

The Potential for Timber Piling in The UK For Ground Engineering

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Abstract

There is increased interest in the use of sustainable materials in construction. Timber piles are widely used in the United States, Canada and Australia but very rarely used onshore in the UK. Although untreated timber piles installed below the water table can last hundreds of years, there is little experience with UK 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 United States, Canada and Australia. In Canada alone over 30,000m³ of preservative treated wood piles are used annually whilst around 500,000 timber piles are used per year throughout the United States. These countries tend to have large resources of timber which 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 30 tonne 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 130,000 m³ of concrete and 18,000 tonnes of steel. Timber piles with 70 tonne design 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 Holland timber piles are used below the water table, and extended to the surface using concrete sections. In the, UK however, timber piles are not currently used onshore for the support of buildings.

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 "guarantees" of only 15 to 30 years. Creosote is still available for industrial applications such a 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 around 75 years, and creosoted piles capped with concrete are expected to last well over 100 years.

An obvious starting point for preservative treated timber pilings, are telegraph poles which are produced at two main plants in the UK, usually from imported Scots pine. A variety of sizes are available from 6m (150mm top diameter) to 24m (470mm top diameter), with the typical prices of medium sized 10m pole of £130. This basic price is close to the cost of pre-cast concrete. The requirements for the straightness of

telegraph poles are, however, likely to be well in excess of those for piling. Log poles of much lower quality could potentially be used for piles. A ball park figure for preservative treatment by creosote is £75 per cubic metre, but this would require debarked, seasoned logs.

Use of untreated timber pilings

Around 200,000 log poles are used annually in the Netherlands for projects such as greenhouses, light industrial buildings, houses, embankments and roads. Pile lengths vary from 5.0m 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. 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. 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 that is actively controlled.

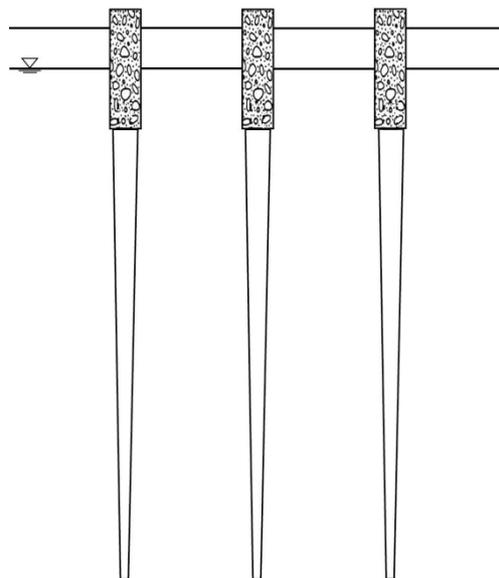


Figure 1: Timber piles with concrete extensions



Figure 2: Timber piles with concrete extensions being installed for a water tank (photo courtesy of D. van Biezen B.V.)



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. (photo courtesy of D. van Biezen B.V.)

UK geology

In the UK areas of soft ground include the floodplain deposits of the 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. On the marshes of Dartmouth, for example, there is typically 12m of peat over gravel terraces. At Bothknennar 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 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.

Costs

The UK has a large forest resource of conifers such as Douglas fir, larch, Norway spruce and Sitka spruce. The basic price of Sitka spruce sawlogs is around £40 per m³, with Douglas fir and larch at £70 per m³ and £105 per m³ respectively. These prices are more geared to sawmill processing. Prices quoted for “log poles” in the UK can vary widely, for example 9m lengths of Douglas fir (at 300mm minimum diameter) can be obtained for £70 per piece. Sitka spruce log poles of 13m length can be obtained for £40 per piece. At around £3 per metre this compares favourably with the cost of a 200mm square pre-cast concrete pile, typically £10 per m. Steel piling is much more expensive. Recently it has become much more difficult to obtain ex-oil production material for re-use, and there is also a high demand for steel as a result of 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, 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 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).

Piling costs in the UK vary considerably depending upon soil conditions, geographical location, size of the project and market forces. Table 1 shows estimated costs based on a typical project comprising 100 no. 200kN capacity piles with nominal load testing (static and dynamic) and 100% integrity testing (where applicable).

Pile Type	CFA	Driven Precast	Driven Steel	Driven Timber
Assumed length and section	10m 300mm dia.	9m 200mm sq.	12m 140mm dia.	9m 200-300mm dia.
Mobilisation	£3,000	£2,000	£2,000	£2,000
Testing	£3,000	£1,000	£1,000	£1,000
Materials and installation	£18/m £18,000	£16/m £15,000	£27/m £35,000 inc infilling void	£11/m plus £30 per concrete extension £13,000
Misc. (cutting down, removal of spoil, etc.)	£6,000	£3,000	negligible	negligible
Project cost	£30,000	£21,000	£38,000	£16,000
Cost per metre	£30/m	£23/m	£32/m	£18/m

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 be an environmental issue, especially 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. Longer lengths tended to be needed for the same capacity.
Driven Timber	Low cost. Sustainable, renewable material. Carbon capture.	Lower capacity, but adequate for many applications. Limited service life of preservative treated timber above the water table. Off cuts can be used for fuel.

Table 2: Pile type benefits/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, 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 40 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. Foundations have received relatively little

attention so far. Figures quoted for the embodied CO₂ of timber, steel and concrete tend to vary depending on the methodology used in their determination. The figures recently quoted by the Concrete Centre (2007) for structural concrete are 372 kg/m³, concrete foundations 173 kg/m³, and steel 15,313 kg/m³, with timber (UK forest, processed softwood) at 141 kg/m³. The lower Concrete Centre figure of 173 kg/m³ 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 1m³ of wood sequesters 0.8 to 0.9 tonnes of CO₂ from the atmosphere. Clearly where unprocessed, green logs are used for piling the figure for embodied CO₂ 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 0.6m³) “contains” 500kg of CO₂ that will be permanently sequestered underground. Production of a similar sized concrete pile will result in the production of around 220kg of CO₂. In Holland a foundation system for roads and embankments, developed by GeoDelft and D. van Biezen B.V., is named after “Kyoto” to emphasis the effective sequestration of carbon dioxide.

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 around 5 times the design value. A second log of similar size was proof loaded to 500kN.



Figure 4: Axial load test on 4.6m log

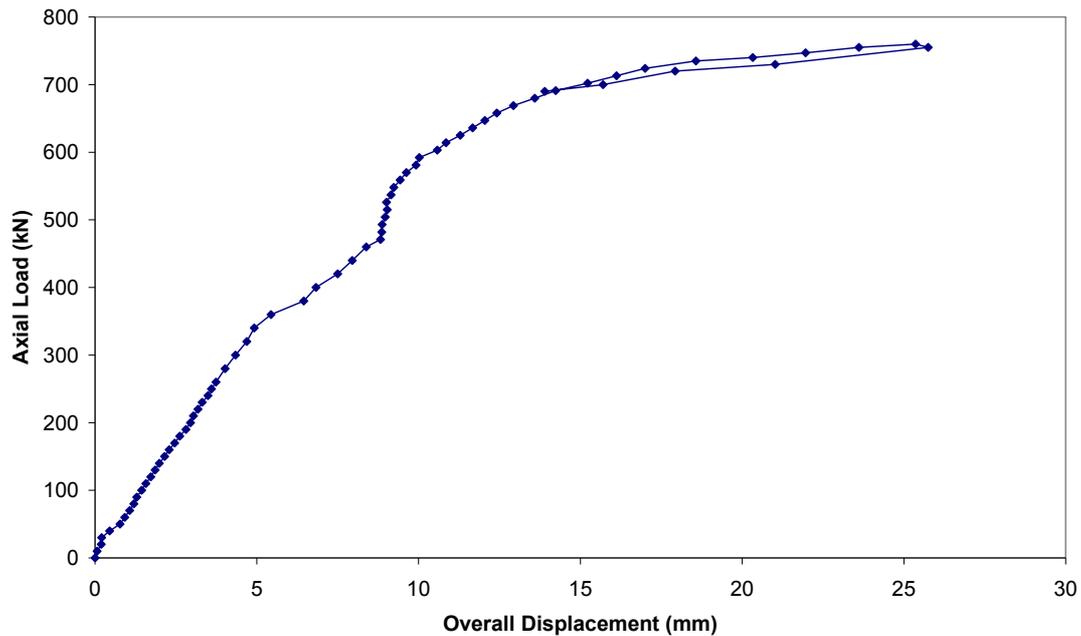


Figure 5: Axial load test results

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 50 kPa will have the same capacity as an equivalent length 200mm square precast concrete pile, ie an allowable working load of around 150 kN. Where a CFA pile is installed, a larger diameter would be required due to the need for a higher factor of safety for insitu concrete. Some of the capacity of the concrete pile would be negated due to its own self weight, whereas for the timber pile greater capacity would be gained from its taper. 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 better, particularly where firm strata can be reached within one log length without splicing. 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 degrees is around 150kN, whereas the structural capacity of the timber is evenly matched at around 200kN. 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 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 600 to 800kN (ultimate) for the timber piles, compared with 500kN for a 177mm diameter

steel pile and 1000kN on a 250mm square precast concrete pile installed on the same site.



Figure 6: Pile driving trials at a site near Middlesbrough

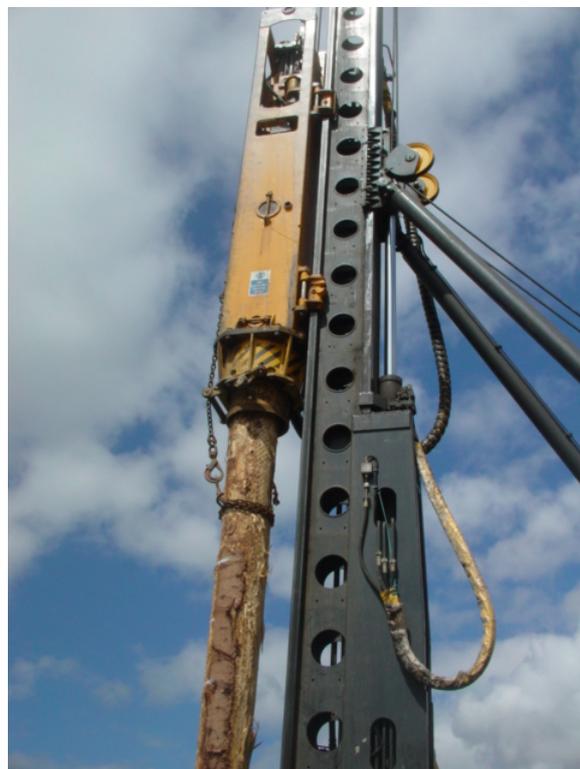


Figure 7: Pile driving trials at a site near Middlesbrough

Tests were also carried out at a site near Skipton 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 around 700kN (ultimate). At the same site 250mm square 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 little experience with UK species of timber, 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 an entirely viable, low cost and sustainable alternative to steel and concrete, with the potential to be used for many projects.

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