BRE

digest

Timber piles and foundations

Digest 479

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Timber is a hugely capable civil engineering material, with the additional advantage of being sustainable. Trees, in particular conifers, make natural piles. Timber foundations may be particularly suitable for countryside structures such as bridges, forest chalets and activity centres, as well as post-and-beam timber buildings in waterfront or flood prone locations. Home grown treated softwood and hardwood timber can offer alternatives to imported tropical hardwoods.
This Digest gives information on the design and installation of timber piling, its history and background, suitable timber species and preservative treatment.

Installing timber piles for beach protection (Photograph courtesy of Aarsleff Piling)

Although timber piles are rarely used on shore in the UK, in other countries notably the United States, Canada and Australia, they are used widely. For many structures, timber piles are a highly suitable choice of foundation, given appropriate ground conditions. They are economical, easy to transport, handle, cut to length and work with on site; and particularly suited for locations with access difficulties, or where excavations and the delivery of concrete would pose problems.

Short, driven timber piles can be the solution for foundations in ground with a high water table, and where firm strata exists below surface material of loose sand, soft clays, or organic soils. In deep silt deposits, where the capacity of the pile is determined by shaft friction, timber piles are especially suitable being tapered and easy to splice. In Sweden and the Netherlands, timber piles are used below the water table, where they have proved practically invulnerable to decay, and extended to the surface using concrete sections. They are resistant to acidic and alkaline soils, and soils with high sulphate or free carbon dioxide content. Timber piles can also be driven for ground improvement, to densify loose granular soils.

Preservative treated softwood or durable hardwood timber can be used for the construction of retaining walls, bank seats, and for foundation pads and footings. Recent advances in the development of cost effective wood modification and timber treatment processes will allow much greater use to be made of timber species which are either non-durable or difficult to impregnate. Polymer encasement may be used in conjunction with environmentally friendly preservatives to protect timber.

One of the suggested methods of reducing global warming has been to bury timber to create carbon dumps. Using timber for piled foundations would effectively achieve this.

Forestry Commission

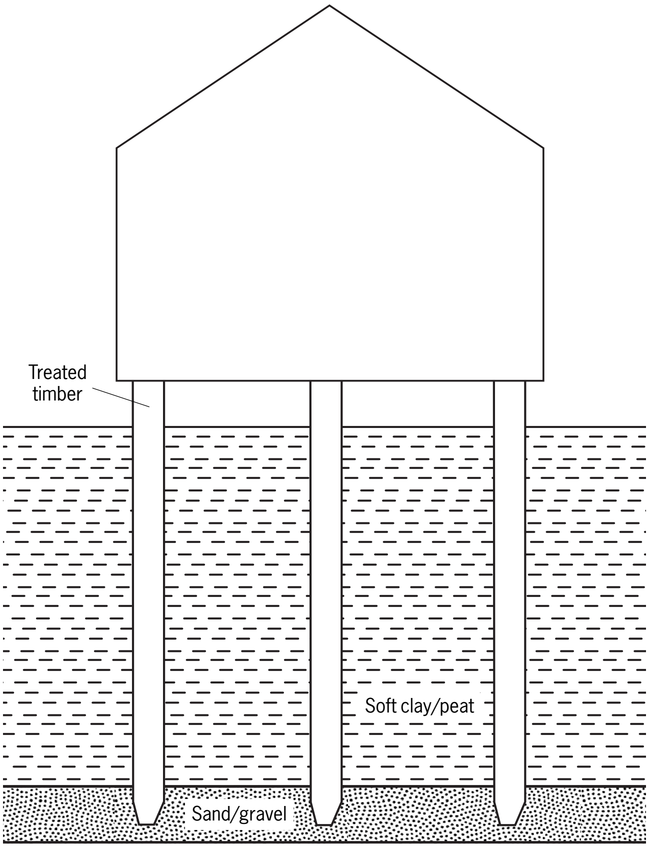

Figure 1 End bearing piles

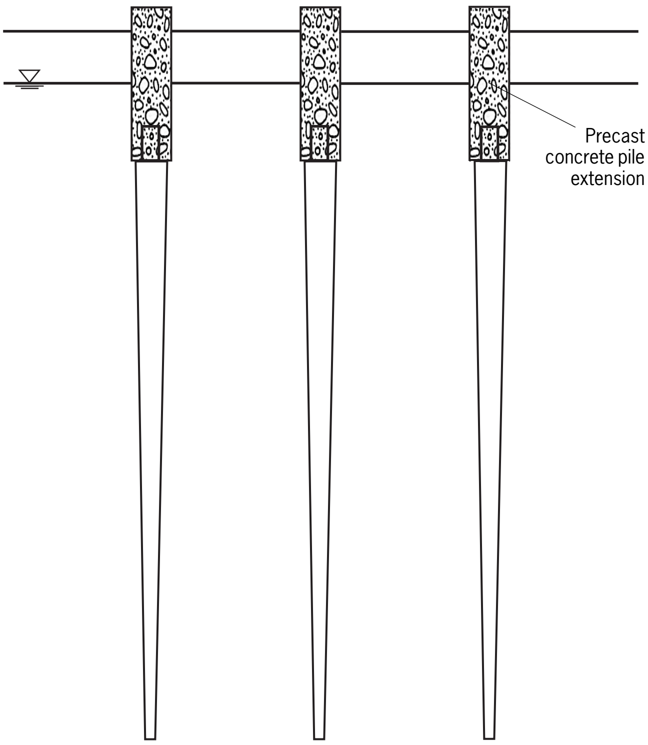

Figure 2 Tapered untreated timber friction piles

History and current use

Timber has been used for piled foundations for centuries (AWPI, 2002). Before 1900 nearly all piles were either untreated wood or stone. Old London Bridge was founded in 1176 on stone filled starlings constructed from elm piles which lasted 600 years (Nash, 1981). The city of Louisiana is founded on timber piles; so too are the Pont Notredame bridge in Paris, the Royal Palace in Amsterdam, the National Theatre of Finland, the Dome of Utrecht and the Reichstag in Berlin.

The Brooklyn Bridge rests on 15-foot-thick yellow pine pneumatic caissons with a design load of 80 000 tons (McCullough, 1972). These immense foundations were each the size of four tennis courts and weighed 3000 tons. In 1902 the Campanile Tower in Venice was rebuilt on 1,000-year-old piles, still in excellent condition, which supported the original structure (Haldeman, 1982). At Tobacco Dock in London, 160-year-old Scots pine piles were recently re-used to support a new shopping and leisure complex (Mitchell *et al*, 1999).

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 210 m diameter Louisiana Superdome supporting 130 000 m^3 of concrete and 18 000 tonnes of steel. Timber piles with 70 tonne design loads have been used for a 300 m long viaduct near Winnemuca, Nevada. In Canada over 30 000 m^3 of treated wood piles are used annually. Most of the deep foundation support for highway bridges in North America comprise treated timber piles. 500,000 timber piles are used per year throughout the United States. The US Army Corps of Engineers used over six million timber piles to construct the locks and dams for the Inland Waterway System. UK on-shore usage of timber as a foundation material is somewhat limited, with few examples. At Barnes Waterside a bat sanctuary was built on timber piles, and at the Stoke Gardens Festival site a timber footbridge is similarly supported. The primary use of timber piles in the UK is marine: for the refurbishment of piers and groynes, and as fenders.

Information on the availability of Certified timber can be obtained from the Forest Stewardship Council (FSC). Specifiers and users of timber, in particular tropical hardwoods, need to be aware of the Convention on Internal Trade in Endangered Species of Wild Fauna and Flora (CITES), and can obtain information on sustainable and legal sources of timber from organisations such as Greenpeace.

Durability of timber piles

Untreated timber piles, when driven below the water table, are virtually immune to biological degradation. Timber piles have been recovered from the remains of Roman and medieval constructions in a state of perfect preservation. The section of an untreated pile above ground water level is, however, vulnerable to decay and one option is to terminate the pile below the water table and continue the foundations in a different material such as concrete. In the past this was accomplished with stone or masonry. The timber piles of historic buildings may decay if the local water table is lowered below the tops of the piles for long periods, either by abstraction or drainage. Both York Minster and the Mansion House in London were originally built in marshy ground on timber foundations which subsequently degraded due to drainage. Boutelje and Bravery (1968) report on similar problems with buildings in Stockholm. In central Europe, untreated species of non-durable softwoods (eg Scots pine and Norway spruce) were formerly used extensively. Below the water table, sapwood (the outer layer of a log) can be subject to slow biodegradation by anaerobic bacteria. Preservative treated timber piles, cut off below ground level and capped with concrete, are expected to have lifespans in excess of 100 years. The expected service life of a treated timber trestle pile is about 60 years in fresh water in the UK.

Timber piles are highly resistant to both acid and alkaline soil conditions. At the Ulan coal mine in Australia, treated hardwood timber piles (each with a load capacity of 80 tonnes) were chosen for a bridge carrying ore trucks because the high free carbon dioxide levels and extreme acidity in the soil would have destroyed both steel and concrete piles. Timber piles were also used for the foundations of the Brambles Container Terminal in Burnie, Tasmania (soil pH 11.5), and the Auburn, NSW, Waste Transfer Station (soil pH 2.5).

Traditional timber species and treatments

In the United Kingdom, Douglas fir in sections up to 400 mm square and 15 m long is the most common softwood used for piles (BS 8004). Pitch pine is also available in sections up to 500 mm square. Formerly greenheart was the hardwood most commonly used, imported rough-hewn in sections up to 475 mm square and up to 24 m long. Other suitable tropical hardwoods given in BS 8004 include ekki, jarrah and opepe. In the past, UK grown hardwoods such as oak, beech, ash and sweet chestnut have been used for piles. Elm is also durable below ground; so much so that it was used for water pipes and coffins. The Rialto in Venice is supported on alder piles. In Scandinavia and Central Europe, Norway spruce, Scots pine and, to a lesser degree, fir and larch have historically been used (Peek and Willeitner, 1981). In the US and Canada, southern pine is used extensively as well as larch, red oak, lodgepole pine, western red cedar and Douglas fir.

Pressure injection of coal-tar creosote began in England in 1838. Following the use of pressure impregnated railway sleepers (railroad ties) in the United States the process was first applied to foundation pilings in the early 1880's. Today, pressure impregnation of creosote or copper-chrome-arsenic (CCA) are the two main types of chemical wood preservation applied to timber used for piles. Some species of hardwoods and most softwoods can be treated by chemical impregnation, although spruce and hemlock are difficult to treat. The preservatives are applied during a high pressure/vacuum process. In the case of CCA preservative, which is water-borne, the chromium acts as an oxidising agent and the metals become highly fixed into the wood structure. The timber is dried before application of CCA under high pressure/vacuum process and allowed to dry again for between 7 to 14 days during which fixation occurs. Pressure cylinders of up to 25 m length are available. Ammoniacal copper-zinc-arsenate (AZCA) is an alkaline preservative system which was developed, in particular, for difficult-to-treat wood species.

Creosote is a complex mixture of over 300 substances derived from the distillation of coal tar, and is a very long serving and effective wood preservative which has low water solubility and is biodegradable when dispersed in soil. There are many instances of creosoted timber structures and wood piles still giving good service after 100 years of ground contact. Although fresh creosote will burn the skin, requiring gloves to be worn during handling of treated lumber, it is not a systemic poison. Freshly creosoted timbers may cause the formation of an oil sheen in contact with water. There are two forms of creosote treatment, full cell and empty cell. In the full cell process, all the available voids in the wood structure are filled as far as possible with creosote by first applying a vacuum to the timber, then flooding the pressure cylinder with preservative. After the vacuum is released atmospheric pressure forces the creosote deep into the structure. Further application of pressure after this stage achieves even greater penetration. At the end of the cycle, a second short period under vacuum is applied to withdraw a small amount of preservative from the surface of the timber leaving it dry and in a reasonable state for handling. In the empty cell process, a longer period under vacuum is applied to remove a greater amount of preservative, leaving the voids in the wood only partly filled but with the internal walls of the wood cells coated. Although creosote is used undiluted with solvents, freshly treated timber is normally allowed to dry for up to 7 days to allow the more volatile components to evaporate. Creosoted timber is particularly suited for acid sulphate soils which can have serious effects on both steel and concrete piles. CCA preservative treatment is affected by dilute acids but unaffected by alkaline groundwater.

For softwood timber piles, logs selected with a thick sapwood layer which absorbs preservative treatment better than heartwood is beneficial since this provides a thick protective layer of well impregnated material. Spikes and hooks should not be used to handle treated timber piles since these may expose less well protected wood. All sawn ends and drill holes should be liberally applied with preservative. For untreated hardwoods the vulnerable sapwood is removed and the timber normally supplied squared off.

Natural durability of timber and resistance to preservative treatment

BRE Digest 429 gives the natural durability classifications of a large number of species, together with their (unmodified) resistance to preservative treatment. Table 1 (below) shows values for some common species, suitable for pilings in non-marine situations. It should be noted that the natural durability ratings relate only to UK conditions, to heartwood, and to fungal attack.

Table 1 Timber species in ground contact or freshwater use in UK (non marine)

Timber species	Natural durability of heartwood	Treatability of heartwood	Treatability of sapwood
Greenheart	Very durable	Extremely resistant	Moderately resistant
Oak (European)	Very durable	Extremely resistant	Permeable
Elm	Non durable	Resistant	Permeable
Douglas fir	Non durable	Resistant	Permeable
Scots pine	Non durable	Moderately resistant	Permeable
Larch	Moderately durable	Resistant	Moderately resistant

Alternative preservative treatments

Creosote has been withdrawn by European Union member states from use in the DIY market (Directive 2001/90/EC, effective from 30th June 2003) but can still be used for industrial applications such as telegraph poles, sleepers, bridges and piles. Restricted uses include playground equipment and applications where there is a risk of frequent skin contact. A similar situation exists with CCA. Users and specifiers of treated timber should refer to BS 8417 and to the British Wood Preserving and Damp-proofing Association for further guidance. Both creosote and CCA treated timber have a good environmental and safety record, but are being phased out for some applications because more benign preservative systems are available.

Many preservative products have been developed over the last 10 years that aim to provide alternatives to creosote or arsenic based preservatives, such as copper-chrome-boron or tebunconazole. Copper compounds are very effective in protecting timber from biological degradation. At the Falun Copper Mine in Sweden, large diameter softwood poles drenched in aqueous copper, some of which are over 400 years old, form cribs and shaft lining. (At 208 m high, this shaft lining was once the tallest wooden structure in Europe.)

Figure 3 Irish grown Sitka spruce logs being used for pilings (Photographs courtesy of P.Quigley/NUI)

Suitability of UK grown timber for pilings

A number of UK timbers are suitable for on-shore pilings and marine usage: Douglas fir, Scots pine, larch, oak and elm. In general, these will be more suitable for installation below the water table on shore unless, in the case of softwoods, they are preservative treated. Douglas fir is available in large sections up to 500 mm square and 12 m long. Other softwoods and UK grown oak can also give very useful service lives out of salt water.

UK grown Douglas fir piles in 300 mm square section have been installed as fenders at Scarborough Harbour. UK Douglas fir was also used in conjunction with ekki for part of the superstructure of Queen's Wharf at Falmouth Docks, together with basralocus driven fenders. Oak tree trunks have been used, buried below beach deposits, as land ties or struts in combination with tropical timber piles to form groynes. Scots pine is also available in large section sizes and lengths. Irish Sitka spruce has been used in trials to construct embankments and foundations suitable for roads, car parks and industrial floors (Rogers and Quigley, 2001). The current basic price of UK grown Sitka spruce sawlogs is around £38/m^3 which compares favourably with concrete. (UK forest production rates are also set to double over the next 10 years.) In the case of timber piles which are driven below the water table there is no need for kiln drying or preservative treatment. Timbers classed as perishable in Digest 429, but which are suitable for use as submerged piles, also include beech and sycamore; both of these are comparable in strength to oak. Untreated Scots pine is not suitable because of the large amount of sapwood in the log.

Wood modification

The principal problem with the application of liquid preservative treatments to timber is the poor penetration into the wood structure of certain species, even under cycles of alternate vacuum and pressure. Impregnation can be improved by mechanical incising of timber, but this is limited to the outer 5 to 10 mm only. Microwave modification of wood (Vinden and Torgovnikov, 2003) offers the ability to open up the cellular structure of wood with only nominal and manageable levels of strength reduction. This allows, for instance, timbers with poor permeability such as Sitka spruce and the heartwood of Douglas fir to be cost effectively processed with much higher levels of impregnation to both sapwood and heartwood. The level of preservative retention in the heartwood of Douglas fir can be increased from around 60 litres/m^3 to around 400 litres/m^3. In addition timber may also be modified by polymer impregnation to produce a wood polymer composite, which can give a softwood all the mechanical properties of a tropical hardwood. Wood modification will allow greater use to be made of softwood timber, for applications such as piles and marine timber, where previously only tropical hardwoods had the necessary properties.

Marine structures

Timber has been long favoured for marine works because of its ability to absorb impacts, its ease of handling over water, and the poor performance, historically, of other materials such as reinforced concrete and iron. Timber is used for groynes and sea defence works as well as jetties, dolphins, fender piling and rubbing strips.

In seawater and brackish estuary waters around the British Isles untreated timbers are liable to attack by marine borers – principally the mollusc Teredo (shipworm) and crustacean Limnoria (gribble). Teredo bores circular tunnels up to 15 mm in diameter and up to 150 mm long horizontally and vertically in timbers leading, ultimately, to severe weakening. Occasionally Teredo damage is observed in timbers which have been floated in marine waters prior to sawing, the damage being characterised by lack of bore dust and the chalky white calcareous tunnel linings (Desch and Dinwoodie, 1981). Limnoria creates shallow tunnels approximately 2.5 mm in diameter and penetrating less than 15 mm in depth, the extensive nature of which leads to erosion. Another crustacean, Chelura, is associated with attack by Limnoria, but cannot by itself burrow very far into timber.

The Sea Action Committee of the Institution of Civil Engineers (ICE, 1947) found Limnoria and Chelura to be active in British waters, with Teredo active south of the

Figure 4 Marine borer attack of an 120 year old greenheart pile

Mersey and Humber. Greenheart, kauri and jarrah were found very resistant to marine borers, while oak and untreated softwoods were not resistant. Borer attack was found to be limited in polluted water such as in docks, although this observation may not be relevant nowadays. Greenheart was found to be in excellent condition after 60 years service in Liverpool, and similarly Danzig fir after 52 years service in the Thames at Northfleet. Creosoted Baltic pine (ie slower grown Scots pine) was recommended for British ports on the grounds of its useful economic life. Other suitable softwoods include Douglas fir, Western hemlock and European larch. BRE's *Handbook of hardwoods* lists a number of tropical hardwoods recognised as being resistant to marine borers such as basralocus, belian, okan, and the Australian hardwoods jarrah, ironbark, southern blue gum and turpentine; the latter is particularly long favoured. Currently there are no Forest Stewardship Council approved sources of greenheart or ekki, although possible alternatives include acariquara and purpleheart. Even the most durable timber species are not permanently immune to marine borer attack (Eaton and Cragg, 1995).

In tropical waters untreated timber piles of non-durable species can have a useful service life of only a few months. In Australia, for example, combined treatment of softwoods with CCA and creosote has been found very effective. Hardwoods, such as turpentine, also benefit greatly from the provision of an outer barrier layer of treated timber. Large section timbers of species which are difficult to impregnate should be incised before impregnation. CCA treated timber is currently under review by the EU for usage in the marine environment. However, copper-chrome-boron wood preservative has been found equally effective in combating marine borers (Eaton, 1989), although the boron, being water soluble, is rapidly leached. BS 3452 (although withdrawn) specified retentions for copper-chrome (CC) treated timber used in seawater.

Marine timber piles may also be protected from borers by wrapping with PVC or polyethylene, sometimes in combination with bitumen based tape. Steiger and Horeczko (1982) reported on the performance of timber piles wrapped in heat shrunk polyethylene in the Port of Los Angeles. Fibre reinforced polymer materials are also suitable for sheathing timber piles. Naturally it is not necessary to sheath the part of a pile which is below the sea bed or above high water. The principal problem with all forms of pile sheathing is damage from boat impact; these protection systems will also not be suitable where high abrasion resistance from scour is required.

Abrasion resistance

Abrasion resistance to scour and spillover is an important design consideration for marine structures such as sea defences and groynes, particularly on shingle beaches. Timber can, in certain circumstances, withstand wear in the marine environment better than either steel or reinforced concrete, with tropical hardwoods being particularly resistant. Dense softwoods with well developed latewood in the growth rings such as Douglas fir and pitch pine perform as well as hardwoods (Oliver, 1974). English oak also has good abrasion resistance. Timber structures can be protected from scour simply by providing a sacrificial layer of planking.

Figure 5 Timber pile driving (Photograph courtesy of Kardon Piling)

Pile driving and design

Timber piles support loads by end bearing, shaft friction or combined end bearing and friction depending on the nature of the strata into which they are inserted. Most timber piles are displacement piles, although occasionally they are installed into pre-augered holes and set in concrete sockets. Timber piles are not suitable for driving through firm strata such as dense sand or gravel. Timber can be used as end bearing piles on rock, provided care is taken to avoid damaging the pile during insertion. Tapered timber piles are particularly suited for use as friction piles in sands, silts and soft clays where the pile capacity is determined by shaft friction. Driven thin end down, trees make natural tapered piles. From a comparative study Blanchet *et al* (1980) found that log taper doubled the shaft friction.

Timber is resilient to impacts and drives well. A helmet or cap protects the pile head from fracturing or brooming during insertion, and in addition the pile may be banded to prevent splitting. Conventional pile drivers are used to insert timber piles with the normal weight of a drop hammer being 1.5 times the weight of the pile. Typically for softwood piles a 0.5 tonne hammer is used, whereas for hardwood piles the hammer weights vary from 1 to 4 tonnes with a drop height not greater than 1.5 m (Maling, 2003). A long narrow drop hammer increases the chance that the pile is hit axially, avoiding damage to the pile and maximising the downward impulse. Diesel hammers are sometimes used for driving hardwood piles in stiff soils, but are not suitable for softwoods. Care must be taken with all hammers not to overstress the pile or to cause splitting of the pile toe. The *Canadian foundation engineering manual* (Canadian Geotechnical Society1992) gives the maximum hammer rated energy for softwood piles at 160 000 J times the pile head diameter. A low-velocity hammer should be used in combination with a soft cushion in the capblock. Driving is stopped when high resistance is encountered. All types of pile, including those made from steel and concrete, can be damaged by hard driving in an attempt to meet a prescribed set. This is usually avoided by adequate site investigation and realistic geotechnical design. Where there is a surface layer of hard fill a pre-bore may be performed using an auger rig. Timber piles can also be inserted using vibratory methods, hydraulically ‘pushed’, or jetted into sandy soil using compressed air or water which can be quick in operation and avoids damaging the pile. In peat, timber piles can even be driven manually (Orr and McEnaney, 1994)

Groups of timber piles inserted into soft clays and silts may need to be loaded temporally to prevent the effect on soil pore water pressures causing buoyancy. Timber piles can be extended in length by splicing, using short sections of steel tube, angle or plates, to reach load bearing strata or to develop sufficient shaft friction. Timber piles can also be coupled to concrete or steel sections to avoid exposure above the water table.

Timber has a high strength to weight ratio, and is particularly strong in compression parallel to grain. According to BS 8004, the timber selected for piles should be straight grained and free from defects; in general, suitable sawn material is obtained from SS (Special Structural) grades. The centreline of a sawn pile should not deviate by more than 25 mm throughout its length; for round piles a deviation of up to 25 mm on a 6 m chord may be permitted. However, for non-critical applications and where hard driving is not required, lower grades of material may be acceptable.

Piles are designed as columns, and consideration should be given to cross-bracing for unsupported lengths above ground level. Typical axial design loads are in the range 100 to 500 kN for softwood piles. Hardwoods piles are normally used for marine applications where either marine borer or high abrasion resistance is required. BS 5268 may be used to calculate the axial capacity of timber piles, including those which extend above ground level. Failure in buckling should be also considered for the pile section in weak soils with an undrained shear strength of less than 15 kPa (eg peat and soft clay).

Table 2 gives values of grade stress in compression parallel to grain for some commonly available UK species. For example, UK grown Douglas fir of SS grade can support an unfactored permissible design stress of 6.6 N/mm^2 in compression parallel to grain. For a long term load the modification factor for duration of loading K_3 is 1.0; however for wet exposure conditions the modification factor K_2 equivalent to 0.6 should be used. For a 250 mm square section pile, this results in an overall value for permissible load of around 250 kN. The alternative Eurocode 5 (DD ENV 1995-1-1) limit state design approach uses characteristic values for the strength classes of timber given in EN 338. GS (General Structural) and SS grades refer to sawn timber and that there are no formal visual grading rules currently applicable to roundwood piles (although grading rules for transmission poles exist). On the basis of test work (Lavers, 1983) which resulted in a mean value of 16.1 N/mm^2 in compression parallel to grain (green strength) being obtained, most UK grown Sitka spruce could be expected to meet the GS grade value in this respect.

Similar methods exist for calculating the load carrying capacity of timber piles to those of steel and concrete,

Table 2 UK grown timber species and BS 5268 grade stresses for compression parallel to grain

Timber species	Grade†	Permissible stress (N/mm^2)‡
Douglas fir	SS	6.6
	GS	5.2
Larch	SS	7.9
	GS	6.8
Scots pine	SS	7.5
	GS	6.1
Sitka spruce	SS	6.1
	GS	5.2
Oak	THA	10.5
	THB	9.0

† SS = Special Structural; GS = General Structural; TH = Temperate Hardwood

‡ Service Class 1 and 2 (apply factor 0.6 for wet exposure)

including those based on dynamic pile driving formulae. In the US, in particular, the traditional method of pile installation involved the Engineering News Formula where the number of hammer blows per last foot driven equalled the number of tons of design capacity, depending on the rated energy of the hammer. This formula has been superseded by more rigorous techniques (such as those based on wave equation analysis) and is now only used for on-site indicative assessment. Typically, for static pile design based on the undrained shear strength of soil, a friction coefficient or adhesion factor (α) of 1.0 is used for straight driven piles and 1.2 for tapered piles. Pile design may also be based on in situ testing such as the Standard Penetration Test (SPT) or Cone Penetrometer Test (CPT). Load testing and re-drive tests should be carried out to verify pile capacities. Further guidance, including appropriate factors of safety for foundation design are given in Eurocode 7 (DD ENV 1997-1). The American Wood Preservers Institute (2002) and Canadian Wood Council (1991) also give guidance and design examples for using timber piles, both axially and laterally loaded.

J W G van de Kuilen gives in *Timber engineering STEP 2* (Blass *et al*, 1995) a useful description of the application of timber piles, with design examples to Eurocode 5 and a note on the Dutch quality requirements for timber.

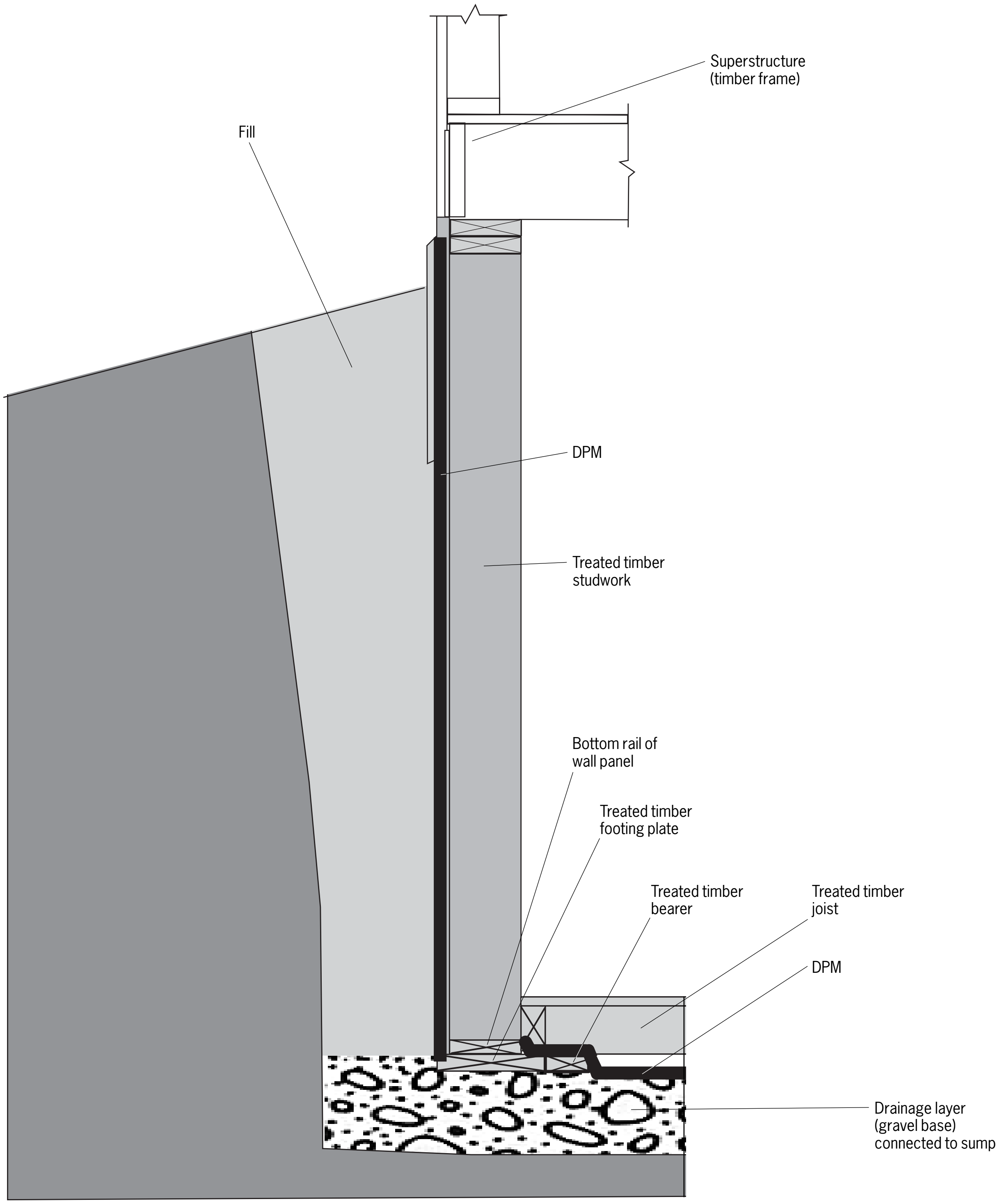

Figure 6 Permanent Wood Foundation system for a basement (after Canadian Wood Council, 1997)

Other geotechnical uses for timber

Timber is a natural and attractive material that can be used for earth retaining structures such as bridge abutments and crib walls. It can be easily combined with soil anchors and geotextiles in the same way as concrete or steel. Round timber and sheet piles can provide an economical wall for moderate heights of retained material. Examples of interlocking timber sheet piles are given in BS 6349-2. *STEP 2* by C Short (Blass *et al*, 1995) contains design examples for timber retaining walls.

Further demonstration of the suitability of treated timber as foundation material is provided by the Permanent Wood Foundation. The PWF system (Canadian Wood Council, 1997) is a lightweight, loadbearing, wood frame foundation for housing and commercial premises (Figure 6). Its use dates back to 1967 in Alberta, Canada. Preservative treated timber is laid directly onto a granular drainage layer 300 mm deep. This drainage layer prevents hydrostatic pressure building up against the foundations, and allows timber framed basements to be constructed in suitable locations. All connectors are corrosion resistant. A polyethylene moisture barrier (DPM) extends over the outside of the walls below ground level terminating at the top of the drainage layer. A separate moisture barrier is placed under the floor of the basement – usually a suspended timber floor.

Stanchions and columns can be founded on footings comprising two layers of nailed treated timber running at 90° to each other (Figure 7). The timber footing is laid on a thin layer of sand over undisturbed soil. A steel plate placed over the top of the footing helps to transfer the load from the column over the timber bearers. The principal advantages of these treated timber foundations are that they are economical, quickly placed, require less plant and, unlike concrete, do not need measures to protect them from freezing during curing. Timber foundations make excellent use of material that is often locally produced and renewable. They can also take the form of embedded poles with concrete pads and collars.

Examples of simple wood foundations for footbridges and countryside structures are given by Jayanetti (1990). Figure 8 shows a timber bank seat. Footbridges can also be supported by timber piers (Figure 9).

Some use is made of hazel, chestnut and willow brushwood faggots for bank stabilization and drainage on waterways. Reclaimed railway sleepers are also used as economical foundations for lightweight prefabricated modular buildings such as schools, and in landscaping.

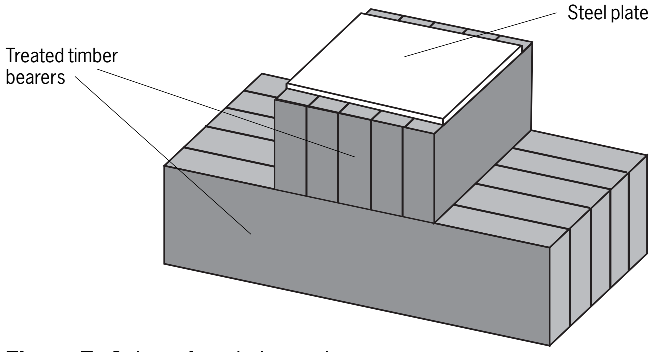

Figure 7 Column foundation pad (after Canadian Wood Council, 1997)

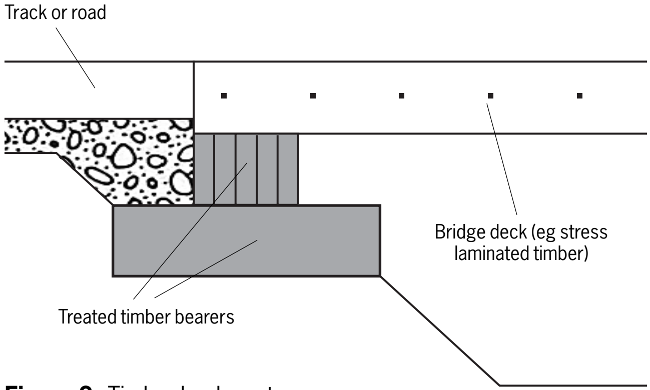

Figure 8 Timber bank seat

Figure 9 Footbridge at Garpenburg, Sweden, with timber foundation piers

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