (D. Martin, 2010). In September 2014, the wreck of the HMS Erebus was located and two years later the HMS Terror was located in "pristine" condition in Terror Bay. (G. Vaidyanathan, 2016).

The challenges faced by Franklin and explorers in the last century may be put into perspective when it is noted that in 2017, a record 33 full transits of the North West Passage were recorded, eclipsing the previous record of 20 full transits set in 2012 (Mooney, 2017). In addition, in 2016 and 2017 the Crystal Serenity carried a total of 1500 passengers through the North West Passage, and each year more cruise lines are developing Arctic Adventure tours. (Mooney, 2017) Clearly the increased temperatures will result in more activity in the Arctic communities. A new airport opened in 2018 at Iqaluit. However, the problems encountered in rescuing a Russian pilot Sergey Ananov, attempting to become the first person to circumnavigate the Arctic in a small helicopter, illustrate the need for a greatly improved infrastructure in the Arctic. It took two days to rescue him (Anon, 2015). If marine traffic in the North West Passage increases significantly, it will be important that new infrastructure is built to support the many visitors and ships that will pass through. China is already taking a keen interest in the potential for shipping goods to Europe via the North West Passage and the Chinese ice breaker Snow Dragon has already complete a successful passage from the Pacific Ocean to the Atlantic Ocean.

With the increasing interest in developing and expanding communities in the Arctic building with treated wood is poised to make an important contribution. However, several challenges exist which will need to be addressed.

This paper is based on over 25 years of observations and inspection of both treated and untreated wood in the Arctic regions of Canada. The objectives of the paper are to:

a) Identify global needs to enhance the existing UCS for treated wood to be used in Arctic regions;
b) Identify changing needs for treated wood in building construction due to global warming;
c) Identify new and emerging building technologies that may impact on the future evolution of buildings in Arctic regions; and
d) Identify data needs for the performance of treated wood in the Arctic.

2. RESULTS AND DISCUSSION

2a Identify global needs to enhance the existing UCS for treated wood to be used in Arctic regions

It is clear from the performance of even untreated wood that the biological hazard in the Arctic is significantly lower than that observe in the more temperate parts of Canada. Based on untreated non-durable softwoods, the biological hazard in the Arctic is less than a quarter of that found elsewhere in Canada. The performance of creosote treated wood is significantly greater in the Arctic than in sub-Arctic parts of Canada.

In a recent study, 180 creosote treated Douglas-fir timber piles treated to a CSA080-1954 standard were assessed. None showed any indications of basidiomycete decay after almost 60 years of service. The average creosote assay for the piles beneath one of the structures, the Nunavut Arctic College (NAC) building, was 141 kg/m^3. This exceeds the creosote retention required in CSA 080 (1954) for sawn timber piles of 128 kg/m^3. Applying the current Use Category system now forming the basis for the CSA 080 standards, together with the 90% application for a single charge of creosote treated wood, for UC 4.2 of 144 kg/m^3, (90% of 160 kg/m^3), 16 piles (53%) met this retention while a further 8 (27%) exceeded the retention required for 90% of UC 4.1 (90% of 120 kg/m^3) for creosote treated wood in ground contact. The 90% value used was 110 kg/m^3 since this is very similar to the 90% value for the original CSA 080 1954 standard. When this was applied, 80% of the pile retentions achieved this requirement. The average creosote penetration of 16 mm exceeds that required by both the CSA 080 (1954) standard and the current CSA 080 (2015) standard of 13 mm. Considering the individual penetrations, 8 measurements (13%) were found to be less than 13 mm out of 60 measurements. This meets the 80% penetration requirement in the current CSA 080 standard.

These observations raise interesting questions regarding the UCS ground contact retentions for timbers to be used in critical structures. Currently in Canada that would be under UCS 4.2 and require a creosote retention of 160 kg/m^3. Under the corresponding AWPA standard, UCS 4C, which is specific for piling, the creosote retention would be 192 kg/m^3.

Clearly in an environment where biological degradation is very slow, wood treated with excessive chemical should be avoided, since any depletion will not be degraded very rapidly. On this basis, there seems a need to create a UCS system specifically for the Arctic. It may be possible to use the current UCS classification and retentions as the basis for an amended version. For example, the current UCS 3.2 creosote retention is 128 kg/m^3 which is the same as that which provided in excess of 60 years for Douglas-fir timber piles in Iqaluit.

A study of the historic huts in Antarctica used by Robert F Scott and Ernest Shackleton in their expeditions in 1901, built with wood taken to by the explorers, and sampled 100 years later was reported by Blanchette et al., in 2004. In the *Betula* and *Populus* samples in ground contact soft rot fungi were isolated. The importance of decay by soft rot and bacteria is evident.

2b Identify changing needs for treated wood in building construction due to global warming

The current practice of using the permafrost to key piles for building construction is dependent on an unchanging permafrost level. If significant lowering of the permafrost occurs then either piles must be inserted much deeper into the permafrost to achieve and adequate service life, or alternative building strategies must be developed. Thus when constructing a building for a 60-year service life, the impact of global warming on the lowering of the permafrost layer must be determined. The current models need revision to account for recent changes in global warming. Techniques for remediating existing piles also need to be developed.

The basic challenge with alternative strategies is dealing with a moving active layer, which changes with temperature. Two alternative approaches have been developed and implemented. The first of these involves permanently freezing the active layer. This is achieved by excavating the active layer and installing pipes which can carry a chemical cooling the surrounding much like refrigeration units. This then can keep the active layer cold and frozen in the summer. Such an approach can take advantage of the changes in the daylight hours, which in the summer are 24-hour daylight. Thus solar powered units could be used to generate the power. In the winter when this technology would not be useful, the natural conditions will maintain the frozen active layer. This approach has been used for the cooperative greenhouse building at Inuvik. An alternative strategy is to excavate the active layer and replace with a thermally insulating material. One material that has been suggested is sulphur of which Canada has a surplus. For small buildings other strategies have been developed and used. For example, a “space frame” approach using screw jacks to level the supporting timbers for a building has been used for a significant number of buildings. A disadvantage of this and related strategies is the need to adjust the jacks every Spring and Fall as the active layer changes.

2c Identify new and emerging building technologies that may impact on the future evolution of buildings in Arctic regions

In 2016 Douglas Cardinal, one of Canada’s foremost architects (he designed the Canadian Museum of History in Ottawa), designed a three bedroom, loft style, prefabricated house, using cross laminated timber specifically for the Arctic (Butler, 2016). The result says Cardinal “is a solid slab of wood, that is as strong as concrete, more fire resistant than steel, and farm more energy efficient than the houses made from traditional stick-frame construction”. “A key aspect of the design is that the insulation and vapour barrier are on the outside of the house, not inside the building packed between the studs, behind the drywall”. A driver for this decision was Cardinal’s concern about mould growth due to the moist warm air meeting the cold air in the wall space leading to mould growth in the wall cavity.

The role of mass timber buildings in the Arctic is one of many recent innovations that are moving into building design for which data on their performance in the Arctic environment should be confirmed, if they are to be used in wood building (Sorensen, 2018).

Remedial treatment to extent timber life through the application of fused boron rods or topically applied diffusible paste in bandages are other techniques which could have important applications in structures in the Arctic.

2d Identify data needs for the performance of treated wood in the Arctic

Clearly one important requirement when seeking to establish the wood preservative standards appropriate for the Arctic is the development of data on service life performance. Since there are currently no test sites located in the Arctic, one approach would be to survey known treated wood components in buildings, to determine both their condition with respect to decay, and their chemical content (retention and penetration). Materials which have been in service for a significant time, will have been treated using older technology. Incising patterns in sawn timber for example have improved markedly since the mid-1980's. In addition, there are several newer preservatives available than were standardized 30 or 40 years ago. Never-the-less it should be possible to use the performance of timber treated with standard preservatives such as creosote or chromated copper arsenate (CCA), to provide a benchmark of what can be achieved with the retentions used from earlier versions of the CSA 080 standards.

However, in structures many components must be considered. An excellent paper by Sand Sivertsen and Mattsson (2011) examined the decay in structures in Svalbad. They draw attention to the importance of the microclimate in controlling potential for decay. When temperatures may rise due to heating in structures the condensation which may occur as well as the summer heat may increase the potential for decay in untreated wood. The author's experience in the North West Territories, also noted that while untreated piles have provided a service life in excess of 35 years, the piles supporting the building perimeter were often more decayed than those beneath the building This resulted from the practice of pushing snow against the side of the building to minimize heat loss from the floor of the building. This provided a source of moisture as well ensuring a warmer environment for the piles. In another example, the notching of creosote treated piles allowed internal decay to develop. Interestingly of the 109 cases where decay was detected, 89 were soft rot.

3. CONCLUSIONS

Building with wood in the Arctic has a long history of good performance. With a significant expansion in the construction of buildings anticipated in the Arctic, data is needed on the performance of treated wood exposed to Arctic conditions. The usefulness of the existing Use Category System (UCS) method of specifying the treated wood, based on the biological hazard to be encountered during use, should be assessed with reference to the needs of the Arctic. The impact of Global warming on the changing permafrost depth should be addressed. The introduction of innovative construction techniques and of new products such as mass timber construction, poses opportunities in Canada although their appropriateness for the Arctic needs to be assessed. Finally, data needs to be compiled on the performance of treated wood in the Arctic, to ensure that the preservative retentions are appropriate.

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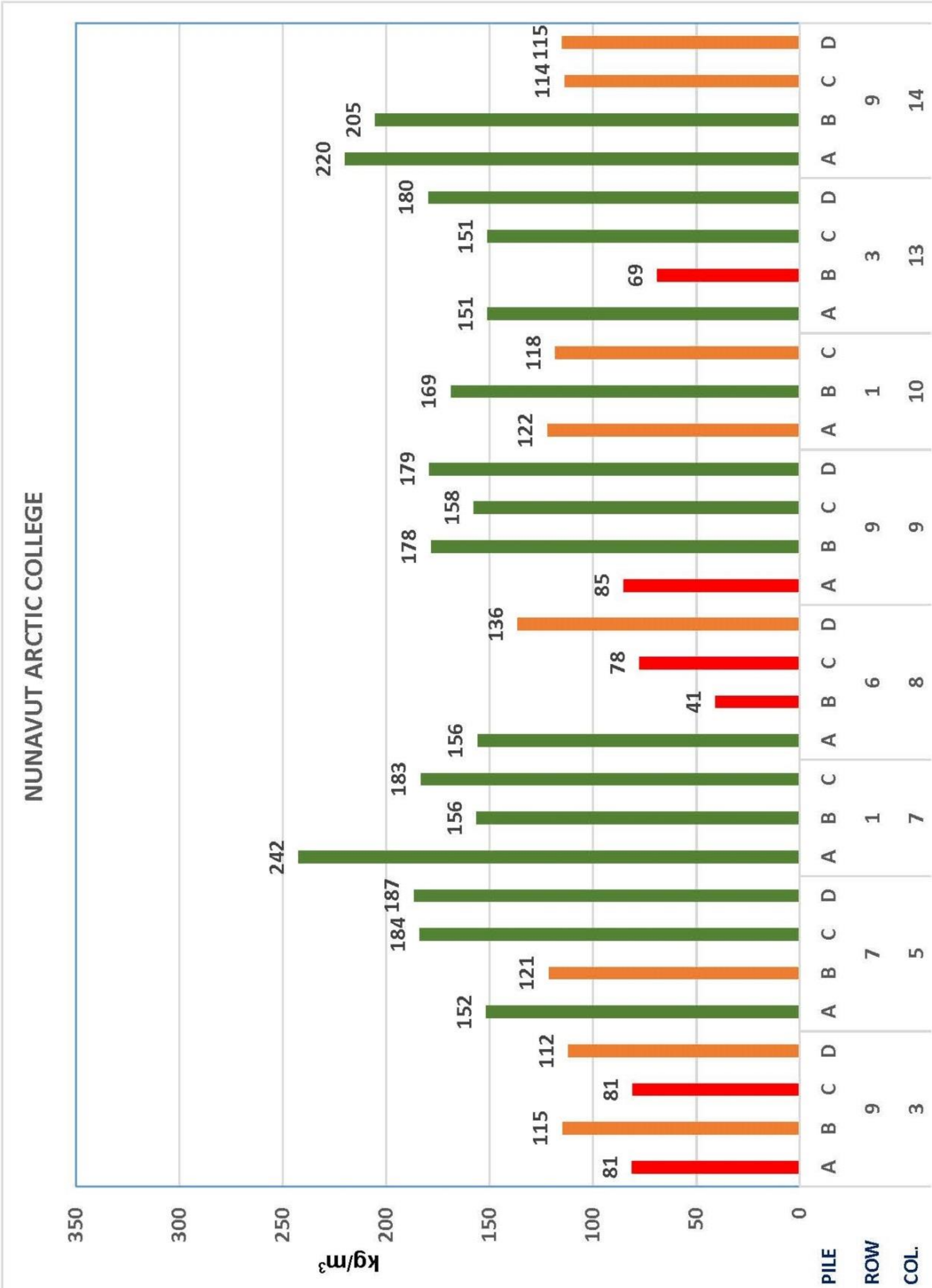

Figure 1. Creosote retentions for piles supporting the Nunavut Arctic College Nunatta Residence Building. (Retentions shown in green exceed 90% of UC4.2 while those shown in sandy brown exceed 90% of CSA 080 (1954) and UC4.1)