Development of UK Grown Timber for Industrial Applications Final Report

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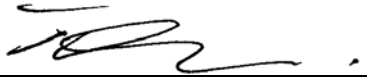
Signature 

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Executive Summary

This report details the final report on the following project: *Development of UK grown timber for industrial applications* (contract FG09/05, BRE project no. CV0733).

The main deliverable of this project was achieved with the production of a BRE Digest 503 *External Timber Structures – Preservative treatment and durability*, in collaboration with the Wood Protection Association.

This Digest was produced following a comprehensive review of the options available for enhanced durability specifications and other measures to protect timber, particularly in ground or water contact. Information from a large number of sources including industry participants was summarised in this report. During the course of the project, as a result of EU legislation, chromium based wood preservatives were withdrawn from the market, emphasising the need for this work.

The following potential enhanced durability processes for timber elements such as piling, poles and bridge beams were the subject of practical investigation:

- Pre-installation of borate preservative via centre borings
- Polymer wrapping

Barrier coatings are used for post foundations for buildings in North America. Remedial and supplementary treatment using borate and sodium fluoride is also practiced in the US, and elsewhere, on items such as utility poles and railroad ties. Thus there are methods, as detailed in the above Digest, that are practical and effective for improving the durability of timber elements. For the most part these have not been taken up in the UK.

A review of the suitability for untreated timber piling installed below the water table in the UK has been carried out, in collaboration with Green Piling Ltd. In a unique piece of work, test driving of Sitka spruce log poles was carried out at site near Middlesbrough. It was found that Sitka spruce had high compressive strength and was resilient to pile driving forces. The log poles obtained were noted to be good quality in terms of straightness, with good development of latewood and low knot content. The potential of timber piling is enormous; however more research is needed to remove doubt on the issue of long term durability, in particular the effect of bacterial degradation. The work so far has highlighted the opportunities for UK grown timber, in particular Sitka spruce, in a new application.

Further work on developing the use of UK grown timber for engineering applications, including piling, would be worthwhile. This could provide the basis for longer term monitoring of test items, together with further development of links between interested parties.

Contents

Introduction

General:

This report details the final report on the following project:

Development of UK grown timber for industrial applications (contract FG09/05, BRE project no. CV0733).

Progress Report 1 (CR 225 806) detailed the initial review stage of the project, together with the development of a project participants and interest group. Progress Report 2 (CR 225 808) detailed findings on potential treatment and protection technologies. Progress Report 3 (CR 225 062) detailed practical work on polymer coatings and application of borate via centre borings. Progress Report 4 (CR 225 813) detailed progress on development of user guidance. Progress Report 5 (CR 225 815) detailed an update on practical work carried out, and a review of the suitability for untreated timber piling installed below the water table in the UK. This final report summarizes the above work and, additionally, details the results of pile driving trials.

The BRE Project Manager is Tim Reynolds (01923 664832, reynoldst@bre.co.uk)

Project Aims:

The project aim is to encourage the use of UK grown timber for civil engineering and industrial applications through the development of improved durability large section material for use as foundation piles, bridges, utility poles and other high value in ground contact or in seawater applications. One area under investigation is the potential to achieve higher durability through a combination of enhanced preservative treatment and polymer coating, together with the development of installation and usage techniques designed to maintain the integrity of the protection system. A main deliverable of the project is to provide guidance on the use of timber as a sustainable civil engineering material, against a background of changing environmental legislation on preservative treated timber.

Key Objectives:

- Develop enhanced durability large section timber components for piles, poles and bridges.
- Develop and provide guidance on the use of timber as an industrial/civil engineering material.

Project participants/interest group:

- Postsaver
- Forest Civil Engineering
- Finnforest / BBH
- Wood Protection Association
- Aldridge piling
- Green piling
- Wykamol group
- Borax
- Gilmore and Aitken (sawmillers); East and Sons (sawmillers)
- John Hutchinson/Fielden and Mawson Architects

Background:

Timber is a highly capable material for civil engineering applications, but concerns over long term durability and environmental issues with respect to the use of preservative treatment have tended to discourage its usage. In other countries, such as the US and Australia, treated timber piling is used widely to support buildings, bridges and piers. In Canada alone some 30,000 m^3 of treated wood piling is used annually. In the UK the use of timber piling onshore is, however, no longer established practice. Similarly the use of timber for highway and other bridges is much greater in North America and Scandinavia, than in the UK. Where timber is used in the UK for civil engineering applications (eg groynes and retaining walls) imported material such as greenheart and radiata pine tend to be favoured over British grown timbers such as Douglas fir.

Progress and activity

Development of guidance

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This Digest was produced following a comprehensive review of the options available for enhanced durability specifications and other measures to protection timber, particularly in ground or water contact. Information from a large number of sources including industry participants was summarised in this report. A visit was also made to the Finnforest / BBH Newport treatment works.

During the course of the project, as a result of EU legislation, chromium based wood preservatives were withdrawn from the market, emphasising the need for this work. Unfortunately, apart from creosote, no preservative treatments are currently available for UK grown softwoods such as Douglas fir for use in the marine environment. Clear environmental guidance on the use of creosote in the UK is lacking.

Investigation of techniques

The following potential enhanced durability processes for timber elements such as piling, poles and bridge beams were the subject of practical investigation:

- Pre-installation of borate preservative via centre borings
- Polymer wrapping

Barrier coatings are used for post foundations for buildings in North America. Remedial and supplementary treatment using borate and sodium fluoride is also practiced in the US, and elsewhere, on items such as utility poles and railroad ties. Fumigants, applied via borings, are also used to extend the life of timber structures. The US Department of Agriculture (1987) publication *Wood Handbook: Wood as an Engineering Material* refers to the use of deep incising to depths of 2.5 inches (approx 60mm) on Douglas fir utility poles. Thus there are methods, as detailed in the above Digest, that are practical and effective for improving the durability of timber elements. For the most part these have not been taken up in the UK. In some instances there are restrictions on the use of preservatives in the EU that do not apply in the US.

Techniques for centre boring timber of large section timbers were developed by Heritage Engineering, to facilitate supplementary borate gel application. Diffusion trials were carried out at BRE on samples of Douglas fir, larch, oak and Scots pine. However initial assessment indicates that borate gel diffusion is minimal in the cross grain direction compared with along the grain. Other proprietary borate formulations or fumigants may be more effective, particularly if applied via conventional side borings. The disadvantage of side borings for structural timber is that they would reduce the bending strength of the timber.

Several of the large scale FRP and polyethylene coated test posts and piles were sent to the Broads Authority for use in waterways work (Figure 1). Test specimens are also being subject to exposure in a water tank at BRE (Figure 2), and were also installed at the Finnforest / BBH Newport utility pole test site. Opportunities to inspect these items for longer term monitoring will be taken. Initial examination FRP coated items exposed to both weather and water over two years revealed the timber underneath to be in perfect condition. A Fibre Reinforced Polymer coated timber pile (4.8m long) was exhibited at the Association of

Drainage Authorities Demonstration in Kent in July 2006, by Aldridge Piling, who are also looking at options for its use on a suitable project or site.

Figure 1: Experimental FRP coated Douglas fir pilings (4.8m long x 250mm sq.)

Figure 2: 200mm diameter coated and uncoated roundwood samples undergoing exposure tests in a water tank at BRE.

Production of a further set of polymer coated 100mm and 150mm roundwood posts for long term exposure tests has been delayed by technical problems at the participating manufacturer. It is hoped that test sample will be available in the near future.

Pile driving trials

BRE and Green Piling Ltd carried out pile driving trials using 13m length Sitka spruce log poles provided by Forest Enterprise at a site near Middlesbrough in June (Figure 3). The site comprised glacial till (firm sandy clay) overlain by 1.5m of fill. These ground conditions are not suited to timber piles *per se* but provided a valuable opportunity to obtain experience of hard driving of timber piles. Specialist pile testers PMC Limited also carried out dynamic load testing, with static load tests planned. It was found that Sitka spruce had high compressive strength and was resilient to pile driving forces. The log poles were noted to be good quality in terms of straightness, with good development of latewood and low knot content. Penetrations of up to 8.5m were obtained. A review of the potential of timber piling installed below the water table was reported in Progress Report 5 (CR 225 815), and for completeness is included in Appendix 1. Green Piling and BRE are currently collaborating on a paper or review article which will give full details of the test work and analysis carried out. The possibility of carrying out pile driving on a soft clay site with more suitable conditions is also being explored.

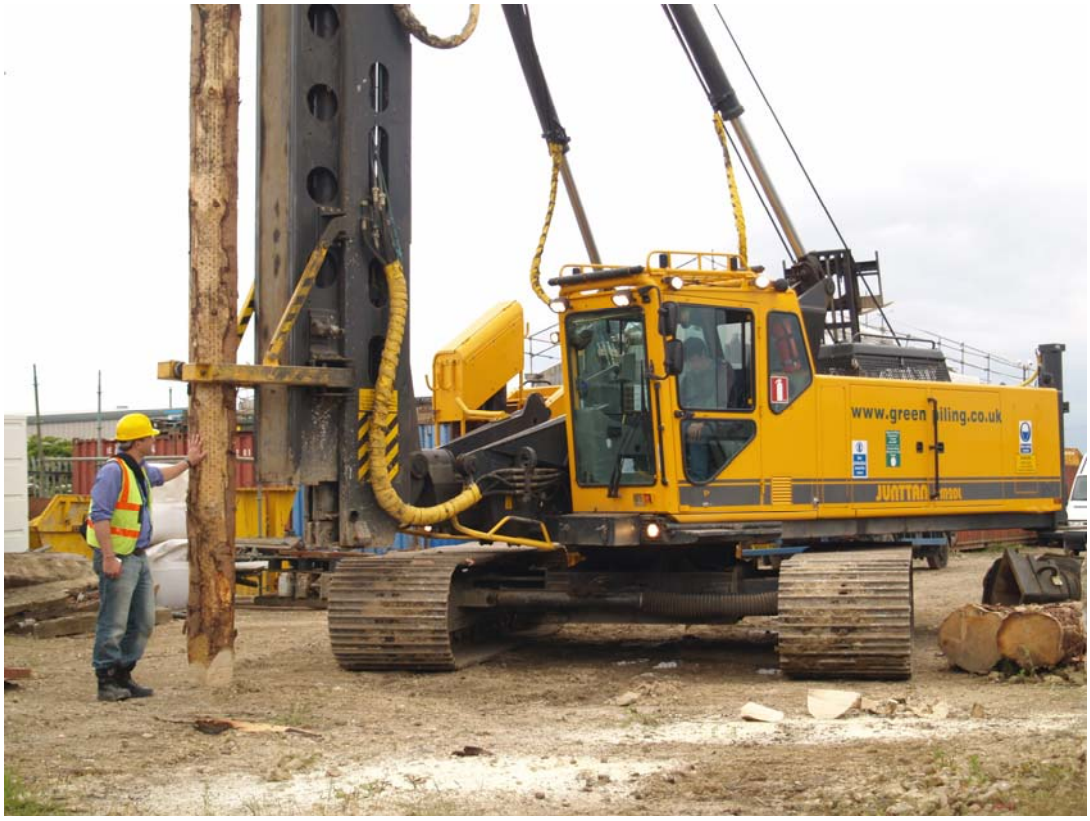

Figure 3: Pile driving trials at a site near Middlesbrough

Figure 4: Piling driving UK grown Sitka spruce

Conclusions and recommendations

The main deliverable of this project was achieved with the production of a BRE Digest 503 *External Timber Structures – Preservative treatment and durability*, in collaboration with the Wood Protection Association. This Digest was produced following a comprehensive review of the options available for enhanced durability specifications and other measures to protect timber, particularly in ground or water contact. Information from a large number of sources including industry participants was summarised in this report. During the course of the project, as a result of EU legislation, chromium based wood preservatives were withdrawn from the market, emphasising the need for this work.

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A review of the suitability for untreated timber piling installed below the water table in the UK has been carried out, in collaboration with Green Piling Ltd. Test driving of Sitka spruce log poles was carried out at site near Middlesbrough. It was found that Sitka spruce had high compressive strength and was resilient to pile driving forces. The log poles were noted to be good quality in terms of straightness, with good development of latewood and low knot content. The potential of timber piling is enormous; however more research is needed to remove doubt on the issue of long term durability, in particular the effect of bacterial degradation. The work so far has highlighted the opportunities for UK grown timber, in particular Sitka spruce, in a new application.

Further work on developing the use of UK grown timber for engineering applications, including piling, would be worthwhile. This could provide the basis for longer term monitoring of test items, together with further development of links between interested parties.

Appendix 1. Review of the potential of timber piling.

Some 200,000 log poles are used annually in The Netherlands for projects such as roads, housing, greenhouses and sports centres. These are driven below the water table and extended to the surface using concrete sections (Figures A1 and A2). The principal species used is Norway Spruce, although larch and Douglas fir are also permitted. Holland is ideally suited to the use of untreated timber pilings, with a geology which consists of, typically, 10 to 15m of soft clay and peat over sand, with a high water table. In the UK areas of soft ground include the floodplain deposits of the Thames, Severn, Forth and Clyde rivers (notably close to the large forest resources of Scotland), the Fens in East Anglia and Somerset levels. Numerous other estruine and river locations likely to be suitable for timber piling also exist. On the marshes of Dartmouth, for example, there is typically 12m of peat over gravel terraces. At Bothkennar near Grangemouth on the Forth Estuary there is 15 to 20m of soft clay over dense sand and gravel; whilst at Hull there is 22m of soft clay over chalk. Ground water levels in these estruine areas are likely to be high, although somewhat affected by tide and seasonal variation, and may be controlled locally by embankments and drainage. Determination of the reliable ground water level is likely to be a complicating factor when considering the use of untreated timber piles in the UK. This information is not difficult to obtain, but is not generally required for other piling materials.

Figure A1: Timber piles with concrete extensions being installed for a water tank in Holland (photo courtesy of D. van Biezen B.V.)

The UK has a large forest resource of conifers such as Douglas fir, larch, Norway spruce and Sitka spruce. However, unlike the situation in Holland no supply chain exists for bespoke, debarked and graded pilings. The basic price of Sitka spruce is around £40 per m^3, with Douglas fir and larch at £70 per m^3 and £105 per

m^3 respectively. These prices are more geared to sawmill processing. Prices quoted for “log poles” in the UK vary widely, for example 9m lengths of Douglas fir (at 300mm minimum diameter) can be obtained for £70 per piece. At around £8 per metre this compares favourably with the cost of a 250mm square pre-cast concrete pile, typically £15 per m. Typical costs for Continuous Flight Auger piling (a type of concrete pile often installed into weak ground) are £20 per m for a 300mm diameter pile, installed. Steel piling is more expensive still at, typically, £25 per m for a 140mm diameter pipe. Recently it has become much more difficult to obtain ex-oil production material for re-use as piling, and there is a high demand for steel as a result of development in China. Additional costs for timber on top of the basic roadside price include debarking where required, some form of inspection based grading, pointing and other preparation. Timber is, however, easier to handle on site (logs can be off loaded by grab) and cut to length. Timber is also light to transport with particular benefits when transported by barge. Approximately 40 logs can be carried on one lorry load.

Figure A2: Timber piles being driven into soft ground using the arm of an excavator, with square section concrete extensions in foreground. (photo courtesy of D. van Biezen B.V.)

Concrete extensions for untreated timber piles are available in Holland at typically 40 Euros for a 2.5m length. Norway spruce piles, grown in the Ardennes, can be picked up from the supplier in Belgium at 80 Euros for an 18m length (130mm diameter tip). The use of untreated logs as pilings, with minimal requirements for preparation, is clearly attractive for projects where a multitude of pilings are required at close spacings, with the proviso that they are installed below permanent water table. Suitable projects might include areas of industrial development such as factory floors, areas of hard-standing or storage,

utilities such as water storage, embankments and roads (some these were identified in the 2001 COFORD report *Field demonstration on the use of Irish grown Sitka spruce piles in embankment construction on soft compressible soils*). In Holland one such road scheme is named after "Kyoto" to emphasis the effective sequestration of carbon dioxide. Improvements to flood prevention embankments are known to be planned for the Thames Estuary where there is a particular issue with the low bearing capacity of the ground (waterlogged peat and soft clay). Where embankments are constructed quickly over such poor ground, without support, they are liable to fail.

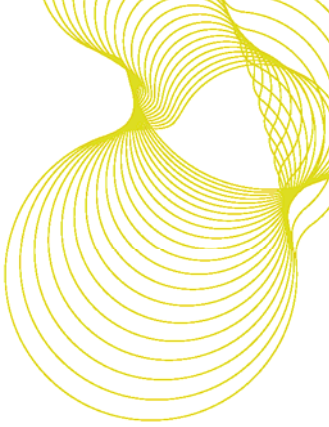
In the UK timber is very rarely considered for on shore piling work or foundations and the use of concrete is occasionally profligate. Charles (2005) in *Geotechnics for Building Professionals* (BR 473) gives an example where a concrete raft 1.5m thick, and weighing 350 tonnes, was used to support a simple log cabin adjacent to the Thames in Staines, which itself weighed just 16 tonnes. A lightweight two storey building in Essex, timber framed and clad, is also known to have been constructed on around 40 pre-cast concrete piles of 22m length and 400mm diameter, where timber piles (as specified by the architect) are likely to have been adequate.

There is increasing interest in sustainable development, "zero carbon" buildings and use of local materials in construction. The quantities of embodied $C0_2$ in foundation materials has received little attention so far. Figures quoted for the embodied $C0_2$ of timber, steel and concrete tend to vary depending on the methodology used in their determination. The figures recently quoted by the Concrete Centre for structural concrete are 372 kg/m^3, concrete foundations 173 kg/m^3, and steel 15,313 kg/m^3, with timber (UK processed softwood) at 353 kg/m^3 (note that an unpublished figure determined by BRE for the latter is negative 550kg/m^3 ie indicating carbon sequestration). The lower Concrete Centre figure of 173 kg/m^3 for un-reinforced concrete trench fill foundations would apply, whereas for driven reinforced concrete piles the higher structural concrete figure is appropriate. Wood for Good (on their website) state that 1m^3 of wood sequesters 0.8 to 0.9 tonnes of CO_2 from the atmosphere. Clearly where unprocessed, green logs are used for piling the figure for embodied CO_2 is going to be close to that value, and it can be calculated that a single 12m long pile of average diameter 250mm (ie volume 0.6m^3) "contains" 500kg of $C0_2$ that will be permanently sequestered underground. Production of a similar sized concrete pile will result in the production of 220kg of $C0_2$.

Concrete is stronger in compression than timber, however the load capacity of piles is very often governed by soil conditions. For example a timber pile of 200mm average diameter and 12m length installed into soft to firm clay (un-drained shear strength of 50 kPa) will have exactly the same capacity as a similar size concrete pile ie an allowable working load of approx 125 kN based on shaft friction alone. Pre-cast concrete piles, however, do not come in sections less than 300mm square. For a project such as a two storey masonry clad timber frame structure the "all up" foundation loads are something around 15 kN/m^2. A typical building might be of the order 80m^2 and require a minimum of twelve 110kN capacity 200mm diameter timber piles, or eight 185 kN capacity 300mm square section concrete piles, evenly spaced along the perimeter ground beams. The permissible structural capacity of the timber pile (assuming a grade of C16) at 130kN, would be evenly matched to the geotechnical working capacity, whereas the enormous structural load capacity of the concrete pile (over 1000kN) is simply not required. Some 25 kN of the shaft friction capacity of the concrete pile is taken off by self weight, which is not the case for timber. Where timber piles are needed to more numerous, the closer spacing can make design of the foundation beams or ground floor slabs simpler. In cases where piles are end-bearing onto granular soils such as sands and gravels overlain by weak material such as peat the case for timber is even stronger, particularly where firm strata can be reached within one log length, without splicing. Thus timber piles are strong enough for many structures on poor ground.

As part of this work the EU "Bacpoles" final project report (*Preserving cultural heritage by preventing bacterial decay of wood in foundation piles and archaeological sites* ref. EVK4-CT-2001-00043), was reviewed. Although several publications including the Timber Piling Council *Timber Pile Design and Construction Manual* (2002) state that timber piles submerged in groundwater will last indefinitely, slow

bacterial degradation, particularly of the sapwood outer layer of the log under certain groundwater movement conditions, as identified in the *Bacpoles* report, is a potential concern for some UK species for which there has been no experience of usage. As stated in BRE Digest 479 *Timber piles and foundations*, untreated Scots pine, for example, is known to be unsuitable. In Holland, the use of untreated timber piling is traditional and widely accepted, with examples of structures, notably the Royal Palace in Amsterdam, lasting hundreds of years. In the UK, where concrete is cheap compared with property prices, there is an expectation that foundations will last indefinitely. Any suggestion of decay however slow or in practical terms insignificant is unlikely to be tolerated. As illustrated above, the potential of timber piling is enormous; however more research is needed to remove doubt on this issue.



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