MARINE USES OF PRESERVATIVE TREATED WOOD

Gouin Barford, P.Eng.
Senior Civil Marine Engineer
Architecture and Engineering Services
Public Works and Government Services Canada
#641 - 800 Burrard Street, Vancouver, B.C., V6Z 2V8

Summary

Marine (salt water) use of wood depends on the availability of preservative treated wood due to the rapid deterioration of unprotected wood, particularly from marine borers. Wood not in full salt water exposure is subject to high decay hazard due to moisture and a generally favourable environment for agents of biological deterioration. Typically, wood is treated to different use categories depending on the specific exposure of the area of the structure it is located in.

The physical characteristics of treated wood (high elasticity, ability to withstand impact loading, ability to form a load sharing system, durability) compare favourably to other possible materials (concrete, metals, plastics). Wood does not have as high a strength as some other materials, and is therefore not favoured for structures required to withstand higher loads (generally larger structures).

The methods of fabrication are generally simple and well known, making it suitable for small structures and do-it-yourself work. Any fabrication after treatment introduces serious weakness into the treated shell and threatens durability. Design which allows all fabrication to be done before treatment, with work thereafter being strictly assembly, is favoured.

Lifetimes between 50 and 100 years are being achieved.

Early uses of wood in the marine environment.

As one of the readily available, relatively easily worked, materials available to humankind, wood has been used for thousands of years for many applications. These uses stretch back before written history, and we are left with the few instances of these early uses which through fortune have survived or left traces of their existence to infer uses specific to the marine environment. A historic marine use, close in place to us here, is the wooden fish weirs built by the First Nations in the mouths of rivers to divert returning salmon for the annual harvest of salmon essential to their way of life.

Other examples, more recent and better documented, include the uses of wood in the early wharves and canals so critical to Canada's growth. Whether these uses were for the frames and seals of the canal lock gates, the stop logs for dams to control water levels for water wheels to power the mills, or for the wharves to allow goods to be moved by deeper draft vessels, wood was the readily available material. Many of these structures had to be built quickly, with little resources either for tools, for labour, or for time to develop more durable structures. In many cases, the use for these structures was short, while a particular trade route was being used or a particular resource (a gold rush) was being exploited. In many parts of Canada, wood was readily available, cut from the forests lining the watercourses and ready to use immediately. Availability and ease of working to suit the purpose to hand were prime reasons to choose among the different species available.

Early alternate materials for wood in marine environments.

As the country developed, it became worthwhile to develop stronger, more durable, structures to serve for longer periods. Wood was still a good choice as it was low cost and readily available, but its lack of durability lead to consideration of other materials. Examples were available from other parts of the world where durable materials for structures were already in use. These included stoneworks, metals, concrete, and various means of protecting wood including sheathing with metal and different non-pressure applied preservatives.

The suitability of wood for these purposes was dependent on the aggressive nature of the environment in which it was used. Today, we use the Use Classification System (UCS) as a guide to how aggressive a particular environment is, and what specific results of pressure treatment are required to provide durability. Within the UCS, "marine" is defined as exposure to salt and brackish water to the extent that marine borers can attack wood, as distinguished from fresh water (generally referred to as "water"). There is recognition that not all marine environments are equally aggressive, although the degree of aggressiveness is generalized at a continental scale without considering the major differences which exist at local scales, for instance within British Columbia over the transition from the full marine environment at the entrance to a fjord to the full fresh water environment in the river upstream of the tidal influence .

For the remainder of this paper, "marine" will be taken to mean salt water environments.

Present alternate materials for wood in marine environments.

The traditional materials available for use in marine environments have expanded as our understanding of material properties and the availability of the various materials have increased.

1. Use of untreated wood decreased as treated woods became available, then increased for specific species as naturally resistant tropical hardwoods became available, and seems now to be reducing perhaps as a reaction to concern over destruction of the tropical forests.
2. Use of treated wood increased as the efficacy of treatment became accepted. Choice of preservatives and results of treatment depends on the UCS category.
3. Use of stone in the form of large stone masonry structures has reduced.
4. Use of concrete has increased. Improvements in the production of concrete have resulted in greater durability, and increased understanding of reinforcing including the use of

prestressed reinforcing have increased strength, increased flexibility, and improved durability (through reduction of cracking).

5. Use of steel has increased. Early concepts of protecting against corrosion through additional thickness of steel are being superseded by galvanizing and improved coatings, as well as by cathodic protection.
6. Use of plastic materials has increased. While expensive and needing care to detail their installation due to their physical characteristics which often differ significantly from other materials, these can offer combinations of high abrasive resistance with low friction, and corrosion resistance.
7. Use of composite materials, whether composites of differing types of plastics or plastics with conventional materials such as steel reinforced plastics. These offer strength, flexibility, high elasticity, and corrosion resistance.
8. Improvements in handling techniques allow plant prefabrication, shipping to site, and speedy erection for many of these materials, including preservative treated wood.

Why use wood?

Aesthetics. People like the appearance of wood. This enjoyment includes the appearance of the surface finish and the geometric shapes of wooden structures.

Physical characteristics.

- Wood has a high resistance to short duration high force loadings. This is particularly useful when the nature of the loading is variable, with a low probability of forces much greater than average, where the occurrence of those forces must still be considered for design. An example is the impact loading from a vessel which becomes slightly out of control during berthing – it doesn't occur very often, but the forces are high and should not result in failure.
- Wood construction has an ability to share loads among the members making up a structure, allowing for distribution of a load among more than the directly loaded member. In cases of severe overload, this sharing allows other members to take the load if one member fails, so that individual member failure does not result in failure of the structure.
- Wood is flexible. In the marine environment, many of the forces which arise are very high if the structure resisting them is rigid, but are much lower is there is some flexibility in the structure. Wood frequently provides this flexibility.
- There is ready availability of the basic tools and skilled workers for fabrication using wood.
- There is an ability to use a variety of fastening techniques.
- With appropriate care in design, selection of wood, and fabrication, intricate structures may be created.
- Strength is low compared to alternate materials, but this may not be a limiting factor for small structures or under some site conditions.

Durability of wood is a concern for most Canadian species. In marine structures, wood out of the salt water is subject to the deterioration mechanisms experienced on land. In the salt water, it is also subject to highly aggressive attack by marine organisms. In Canadian waters, the latter are typically Teredinidae, commonly referred to as Teredo, and Limnoria. Limnoria attack the exposed surface of wood, creating a shallow honeycomb structure which wears away exposing fresh surface to attack. Teredoes bore deep within the wood and PWGSC experience includes failure of untreated size 36 piles (14”) within 6 to 12 months of installation, a rate of loss of strength consistent with studies reported in Tidelines.

Preservative treatments of wood increase the durability of wood. The standard treatments are effective where wood is out of salt water. Where exposed to salt water, only a few chemicals are recognized as providing protection. These chemicals ((ACZA, CCA, and creosote) need to be present in the wood with much higher retentions and penetrations to be effective in marine exposure. When properly treated and installed, the life achieved in service may be in excess of 40 years for timbers and approaching 100 years for piles.

The preservatives available for use in marine structures provide a shell treatment to wood. Traditional site stick build construction breaches this shell by cutting to length, by cuts or drilling for attachments, by specific site cuts for framing details. These cuts should be treated with field preservatives, but this process is problematic for several reasons. Field application:

- is not as effective because the retentions and penetrations do not match what is achievable by plant processes.
- requires interruptions/changes in the type of activity carried out by the field crew, leading to inefficiencies.
- subject to weather (e.g. should be applied to dry wood but rain may make it hard to keep the wood dry).
- is harder to ensure chemicals are properly contained during application to minimize environmental contamination.
- is harder to ensure chemicals are fixed in the wood for environmental protection and long term efficacy.

Cost. For some types of structures, wood remains the cheapest material.

Specific past and current uses, Pacific Coast of Canada

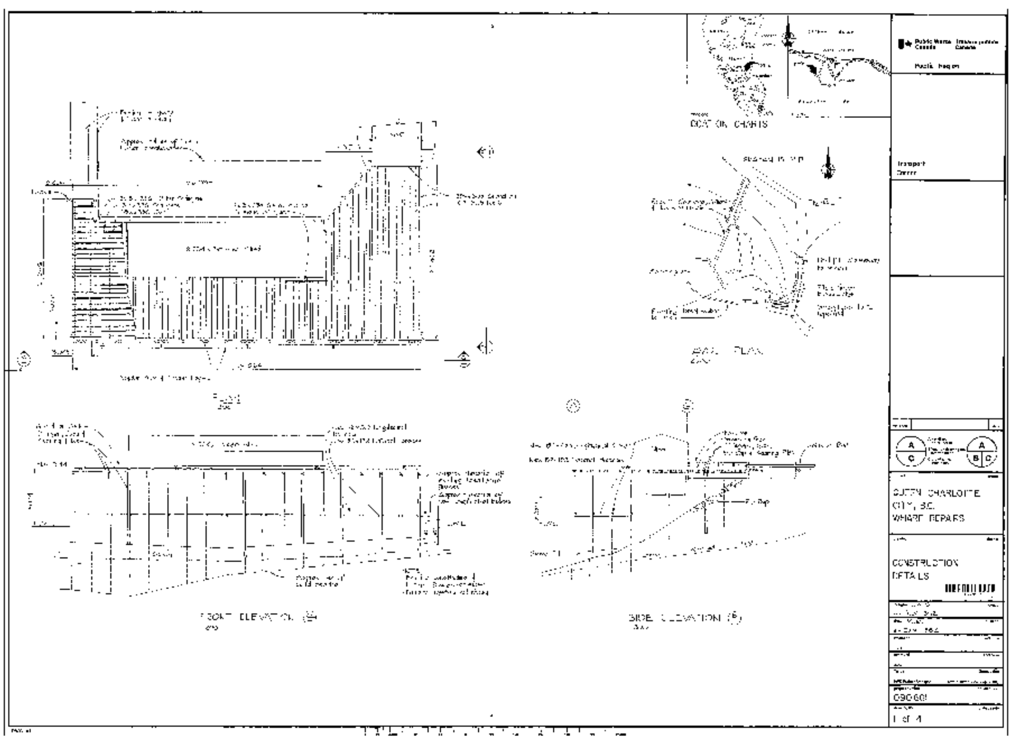
Early use of preservative treated wood was for the piles supporting the structures. These are exposed to the most aggressive zone for marine borers (subtidal up to low intertidal, frequently in estuaries where salt concentration is slightly lower than full marine). Without the use of preservatives, in many installations lifespan was likely from under a year to a few years. Fortunately, it is easy to manufacture piles with almost full sapwood, allowing ready retention and penetration of preservatives. Treated piles became common along the coast, for most structures, almost without consideration of desired lifespan since the lifespan without treatment is so short.

As communities and their associated marine structures became more permanent, the early practise of treated piles with untreated sawn wood substructures and superstructures resulted in wharves being rebuilt, re-using the treated piles and replacing the deteriorated untreated wood members. Natural progression occurred, with substructure members out of full marine treatment becoming commonly treated and eventually the superstructures becoming treated.

As treatment technologies improved, treated sawn members started to be used in the full marine exposure zone, UC5A. These improvements in treatment technologies were in place at a time when marine structures were being extended into deeper waters and used for heavier loadings. Wood was still the preferred building material. The early ready availability of large size trees was being reduced, and more sophisticated engineering designs were used to compensate.

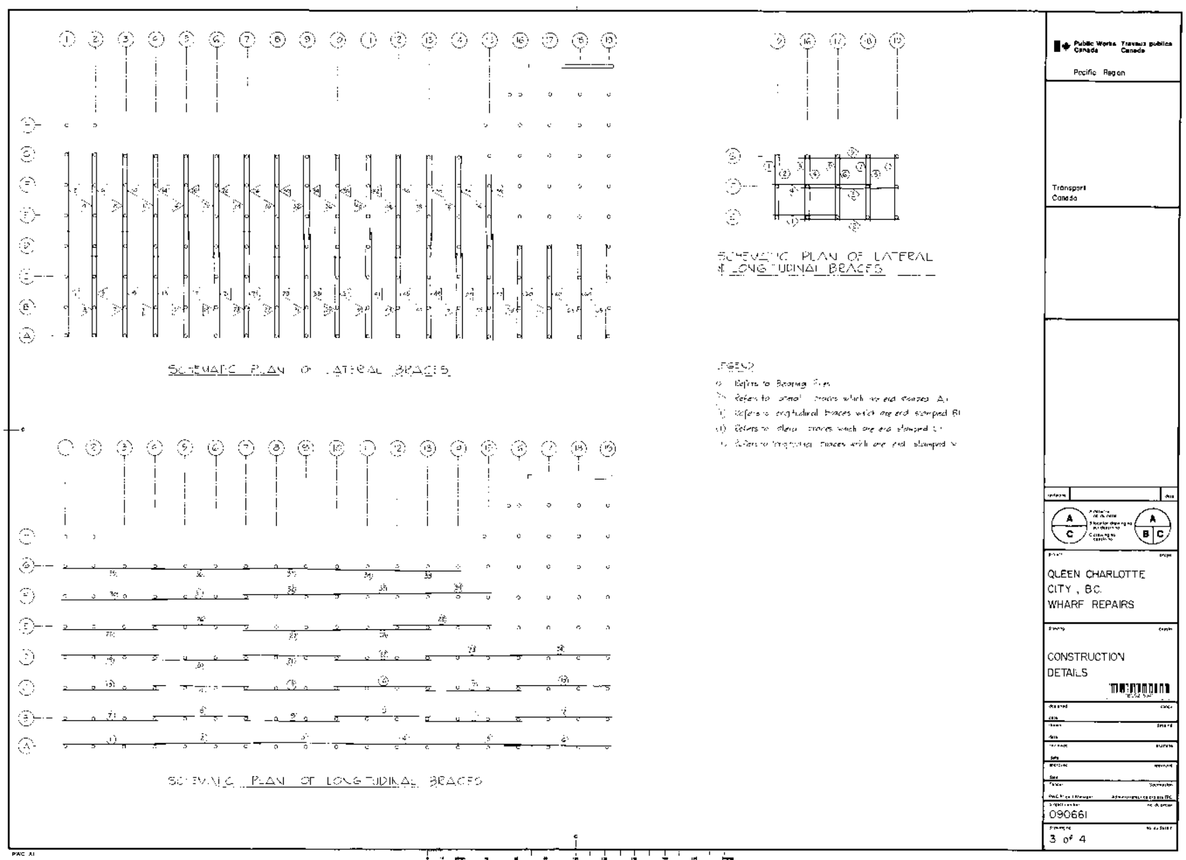
Treated wood was used in innovative ways. Many of the Fraser River deep sea shipping channel structures were primarily wooden structures used as hydraulic structures to direct the main flow of the river to create self-scouring conditions and minimize dredging. Treated wood was chosen due to some exposure to marine borers due to a salt water wedge underlying the surface fresh water and due to exposure to rot in the portions of the structures above usual water levels.

Structures from the 1950's through the 1980's show increasing use of treated and high end manufactured wood.



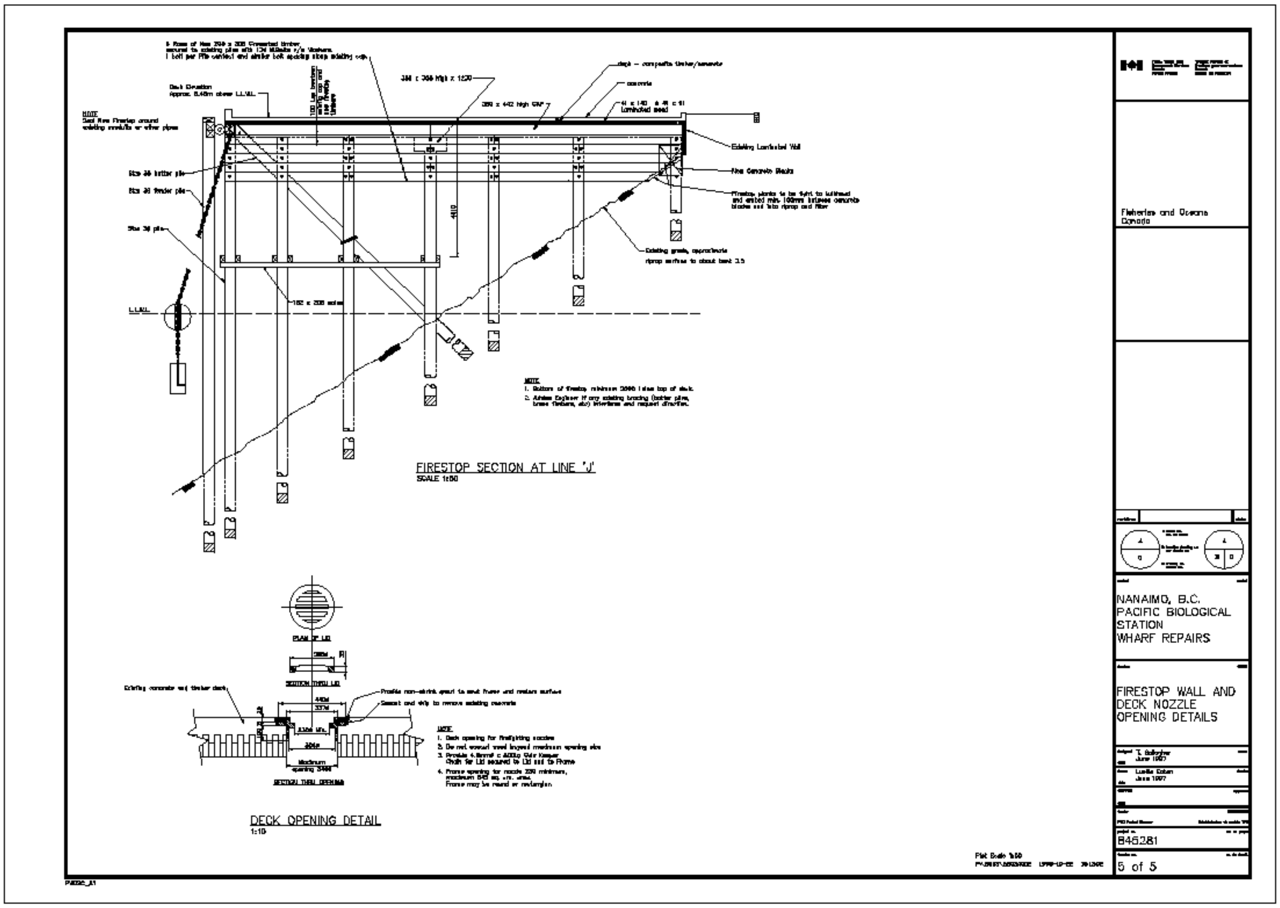
Queen Charlotte City, B.C. Wharf

Typical construction, adapted to large tide range (7.8 m) by use of long piles with horizontal bracing. Lowest level of bracing is exposed only on lower tides, and may only be worked on during the lowest annual tide cycles.



Queen Charlotte City, B.C. Wharf
Layout of horizontal bracing – lateral and longitudinal directions, intersections at piles.

- Supporting piles were treated (usually creosote).
- Bracing to allow longer piles, or the piles to support higher loads, became common, using latticework of horizontal and inclined sawn timber members, treated, usually with creosote.
- Cap timbers became treated, usually with creosote.
- Stringers became treated, usually with creosote but also with water-borne preservatives (ACA, ACZA, CCA).
- Decking became treated, usually with waterborne treatments due to human contact potential.
- For structures requiring high loading capacities, nail laminated decking was used, usually creosote treated and with an asphalt wearing surface.

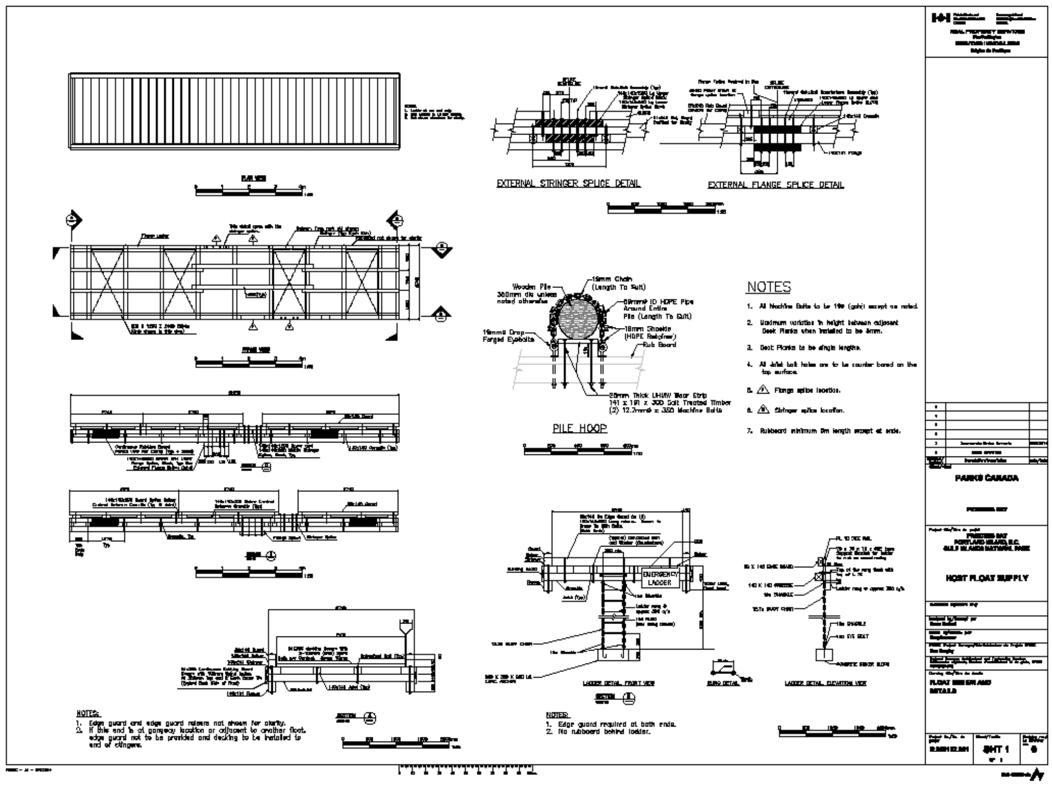


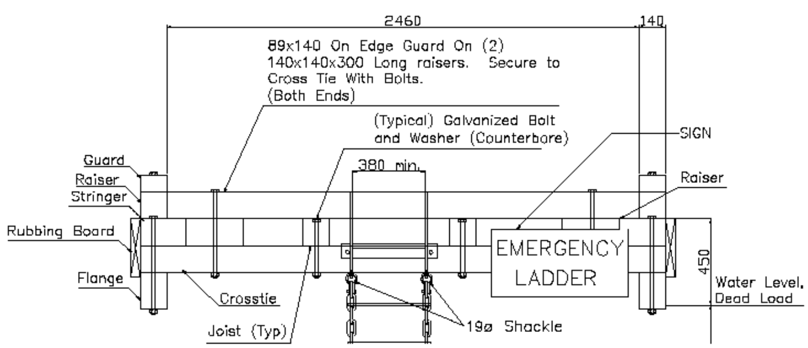
Nanaimo, B.C., Pacific Biological Station Wharf
High loading capacity, laminated deck, horizontal and diagonal bracing, timber firestops, fendering system including fender piles

- Structures requiring high load capacity and long spans used glue laminated treated wood members, usually creosote treated. These included loading ramps for ferries, and occasionally the gangways to floats.
- Handrails slowly became treated, along with the bullrails used at their base. Due to human contact potential, these usually are treated with water-borne preservatives. The high potential for these to be damaged due to accidents (vehicles misjudging their location, vandalism, etc.) and the fact that their frequent painting for aesthetic reasons imparted some durability resulted in these members being among the last classes to be converted to treated wood use.
- On larger wharf structures (> 50 m in length), fire safety concerns are mitigated by the use of fire stops (if >50 m) and fire separations (if greater than 120 m). Wharf structures constructed of large dimension wood are considered to be of "combustible" construction. Where the fire standard requires fire separations and barriers to provide a 1½ hour fire-resistance rating, they may be constructed of heavy timber (> 200 mm minimum dimension). Where this choice was made, the wood was treated, typically with creosote.

- Ships coming alongside wharves and other structures exert high forces as they berth, then are abrasive to the contact surface through the action of tide and waves. The berth contact, for smaller ships, is typically wood due to its ability to take high forces in the short term, its high compressive strength, and its high elasticity in bending. Typically, the contact for wharves is driven wood piles, called fender piles, preservative treated with creosote. For larger structures, other materials are used in more complex fendering, with past use of wood facing having given way to plastics over the last couple of decades.

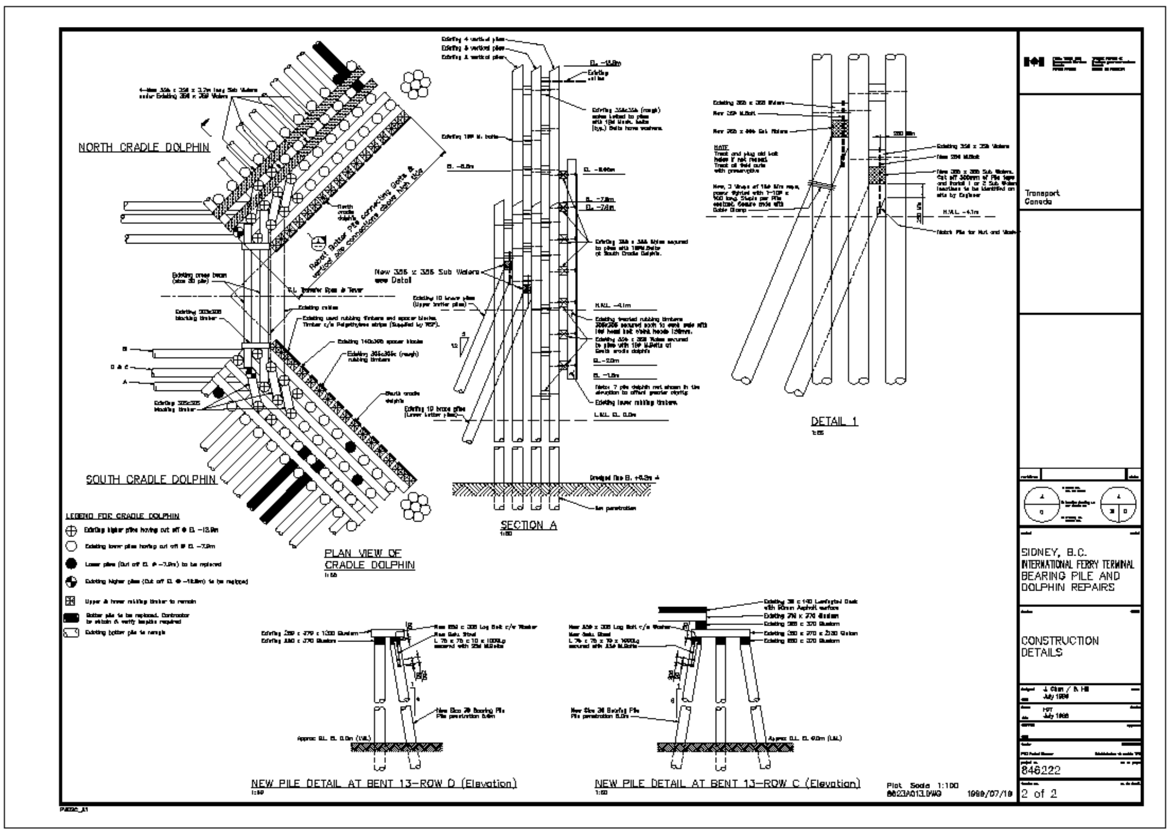
- Floats, more commonly used on the Canadian Pacific coast than on our Atlantic coast, were traditionally built from the plentiful supply of large diameter logs. Due to marine borers, the life of these logs in many instances was between 5 and 10 years. Crews became adept at rolling new logs under the old logs to keep the structure afloat. As these logs became scarce and more valuable, float design shifted to sawn timber members. The present designs use full marine treatment (UC5A), usually creosote, for members below or just above the waterline under dead load, then salt water splash zone treatment (UC 4.1) for members away from human contact, again typically creosote treatment. In the contact area, UC 3.2 treatment is used, treating with waterborne preservatives. One exception is the rub boards on the side of the floats which are a contact surface for vessels – these typically receive waterborne preservative treatment to UC 3.2 even when their lower edge is just immersed in salt water – skippers seem to like to keep their white paintwork white, and the rubboards are not structurally critical.



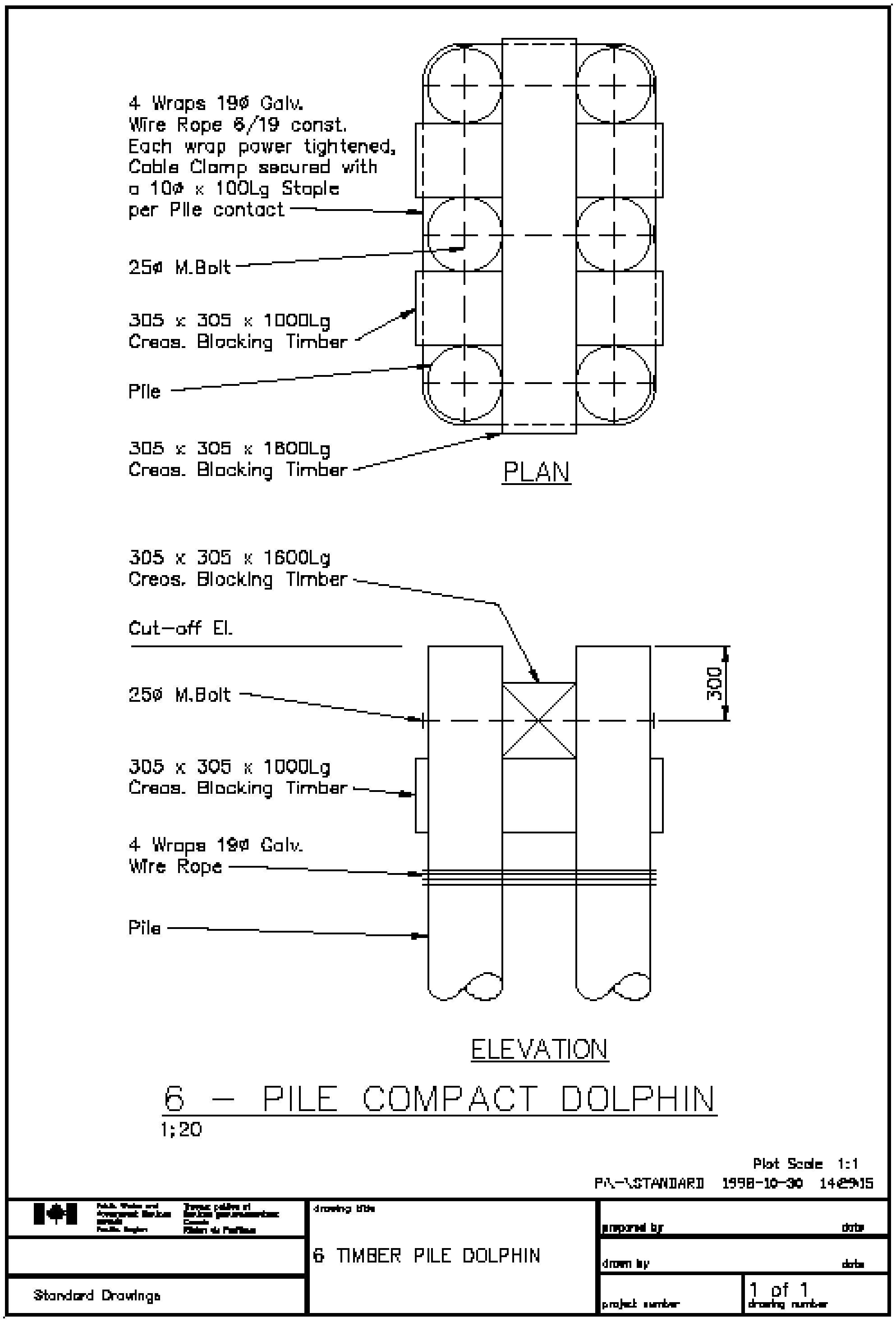


Princess Bay, B.C. Float framing for prefabrication and UCS zones

- Companies supplying components for small private marine facilities typically for installation by private owners, are providing prefabricated float kits, using small repetitive modules or providing all materials for assembly.
- Pile dolphins to take horizontal loads are used for mooring floats, for direct mooring of vessels, or for guiding vessels into berths. Typically driven creosoted piles are used with treated sawn timber used for connections. Dolphins for demanding applications with high loads such as positioning roll-on roll-off ferries are complex while those for small float mooring are simple construction.



Sidney, B.C., Cradle Dolphins to Centre and Hold Ferry During Loading


4 Wraps 19ø Galv.
Wire Rope 6/19 const.
Each wrap power tightened,
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a 10ø x 100Lg Staple
per Pile contact
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Challenges

Treated piles have excellent durability, commonly 50 to 100 years. The challenges are protection of field cuts – the top where the pile has been cut off to the correct elevation after driving, bolt holes for connections, and other framing done after driving. Due to the forces and uncertainties in the pile driving process, framing before treatment is not presently successful. Solutions include careful design with attention to detail, minimizing cuts, vigilance during construction that field treatment is done correctly from both a preservative and an environmental perspective, monitoring during use to detect deterioration, and precautionary techniques to re-treat areas affected by original cuts when the structure is exposed during major rehabilitations.

Sawn members do not have the track record of piles, partially due to not having been used over as long a period and to less sapwood. Despite this, lifespans of over 25 years are commonly achieved for main substructure elements before a need for structure refurbishment is identified, often due to corrosion of steel fasteners and deterioration of surfaces exposed to wear such as decking. If original sizes are still adequate for strength, these main substructure elements continue in service after structure refurbishment with expected additional lifespan of 20 or more years. As with piles, the weaknesses are in the field cuts. As well as the solutions identified for piles, greater care in design and fabrication allows fabrication of more details before treatment. Examples include, for diagonal braces, drilling a bolt hole at one end before treatment, then installing the brace with that hole in the full marine exposure area, with the remaining necessary cuts being done in the field in areas with lower deterioration potential.

The in-service environmental consequences of treated wood.

- Direct effects on the water column and the surface of the water have been minimized by use of BMPs during treatment.
- Application of field cut preservatives needs to be done thoroughly, but frequently the weather and construction schedules do not co-operate with this.
- There is high time and effort required for application of field preservatives to obtain good treatment and to ensure the preservative chemicals are transported, shipped, and disposed of correctly. The application of the preservatives may no longer be done casually with a brush dripping chemicals into the water.
- The build-up of chemicals in the sediments from long term leaching and/or surface abrasion of treated wood circumscribes future uses or actions of an owner of a marine structure. Effects include more expensive dredging to maintain depths due to disposal of sediments contaminated by the preservatives (usually PAH from creosote, but including metallic compounds) and may include extensive remediation of a site after the marine structure is no longer required.

The perception of environmental consequences.

- While at present negative perception is still focussed on creosote and CCA, there is a level of concern for all treated wood.
- The above is somewhat balanced by an increased awareness of the extended lifespan that is achievable with the use of treated wood.
- Education of the public and the regulatory bodies is still required, for both creosote and water-borne preservatives. While the preservative industry is aware that treated

waterborne wood does not leave the plant until the chemicals are fixed in the wood, the general public and individuals in the regulatory agencies are not convinced that the chemicals are fixed in the obviously wet wood.

The use of fabrication before treatment.

- Some uses of treated wood, such as driven piles, are difficult to prefabricate due to unknowns during site installations. Exact penetrations into the ground are unknown, and twisting or other displacement often occurs during driving – while these do not create difficulty for site fabrication, they mean that pre-fabricated joints and connections do not line up and require redoing on site.
- Other uses, such as float construction, are suitable for fabrication before treatment. Fabrication occurs in a factory setting, little affected by weather, suitable for strict tolerance control. Attention to detail design and strict fabrication tolerances ensure easy assembly after treatment, with no field cuts and consequently no application of field preservatives. If, during service, a specific member becomes damaged, a replacement may be fabricated, treated and then installed on site without use of field cuts. There is no generation of treated wood waste because all cuts are done before treatment.

Orders for small quantities of treated materials custom fabricated before treatment may encounter substantial delay until a treatment plant has enough material to treat to the required results. Long delays cause owner frustration, and/or plants, to reduce delivery time, may combine members in a single treatment cycle to the highest specified treatment level, resulting in overtreatment of some members.

The use of treated wood in wear areas needs more consideration. At least some of the observed contamination of sediment at marine installations is likely due to abrasion of the treated wood, which then drops to the bottom (if creosote treated) or floats with the water column. The additional cost of providing a different material as a wear surface may be worthwhile.

The traditional wood used for treated wood structures in marine exposure is coastal Douglas Fir. This is considered refractive (hard to treat), and failures of treatment cause expense for the plant operator and the constructor, with delays in completion affecting the owner. It is becoming hard and expensive to obtain. There is reluctance to switch to other species, with reasons including the known high strength and stability of Douglas Fir in service, concern with ensuring that not all pieces of an order would come from treatable species within a commercial species group and hence not all members would be treatable, and concern that many designs are traditional based on coastal Douglas Fir and may not work as well with other species.

Future

Treated wood is likely to be of substantially reduced importance for large marine structures intended for high load use.

Treated wood is likely to continue for small, lightly loaded structures. Its appeal is expected to be for architectural/ traditional reasons and for suitability to small crews / do –it yourself installations. These are likely to continue to be assembled on site, with field cuts, and may increase if pre-fabricated kits become more widely known.

Small to medium size commercial marine applications not requiring high load capability are likely to continue using treated wood. Its appeal is expected to be for architectural/ traditional reasons, for the physical strength and flexibility of wood, and for low initial and life-cycle cost projects. Due to the expected sophistication of the owners of these projects, and the long time frame for other activities including permitting, financing, etc., the time and effort to allow fabrication of wood before treatment is likely to be accepted as worthwhile.

The increased domestic market for treated wood provides better access to treated wood suitable for ground contact and freshwater/salt water splash (UC4.1). In applications where field cuts may be accepted, this improves ability to use treated wood in marine structures.

Improved field preservatives and methods of application are required. Alternately, development of a through treatment adequate for the Use Categories encountered would be a major benefit.

Perception and physical challenges will continue to affect the use of preservatives. Continuing research on the effects on the environment is required. Continuing dissemination of information including benefits is required.

Literature

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