

# EXTERNAL TIMBER STRUCTURES

## Preservative treatment and durability

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Timber is a highly capable engineering material for use in such applications as bridges, piling and retaining walls. EU legislation aimed at harmonising biocidal regulations and reducing environmental risk has resulted in restrictions on the usage of the two principal timber preservatives, which were traditionally and extensively used for external structures, these being chromated copper arsenate (CCA) and creosote.

A restriction has also recently been placed on other wood preservatives containing chromium. However, over the past 15 years preservative products have been developed with the aim to provide equivalent performance to CCA, whilst creosote treatment is still an option for certain applications. Wood preservative specifications are now more closely tailored to end use.

This Digest provides guidance on appropriate and enhanced specifications of timber preservatives, together with additional measures for maximising the service life of timber. The Digest is supplementary to the guidance given in BRE Digest 479 *Timber piles and foundations*,<sup>[1]</sup> and Digest 481 *Timber bridges*,<sup>[2]</sup> and the specification processes of BS EN 335-1,<sup>[3]</sup> BS EN 350-1,<sup>[4]</sup> BS EN 460,<sup>[5]</sup> BS EN 599-1<sup>[6]</sup> and BS EN 351-1.<sup>[7]</sup> It is also complementary to the recommendations given in BS 8417,<sup>[8]</sup> a new edition of which is about to be published, and the 2007 edition of the Wood Protection Association manual *Industrial wood preservation specification and practice*.<sup>[9]</sup>

### EXTERNAL TIMBER STRUCTURES

Timber is a highly versatile construction material, strong and lightweight, with tremendous ease of handling and workability. It is both attractive in its appearance and its environmental credentials. Timber structures such as bridges and retaining walls tend to exhibit a natural empathy with the landscape. Worldwide, the use of timber for bridges has experienced a major revival for both vehicular and pedestrian bridges (Figure 1).



**Figure 1:** Road bridge supported on timber piles and abutments near Whistler, British Columbia, Canada (photo courtesy of G Freedman)

Recently, there have been major programmes of timber bridge building in North America, Canada, and Northern Europe. Correctly selected timber has good durability, in particular to de-icing salts (Figure 2). Timber is also widely used in countries such as the USA, Canada and Australia for foundation piling (Figure 3). In Canada, over 30 000 m<sup>3</sup> of treated wood piles are used annually, whilst around 500 000 timber piles are used per year throughout the USA. These countries tend to have large resources of timber, which are either naturally durable or treat well, but moreover exhibit a far greater acceptance of timber as a civil engineering material. In North America, there are over a million timber pole and permanent wood foundation buildings.



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**Figure 2:** Sioux Narrows Bridge, Ontario, Canada built in 1936 from incised, creosoted Douglas fir. Still in use as a single lane highway bridge (photo courtesy of Ben J. Haight)



**Figure 3:** (a) 20-ton bearing capacity preservative-treated Southern Yellow Pine piles being installed for a lakeside residential development in Florida, USA (b) (photos courtesy of EW&S Contracting Co. Inc)



**Figure 4:** (a) and (b) Timber piling with concrete extensions (photos courtesy of Willem van Delft/D van Biezen B.V.)

Approximately 200 000 timber piles are used annually in the Netherlands, driven below the water table and extended to the surface using concrete extensions (Figure 4). This method has also been used for projects such as housing, sports halls, and roads with pile lengths varying from 8 to 23 m, and pile loads from 5 up to 350 kN. JWG van de Kuilen gives design examples in *Timber engineering STEP 2*<sup>[10]</sup> together with details of the Dutch quality requirements for timber.

Timber is man's only truly sustainable building material. However, without preservative treatment, most types of softwood do not provide sufficiently useful service lives for applications in which timber is exposed to the weather, when in contact with the ground, in freshwater or seawater. The sapwood of both hardwoods and softwoods is especially vulnerable to decay. Bridges, piles, and retaining walls are critical structures that require prescribed resistance to decay in order to plan inspection, maintenance, and ultimately replacement schedules. Without timber treatment, alternative materials such as tropical hardwoods or concrete would have to be used for many of these applications.

## USE CLASSES

Timber is a natural biological product and subject to degradation, depending on service conditions, by a number of agents:

- Wood boring insects (eg House longhorn beetle)
- Marine borers (eg shipworm, gribble)
- Fungal decay (eg wet rot, dry rot)
- Bacteria.

Timber may also be subject to degradation by exposure to UV light, weathering or physical erosion.

BS EN 335-1<sup>[3]</sup> describes five Use Classes (formerly termed Hazard Classes) of timber exposure:

1. Internal, with no risk of wetting
2. Internal, with risk of wetting
3. External, above the damp proof course
4. In permanent ground contact or in freshwater
5. In permanent contact with seawater.

It has been noted that occasionally timber treated to comply with Use Class 3 (external use) has been supplied and used in applications where it is effectively exposed to Use Class 4 (ground contact). Even where timber is not in obvious contact with the ground (eg bridge decking and beams) build-up of debris, such as dirt, can effectively place the component in a higher Use Class. Instances of poor selection of timber and preservative type, or superficial application of preservatives (eg by brush or dip application) can lead to early structural failure, especially when combined with poor detailing. Unfortunately, ‘treated timber’ is sometimes sold without particular reference to the preservative or species type.

Timber that is kept dry (ie below 20% moisture content) is not vulnerable to fungal decay. Bridge components below a road deck may be protected from rainwater; however, more open structures, such as footbridges, will periodically become saturated. The duration for which a timber element remains wet is critical – parts of structures that can dry more quickly will be at a lower risk of decay. Although timber pilings installed below the water table can last for hundreds of years, for many structures, such as bridges and jetties, where the piles also form part of the superstructure, the section that is exposed to both air and water is most vulnerable to decay.

## TYPES OF WOOD PRESERVATIVE

The Wood Protection Association leaflet, *Preserving timber in confidence*<sup>[11]</sup> lists the four main types of wood preservatives currently used for industrial pre-treatment:

- Organic solvent borne
- Waterborne – low pressure
- Waterborne – high pressure
- Creosote and pigment emulsified creosote.

Only creosote high pressure treatments and waterborne high pressure treatments are suitable for external timber structures. Organic solvent-type wood preservatives are mainly used for exterior joinery.

The specification and use of wood preservatives in the UK follows the European Standards which relate the natural durability of the selected wood species to the end use environment and then indicate whether treatment is required. The UK has an interpretative document, which smoothes the transition from process-based specifications to results-based specifications in the UK – BS 8417 (2003)<sup>[8]</sup> *Recommendations for preservative treatment of wood*.

The key documents are:

- Use Class BS EN 335-1<sup>[3]</sup> and BRE IP 1/03<sup>[12]</sup>
- European Standards BS EN 350-1,<sup>[4]</sup> BS EN 460,<sup>[5]</sup> BS EN 599-1,<sup>[6]</sup> BS EN 351-1<sup>[7]</sup>
- BS 8417: 2003<sup>[8]</sup>
- Wood Protection Association manual, *Industrial wood preservation specification and practice*,<sup>[9]</sup> which mirrors BS 8417 but has commodity codes.

A number of preservative products have been developed that aimed to provide alternatives to CCA with equivalent performance in the field. Some of these have focused on removing the arsenic compound from the preservative formulations, eg chromated copper boron systems that use boron. There are newer preservatives in the copper-organic group in which both chromium and arsenic have been replaced by organic biocides. Boron (usually in the form of disodium octoborate) is a water soluble preservative which, for this very reason, is not used for the pressure impregnation of timber for external structures.

Boron is used in the remedial treatment sector, often in the form of an injectable paste or rods, or for use on timbers protected from water, eg roof timbers and sole plates.

### Recent legislation on preservative treatment

The two principal timber preservatives that were traditionally and extensively used for external structures, including bridges and piles, are chromated copper arsenate (CCA) and creosote. Both have been the subject of recent EU legislation:

- Creosote was withdrawn by EU member states from use in the DIY market (Directive 2001/90/EC, effective from 30 June, 2003) but can still be used for industrial applications such as telegraph poles, sleepers, bridges and piles. Restricted use includes playground equipment and applications where there is a risk of frequent skin contact.
- Amendment to the Marketing and Use Directive for arsenic (Directive 2003/2/EC, effective 30 June, 2004) limited CCA to a few derogated applications, but these included bridges and onshore piling. CCA was banned entirely for marine use.
- The introduction of the Biocidal Products Directive 98/8/EC with its risk-based approach to regulation provided the appropriate mechanism for harmonising the control chromated copper.

However, the costs implied in supporting the continued use of CCA for the derogated end applications were not justified by the residual uses alone. Furthermore, two of the active ingredients (arsenic pentoxide and chromium trioxide) were not supported with full data packages in the Biocidal Products Directive; therefore, approval for the use of CCA preservative was withdrawn in Europe, which was effective from September 2006. Although for the time being it is possible to import timber treated with CCA into the EU for use only in accordance with the restricted list, this is expected to be prohibited by new legislation.

Preservatives containing chromium were withdrawn from the UK market starting September 2006, affecting both chromated copper and chromated copper boron preservatives.

There are four main groups of copper organic wood preservatives for ground contact applications. They are the copper azoles (eg Tanalith E), copper HDO (eg Wolmanit CX-8), ammoniacal copper quaternary compounds (eg ACQ 1900), and the ACQ plus boric acid formulations (eg Celcure AC 500). In general, these CCA alternatives tend to require higher preservative loadings, and greater care is required in the selection of timber species and design of the structure to maximise durability. Timber that is supplied for general landscaping purposes will be less suitable than that classed as 'heavy duty' or for industrial applications, such as transmission poles and motorway fencing, even though both groupings are in Use Class 4. Unless otherwise stated by the manufacturer, none of these proprietary CCA alternatives should be considered as being suitable for use in seawater, although other protective measures may be taken against marine borers, such as polymer wrapping.

Creosote is available for industrial applications such as utility poles, sleepers, bridges and piles. Restricted uses include playground equipment and applications where there is a risk of frequent skin contact. Creosoted utility poles have an expected service life of approximately 75 years, while creosoted piles capped with concrete are expected to last well over 100 years. The majority of piles used in the USA are creosoted Southern Yellow Pine. Of the 150 bridges, recently constructed under the Nordic Timber Bridge Project,<sup>[13]</sup> many were creosote-treated. One advantage of the preservative is that it also acts as a water repellent, limiting the development of splits, which can otherwise allow fungi to penetrate.

When in contact with water, heavily creosoted timber has a tendency to form an oil sheen. Modern creosoted timber production processes are capable of producing a product that is surface dry and less prone to bleeding under the action of sunlight. Organisations such as the Environment Agency should be consulted over the use of creosoted timbers in sea and fresh water. Natural England, for example, requires a risk assessment to be carried out on a case-by-case basis, when preservative-treated timber is used on Sites of Special Scientific Interest. Information is available in the US Department of Agriculture Forest Service's publication, *Guide for minimizing the effect of preservative-treated wood on sensitive environments*,<sup>[14]</sup> and the Timber Piling Council publication, *Treated wood in aquatic environments*.<sup>[15]</sup>

## NATURAL DURABILITY AND TREATABILITY

BRE Digest 429<sup>[16]</sup> gives the natural durability classifications of a large number of species, together with their resistance to preservative treatment. Natural durability classifications are also given in BS EN 350-2<sup>[17]</sup> and BS 5268-2.<sup>[18]</sup> Some of these timbers are not available from sustainable sources or with appropriate certification. Table 1 shows values for several commonly available British-grown species. The natural durability ratings provided relate to UK conditions, and refer to heartwood and fungal attack only.

Without preservative treatment, softwoods usually have insufficient natural durability to provide a suitably long service life for Use Classes 4 and 5. Of the species which are grown in the UK, Douglas fir is available in large section sizes of up to 400 mm<sup>2</sup> × 12 m in length. Its measure of natural durability and abrasion resistance has made it favoured for bridge members, fenders, decking and piling. Formerly, it was used for groynes on the North Sea coast. Corsican pine and Scots pine have a relatively large amount of sapwood that treats well. Consequently, these species are used for telegraph poles and other roundwood applications, although the amount of sapwood can vary.

Of the British-grown hardwoods, oak is well known for its durability, being used for lock gates, with a service life of approximately 30 years. Both alder and elm are quite durable as pilings in water. These naturally durable species contain chemicals, which are toxic to wood destroying organisms, but leach out over time. Some hardwoods have low durability but are permeable to preservatives. Creosoted beech was extensively used in the past for railway sleepers. For all hardwoods that are not treated with a preservative as an additional measure of protection, the sapwood should be excluded.

Imported timbers which treat well include Radiata pine and Southern Yellow Pine. Some very durable tropical hardwoods are available with suitable certification. Reclaimed timbers, such as those used for sleepers, telegraph poles, and groynes can also be used for landscaping and jetties.

Table 1: Natural durability of selected timber species in ground contact

Timber species	Natural durability of heartwood	Treatability of heartwood	Treatability of sapwood
Oak	Durable	Extremely difficult to treat	Easy to treat
Elm	Slightly durable	Moderately easy/difficult to treat	Easy to treat
Douglas fir	Slightly to moderately durable	Extremely difficult to treat	Moderately easy/difficult to treat
Larch	Slightly to moderately durable	Extremely difficult to treat	Easy to treat
Scots pine	Slightly to moderately durable	Difficult/extremely difficult to treat	Easy to treat
Corsican pine	Slightly durable	Extremely difficult to treat	Easy to treat
Beech	Not durable	Easy to treat	Easy to treat
Sweet chestnut	Durable	Extremely difficult to treat	Moderately easy to treat



**Figure 5:** Footbridge on timber pilings (photo courtesy of Outdoor Structures Australia)

## MAXIMISING THE SERVICE LIFE OF TIMBER COMPONENTS

For timber that is used for bridges and piles, optimised specifications of species and preservative can be formulated (Figure 5). Certain timbers take up and retain wood preservatives better than others, and some forms of timber, such as roundwood, are better suited for some applications than squared-off material. Air dried, well seasoned timber tends to take up preservatives better than kiln dried timber. The moisture content should be well below 20%, throughout the timber's section, before pressure treatment is applied. For large section timber, and particularly Douglas fir, the correct seasoning process can take many months. Treatment after drying also allows the preservative to enter the wood via splits, which would otherwise allow fungi to access the less well protected interior. Components such as bridge beams should be prefabricated with drill holes, notches, and so forth, as much as is practical, prior to pressure treatment. When this is not possible, all site cuts should be treated.

Higher loadings of preservatives are also available. Longer and repeated pressure schedules can be used to increase penetration. Of key importance, is the dialogue between the timber engineer and the preservation specialist, thus tailoring the materials and treatments to end usage. Some types of preservative are not suited for use in water (eg jetty posts). Pre-treatment and post-treatment selection processes (eg for sapwood content and preservative loadings) can also be applied.

### Dual preservative treatment

In the USA, dual treatment of creosote and boron (which would otherwise leach) is used for railway sleepers, whilst in Australia, dual CCA and creosote-treated pilings are used both on land and in saltwater. The Flisa highway bridge in Norway (182 m overall length) is protected by dual waterborne preservative and creosote treatment, with the main timber beams being additionally protected from rain by copper sheathing. Such combinations of preservatives are not commonly available in the UK, but could be specified.

Although normally installed remedially, diffusible preservatives, such as boron and sodium fluoride, can also

be installed as an initial measure to increase service life (eg by side or central borings). Morrel et al.<sup>[19]</sup> reported that fused borate rods appeared to have excellent prospects for controlling the internal fungi of Douglas fir utility poles. However, borate diffusion is known to be highly dependent on the moisture content of timber. Boron rods or paste should not be incorporated into any marine or river structures without first considering the risk to fish and other aquatic life.

### Incising

Improving the permeability of large section timbers can also be achieved by incising, which involves perforating the surface of the component with tiny holes.<sup>[20]</sup> Incising was recommended in BS 5589 for marine timbers.<sup>[21]</sup> BS EN 12465<sup>[22]</sup> defines the minimum limit of the incised zone for utility poles (when applied) as 400 mm above and below ground line. In the past, incising was widely used, and it is still available at some of the major preservative treatment plants. The process is particularly suited to Douglas fir when used in square section.

### Water repellents

Water repellent finishes offer considerable protection to exterior timber structures. As unprotected timber dries out after periodic wetting it develops splits and checks, which allow organisms that are harmful to wood access to the less well protected interior. Some wood preservative and water repellent combinations are available. Water repellents can also be applied by brush or spray after construction.

### Ground-line wraps

Ground-line wraps (which combine a diffusible preservative with a plastic sleeve) can be used to extend the service life of timber piling and posts. The wrap acts as a moisture barrier preventing the preservative from leaching into the surrounding soil. Some commercial systems for the protection of fence posts involve the periodic remedial application of diffusible preservatives. Similar systems have been used for utility poles and could be adapted for use on piling and foundation posts.

### Barrier wraps and polymer coatings

Barrier techniques used to prevent damage to wooden ships from shipworm and gribbles date back to the 18th Century with the use of copper plating, hence the term 'copper bottomed'. Wrapping of timber marine piles is widely practised in the USA, using plastics such as PVC and high density polyethylene. In the UK, proprietary bitumen tapes and polymer wraps are available. For remedial repairs and strengthening of timber piles, shells of fibre reinforced polymers and epoxy grouting can also be used.

Plastic barrier wrapping is known to also work well on items such as fence posts<sup>[23]</sup> and could be used on timber piling or foundation posts with the following similar aims:

- To provide an additional layer of protective material isolating the timber from soil/water organisms including fungi and bacteria



**Figure 6:** Agricultural building with coated post foundations (photo courtesy of Postsaver Ltd)

- Reducing depletion of preservative
- Containing water-soluble preservatives within the element.

The use of foundation posts, protected by polyethylene/pitch barrier wraps (Figure 6), are beginning to be used for residential buildings in the USA and have been used for agricultural buildings for some time.

A number of polymer-coated wood products are marketed in the USA for use as marine and freshwater pilings, railroad ties, crib walls and playground equipment (Figure 7). All use timber which is preservative treated. These products have been mainly used for recreational structures such as boardwalks and activity centres. BRE is currently carrying out trials on plastic and fibre reinforced polymer wrapped foundation posts and piling, including systems where dry preservative treated timber is totally encapsulated.

### Engineered timber products

Glue-laminated timber comprised of selected permeable sapwood, and reformed timber such as laminated veneer lumber, can have preservatives incorporated during the manufacturing process. Forms of 'technical' plywood are available, specifically for external use, which are impregnated with resin or have special plastic coatings.

## DETAILING AND CHOICE OF MATERIALS

For structures such as bridges, much can be achieved in terms of increased durability through a good design and choice of materials. An overall design strategy should allow for ease of inspection and, if necessary, replacement of members or the introduction of reinforcement. Fortunately, timber connections can be made with relative ease. Also, timber structures tend to be lighter, making the provision of temporary supports and strengthening simple. The effects of ultimate decay on a timber structure should be anticipated so that catastrophic failure of critical members is avoided. Redundancy can be introduced by increasing the number or size of members.

Timber is less vulnerable to decay if protected from moisture, with one option being the use of a bridge deck



**Figure 7:** Polymer coated timber piling (photo courtesy of CMI)

for weather protection. Furthermore, pile and post tops can be capped. Details should be incorporated that facilitate water shedding, allowing for circulation of air and avoiding dirt and water traps. Flat surfaces should be chamfered to promote water run-off by surface tension (Figure 8).

Wherever possible, preservative-treated timber should be used at the supplied lengths. Unnecessary cross-cutting or notching should be avoided. Treated timber should not be planed. The use of well seasoned or conditioned timber can reduce the development of splits, during service. The structure should be prefabricated as much as possible prior to treatment with the preservative. When site cutting or drilling is unavoidable, liberally apply preservative to the exposed surfaces and use end grain sealant. Do not point piles or shorten posts following treatment.

The effects of timber movement should also be considered on timber connections. In general, single connections are less prone to movement-induced splitting. Avoid making drill holes close to the ends of beams. Where multiple connectors are required (eg to fix decking), these should be staggered and pre-drilled. Connectors should be corrosion resistant. In addition, provide seals or drains at bolt heads and washers to reduce water penetration into the connection area. Decking boards should be placed heart side down. Reject all timbers with defects such as splits. Special decking boards are available, which promote durability by shedding water and allowing ventilation over supports.

Keep end grain timber free from abutments and out of ground or water contact, while allowing free air circulation. Whenever possible, prevent timber contact with ground or damp brickwork/concrete. Use a damp proof course and flashings at bearings, and prevent the build-up of dirt and vegetation. A damp proof course can also be applied between the decking at the main beams. Stress laminated decks should be protected by an effective damp proof membrane, which is detailed to shed water away from the structure. Metal column bases should be designed to keep timber dry, with weep holes or slots for drainage.

Maintenance and inspection schedules should be specified and adhered to. This can involve re-application of water repellents and application of remedial treatments, and structural repairs.



**Figure 8:** Roundwood retaining wall showing rounded ends to promote water run-off (photo courtesy of M&M Timber Ltd)

## SUMMARY

- Preservative treated timber can provide useful service lives for external structures
- Optimised preservative specifications and timber selection processes can be used to promote durability
- Dialogue between the timber engineer and the wood preservation specialist is important
- Other protective measures such as incising and polymer coating are available
- Good design and detailing are essential.

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