

# PAPER

## The Potential for Timber Piling in the UK

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### Abstract

There is increased interest in the use of sustainable materials in construction. Timber piles are widely used in the US, Canada, Australia and the Netherlands, but very rarely used in the UK, other than for marine work. Although untreated timber piles installed below the water table can last hundreds of years, there is little experience of using this technique with UK-grown species of timber, nor is there an existing supply chain for bespoke graded or preservative treated pilings. This paper presents the results of an investigation into the potential of timber piling in the UK, covering aspects of structural and geotechnical design, economics, sustainability and suitable ground conditions.

### Introduction

Timber piles are widely used in the US, Canada and Australia. About 500,000 are used per year throughout the US. These countries tend to have large resources of timber that are either naturally durable or take preservative treatment well, but moreover exhibit a far greater acceptance of timber as a civil engineering material. Graham (2000) reports on the use of 30t capacity timber piles for the foundations of the Cargo Terminal at John F Kennedy Airport. Timber piles were also used for the 210m diameter Louisiana Superdome supporting 130,000m<sup>3</sup> of concrete and 18,000t of steel. Timber piles with 70t design working loads are in use on a 300m long viaduct near Winnemucca, Nevada. In deep silt deposits, where the capacity of the pile is determined by shaft friction, timber piles are particularly suitable being tapered. In Sweden and the Netherlands timber piles are used below the water table and extended to the surface using concrete sections.

Notable structures built on timber piles in the UK include Newcastle's High Level Bridge (built 1853) and the Medway Martello towers (built 1848). The Royal Dockyards at Sheerness are founded in marshy ground on 1M timber piles (c. 1813). Westminster Bridge (opened 1860) is founded on elm piles. Scots pine was used for the piles underneath Tobacco Dock in Wapping, east London (c. 1812), probably driven through soft river alluvium (peat and silt) on to gravel. Beech piles were used for the Albert Dock (c1846). *HMS Victory* Dry Dock in Portsmouth is also founded on timber (c. 1790).

### Preservative treatment

Timber piles installed above the water table are vulnerable to fungal decay. Recent EU legislation has resulted in restrictions on the usage of the two principal timber preservatives traditionally and extensively used for in-ground contact use, these being chromated copper arsenate (CCA) and creosote. A restriction has also recently been placed on other wood preservatives containing chromium. Although there are several CCA alternatives such as copper azoles, these proprietary formulations tend to have a "desired service life" of up to 30 years. Longer service life may be obtainable with higher preservative loadings and good timber selection. Creosote is still 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 about 75 years, and creosoted piles capped with concrete are expected to last well over 100 years. There are, however, no specific environmental guidelines for the use of creosoted timber as deep foundation piles in the UK.

An obvious starting point for preservative-treated timber piles are telegraph poles, which are produced at two main plants in the UK, usually from Scots pine imported from Scandinavia. A variety of sizes are available from 6m (150mm diameter at 1.5m from the butt) to 24m (470mm diameter), with the typical price of medium-sized 10m pole (230mm diameter) being £154, which is marginally above the cost of precast concrete. Costs rise markedly with length – a 24m long preservative-treated utility pole costs over £1700. The quality requirements for telegraph poles in terms of straightness and uniformity are likely to be well in excess of those needed for piling.

### Use of untreated timber pilings

About 200,000 log poles are used annually in the Netherlands for projects such as agricultural and light industrial buildings, houses, embankments and roads. Pile lengths vary from 5m to 23m, and pile working loads generally from only 5kN up to 350kN. These are driven below the water table and extended to the surface using concrete sections (Figures 1, 2 and 3). The principal species used is Norway spruce, although larch and Douglas fir are also permitted under the Dutch piling code (NEN 5491).

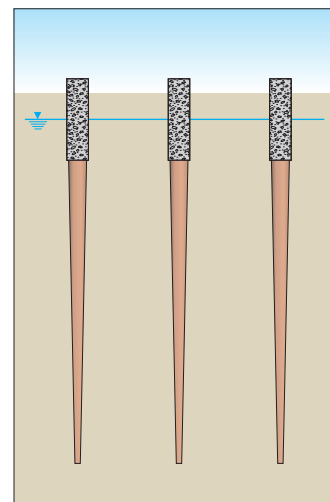


Figure 1: Timber piles with concrete extensions



Figure 2: Timber piles with concrete extensions being installed for a water tank

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Scots pine is not suitable because of the susceptibility of the outer layer of sapwood to bacterial degradation, even below the water table. Pile design is usually based on Cone Penetration Tests. The logs are driven either by vibrator or drop hammer, without pointing or debarking. The Netherlands is ideally suited to the use of untreated timber pilings with a geology that consists of, typically, 10m to 15m of soft clay and peat over sand, with a high water table that is actively controlled.

### UK geology

In the UK, areas of soft ground include the floodplain deposits of the lower Thames, Severn, Forth and Clyde rivers, the Fens in East Anglia and Somerset Levels. Numerous other estuarine and river valley locations likely to be suitable for timber piling also exist. Flood risk is certainly an issue, particularly for housing. However, there are other possible civil engineering applications, such as embankments and bridges. On the marshes of Dartmouth, for example, there is typically 12m of peat over gravel terraces. On Foulness Island, Essex, 1m of desiccated crust overlies about 10m of very soft silty clay with peat and sand layers, similar to the conditions across the North Sea in the Netherlands. At Bothkennar near Grangemouth on the Forth Estuary there is 15m to 20m of soft clay over dense sand and gravel, while at Hull there is 22m of soft clay over chalk. Ground water levels in these estuarine areas are likely to be high, although somewhat affected by tide and seasonal variation. Water levels 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 because of the need to keep them permanently submerged.



Figure 3: Timber piles being driven into soft ground using the arm of an excavator (to be followed by vibro-driving). Square section concrete extensions are in the foreground

### Costs

The UK has a large forest resource of conifers, such as Douglas fir, larch, Norway spruce and Sitka spruce. The current basic price of Sitka spruce sawlogs is about £40 per m<sup>3</sup>, with Douglas fir and larch at £80 per m<sup>3</sup> and £100 per m<sup>3</sup> respectively. These prices are more geared to sawmill processing. Prices quoted for “log poles” in the UK can vary widely. Typically, 12m lengths of Douglas fir (at 300mm minimum diameter) can be obtained for £80 per piece. Sitka spruce log poles of 12m length can be obtained for £40 per piece. At about £3 per metre this compares favourably with the cost of a 200mm square pre-cast concrete pile, typically £11 per metre. Steel piling is much more expensive. Recently it has become much more difficult to obtain ex-oil production steel tube for reuse. There is also a high demand for steel as a result of economic development in China.

Additional costs for timber on top of the basic roadside price include some form of inspection and grading, debarking and pointing (where required). Timber is lightweight and easy to transport, handle on site and cut to length. Approximately 40 large logs can be carried on one lorry load. Concrete extensions for untreated timber piles are available in the Netherlands at typically €45 (£42) for a 2.5m length. Norway spruce piles, grown in the Ardennes, can currently be obtained from the supplier in Belgium at €50 (£47) for a 13m length, and €85 (£80) for an 18m length.

Piling costs in the UK vary considerably depending upon soil conditions, geographical location, size of the project, market forces and the required factor of safety. Recently because of the downturn in construction the market has been subject to drastic discounting. Table 1 shows costs estimated (during early 2008) on a typical project requiring 100 no. piles, based on experience. Ground conditions are taken to comprise soft to firm clay, with pile working loads of about 110kN. Nominal load testing (static and dynamic) and integrity testing (where required) are also estimated.

Table 2 summarises pile type benefits and disadvantages.

### Environmental benefits

The use of concrete in foundations is occasionally profligate. Charles (2005) in *Geotechnics for Building Professionals* gives an example where a concrete raft 1.5m thick was used to support a simple log cabin adjacent to the River Thames in Staines. A lightweight two-storey building in Essex, timber-framed and clad, is also known to have been constructed on 40 concrete piles of 22m length and 400mm diameter, where timber piles are likely to have been adequate.

There is increasing interest in sustainable development, “zero carbon” buildings and use of local materials in construction. Foundations have received relatively little attention so far. Figures quoted for the embodied CO<sub>2</sub> of timber, steel and concrete tend to vary depending on the methodology used. The figures recently quoted by the Concrete Centre (2007) for structural concrete are 372kg/m<sup>3</sup>, concrete foundations 173kg/m<sup>3</sup>, and steel 15,313kg/m<sup>3</sup>. With timber (UK forest, processed softwood) at 141kg/m<sup>3</sup>, the lower Concrete Centre figure of 173kg/m<sup>3</sup> for unreinforced concrete trench fill foundations would apply, whereas for driven-reinforced concrete piles the higher structural concrete figure is appropriate. Wood for Good (on its website) states that

Pile type	CFA	Driven precast	Driven steel	Driven timber
Assumed length and section	10m 300mm dia.	10m 200mm <sup>2</sup>	14m* 140mm dia.	10m 200mm-300mm dia.
Mobilisation	£3000	£2000	£2000	£2000
Materials and installation	£20/m	£18/m	£28/m	£9/m
Sub-total	£20,000	£18,000	£39,200	£9000
Misc. (removal of spoil, void filling etc.)	£6000	£3000	£2500	£3000 inc. concrete extensions
Testing	£2500	£1000	£1000	£1000
Project cost	£31,500	£24,000	£44,700	£15,000
Cost/m	£32/m	£24/m	£32/m	£15/m

\*Note – the assumption is made that the steel pile is driven further into firmer strata from 10m.

Table 1: Estimated piling costs

Pile Type	Advantages	Disadvantages
CFA	Minimal vibration and low noise.	Generally more expensive and slower than driven piles. Spoil disposal is expensive and can be an environmental issue if contaminated.
Driven precast	Generally cheaper, cleaner, quicker and greener than insitu methods.	Vibration and noise can be a problem (but modern hammers are much improved). Slender piles can be prone to damage during handling and driving.
Driven steel	Fast and clean. Steel is less likely to be damaged on obstructions. Easy to adapt to unforeseen soil conditions. Re-cycled steel is environmentally friendly.	Expensive.
Driven timber	Low cost. Sustainable, renewable material. Carbon sequestration. Offcuts can be used for fuel.	Lower structural capacity, but adequate for many applications. Limited service life of preservative-treated timber above the water table. Only suitable in certain ground conditions. More difficult to splice

1m<sup>3</sup> of wood sequesters 0.8 to 0.9 tonnes of CO<sub>2</sub> from the atmosphere. Clearly where unprocessed, green logs are used for piling, the figure for embodied CO<sub>2</sub> is going to be close to that value and it can be calculated that a single 12m long pile of average diameter 250mm (that is, volume 0.6m<sup>3</sup>) “contains” 500kg of CO<sub>2</sub> that will be permanently sequestered underground.

Production of a similar sized concrete pile will result in the production of about 220kg of CO<sub>2</sub>, even without consideration for the steel reinforcement. In the Netherlands a foundation system for roads and embankments, developed by GeoDelft and D. van Biezen B.V., is named “Kyoto” after the climate change protocol to emphasis the effective sequestration of carbon dioxide.

**Table 2: Pile type benefits/disadvantages**



**Figure 4: Axial load test on 4.6m log**

### Timber strength

Timber is strong in compression. In recent static load tests carried out at BRE on a 4.6m long green Sitka spruce log with an average top diameter 240mm and base 360mm; the sample withstood an axial load of 760kN before failure (Figures 4 and 5), which is about five times the design value. A second log of similar size was proof loaded to 500kN.

Although concrete is stronger in compression than timber, the load capacity of piles is very often governed by soil conditions. For example, a timber pile of 250mm average diameter and 12m length installed into soft to firm clay with an undrained shear strength of 50kPa will have the same capacity as an equivalent length 200mm<sup>2</sup> precast concrete pile, that is, an allowable working load of about 150kN. Where a continuous flight auger pile is installed, a larger diameter would be required because of the need for a higher factor of safety for insitu concrete. Some of the capacity of the concrete pile would be negated because of its own self weight, whereas for the timber pile greater capacity would be gained from its taper. In cases where piles are end-bearing on to granular soils, such as sands and gravels, overlain by weak material, such as peat, the case for timber is even better, particularly where firm strata can be reached within one log length. A value for the working end bearing of a 250mm diameter pile at 12m depth on medium-dense sand or gravel with a friction angle of 30° is about 150kN, whereas the structural capacity of the timber is evenly matched at an estimated 200kN (permissible load). Thus timber piles are suitable for many lightweight structures.

### Pile driving trials in the UK

During piling trials carried out at a site near Middlesbrough, British-grown Sitka spruce was found to be highly resilient to driving forces (Figure 6 and 7). The site comprised glacial till (firm sandy clay) overlain by 1.5m of fill. Although these ground conditions are not suited to timber piles per se, this provided a valuable opportunity to obtain experience of hard driving of timber piles and to carry out indicative dynamic load tests. The log poles (13m long with approx 250mm diameter tip) 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 before refusal. Indicative CAPWAP dynamic tests ranged from 600kN to 800kN (ultimate) for the timber piles, compared with 500kN for a 177mm diameter steel pile and 1000kN on a 250mm<sup>2</sup> precast concrete pile installed on the same site, driven to similar depths. Tests were also carried out at a site near Skipton, north Yorkshire, on the flood plain of the River Aire, where the timber piles were driven to 12m into soft alluvium to firm clay overlying glacial till. Dynamic tests gave indicative capacities of about 700kN (ultimate). At the same site 250mm<sup>2</sup> precast concrete piles achieved similar capacities at the same depth, but were driven further into the till to achieve capacities up to 1100kN.

### Conclusion

Timber piling is widely used around the world, but seldom considered as an alternative to steel and concrete despite greater interest in sustainable construction.

Although untreated timber piles installed below the water table can last hundreds of years, there is no long term experience with UK grown conifer species, nor is there an existing supply chain for bespoke graded or preservative treated pilings. Around 200,000 untreated timber piles are used annually in The Netherlands, driven below the water table and extended to the surface using short concrete extensions. Suitable ground conditions exist in many parts of the UK. Britain also has an extensive forest resource. Timber piling is a viable, low cost and sustainable alternative to steel and concrete, with the potential to be used for many projects.

### Acknowledgements

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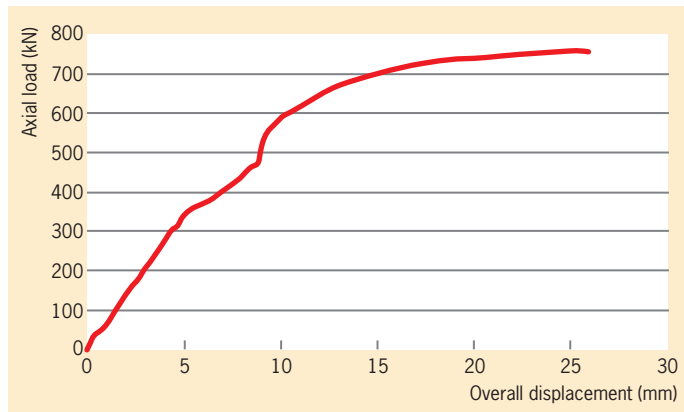


Figure 5: Axial load test results



Figure 6: Pile driving trials at a site near Middlesbrough

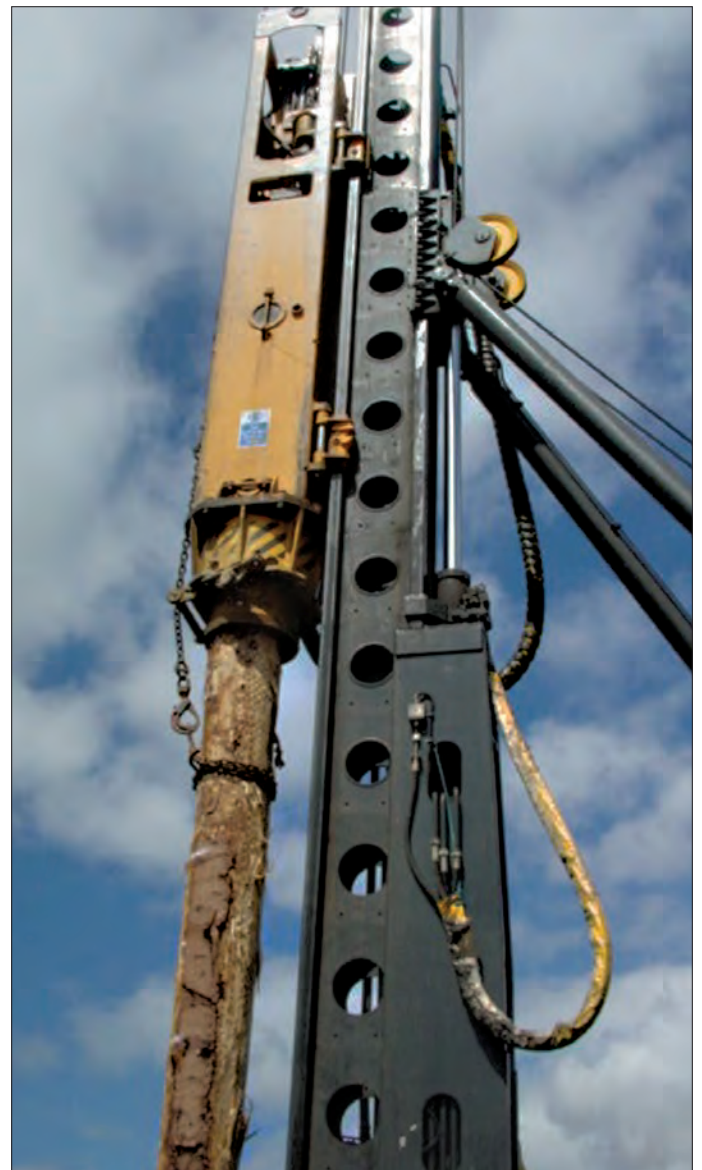


Figure 7: Pile driving trials at a site near Middlesbrough