

Design of timber groynes

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Abstract

The performance and durability of timber groynes (or ‘groins’) is highly dependent on the design and detailing of the structure. Using knowledge and experience developed over generations an effective functional design can be achieved, which may ultimately result in lower whole life costs and provide environmental advantages over alternative materials.

Introduction

Timber groynes have historically been used in large numbers, but the adoption of alternative materials such as rock has led to a decline in the use of traditional timber structures. Nevertheless timber groynes can provide substantial advantages over other forms of groynes or alternative beach control structures. These include the ease with which the level and profile of the groyne may be adapted (by adding or removing planks) or maintained, and their appearance and small footprint are particularly advantageous on amenity beaches. The use of relatively small volumes of renewable materials, may also offer lower whole life costs and environmental advantages over alternative materials such as rock, steel and concrete (Crossman & Simm, 2002). The performance and durability of timber groynes is highly dependent on the design and detailing of the structure and there is concern that with fewer timber groynes being used, knowledge and experience developed over generations may be lost. This paper describes experience and established best practice from a number of sources, and it is hoped will contribute to the development of efficient and effective structures.

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Effective functional design

Most timber groynes are intended to reduce the net sediment transport along a section of shoreline, in order to retain sufficient beach material to absorb wave energy and reduce the risk of flooding and / or coastal erosion. Groynes (Fleming, 1990; Simm et al, 1996; USACE, 1992) help retain the beach by (a) acting as a barrier to beach movement making beach reorientation possible, (b) intercepting wave induced currents, and (c) by deflecting tidal currents. By understanding how groynes work it is possible to develop an efficient and effective functional design. Key design parameters include:

Length Groyne design should start with the required beach profile to provide the necessary standard of defence. The length needs to be sufficient to retain the required beach width, reducing a proportion of potential longshore transport under normal conditions. Since the cost of extending the structure across the whole breaker zone is normally excessive, and a total reduction in longshore transport would starve downdrift beaches, some compromise in length is necessary. Groynes extending through the surf zone will trap more sediment and the bays will fill up until the beach material passes around or over the groyne. Beach nourishment is often carried out immediately following the construction of a groyne field to facilitate the continued transport of material to downdrift beaches. Short groynes, not extending across the surf zone, have the advantage that they don't intercept all of the sediment transport along a shore, and thus cause less downdrift erosion. However a smaller spacing is required. In practice it has proven to be effective to construct groynes beyond the breaker line of a summer wave climate at mean high tide level, as this is the season when the wave climate builds up the beaches. When a wider beach is desired, the groynes can be constructed with a length related to the future breaker line. To avoid outflanking at the upper end of the beach, the groyne should run sufficiently far back into the beach to allow an occasional drop in beach level (and retreat of the beach head). Alternatively the groyne can extend to a revetment or seawall, preventing outflanking of the groyne. As the length of the groyne is largely dependent on the beach material, in some cases such as an upper shingle and a lower sand beach, a combination of alternating long and short groynes can be useful.

Height As for the length of a groyne, the height is governed by the required beach profile in the first instance. The height is of great importance in reducing currents and sediment transport across the groyne, but excessive height can lead to a focussing of flow and scour at the head of the groyne, as well as an increase in wave reflection. In most situations it is preferable for the groynes to protrude just above the beach level, with adjustments made as the beach levels change. This will allow some sediment to be transported over the structure and will reduce wave reflections from the groyne. Most of the sediment transport will be trapped, as the largest concentration of sediment travels along the bottom (bed load). In practice it will be uneconomic to continuously adjust the groyne height, but seasonal works restricting the groyne height to a level approximately two to three plank widths (0.5 - 0.75 m) above beach level will improve the functioning

of the groyne. A tolerance of another two plank widths will often be acceptable on shingle beaches, as these are less susceptible to scour and reflection. An alternative in some situations is to maintain the beach levels through periodic renourishment rather than adjusting the groyne planking. A groyne profile matching the beach profile will reduce near shore longshore currents (induced by waves and tides), but minimise the local increase in flow velocity adjacent to the structure. For new groyne systems, where a build-up of beach material is anticipated, the groyne height should be gradually increased, working from the downdrift end as the beach develops, however it should be noted that downdrift erosion is likely to take place until the system is filled. Similarly, gradually increasing the height during the groyne's lifetime can reduce the concentration of abrasion on the structure.

Spacing and orientation The spacing of groynes should be determined by the approach angle of incoming waves, and is largely dictated by the best balance between size of beach and number of groynes so that the worst case beach crest plan shape maintains a sufficient crest width at its narrowest point. As waves travel inshore refraction will change the approach angle of the incoming wave and diffraction around the head of any structures will contribute to the curved shape of the shoreline. An effectively spaced groyne field will result in a beach alignment running from the heel of a groyne to the head of the next. The spacing will normally result in a parabolic shaped shoreline curving slightly back towards the end of the upstream groyne. Obviously the length and spacing of a groyne are closely linked. Dependent on the alignment of the beach, the groynes can be closely spaced for waves approaching at an angle or more widely spaced for a more perpendicular wave approach. When the wave direction varies widely, the longshore transport usually varies too, requiring a less close spacing than for extreme angles of wave approach. At locations where the wave and littoral drift direction vary, groynes are normally orientated perpendicular to the coastline. However when the littoral drift and wave directions are consistent, a more effective angle can be selected. When aligning groynes in a downdrift angle, the parabolic shaped beach will be most effective against outflanking. The groyne provides maximum shelter for the beach, and additionally rip currents will be directed at an angle away from the shore, decreasing the transport of beach material offshore.

Permeability Permeable groynes or pile screens often have the same function as conventional impermeable structures, but work in a slightly different way. They reduce alongshore currents, such as tidal currents but provide less of a barrier to the movement of beach material. In some cases they might be useful, reducing currents close to the shore, however they have not generally been successful at locations with significant wave activity, and performance is generally less predictable than for conventional groynes. Additionally, with an impermeable groyne, abrasion is concentrated on a few predictable locations, and the structure obtains its strength and stability by spreading forces over a certain length (and height) of the structure, rather than each pile resisting forces individually. However, permeable pile screens may deserve consideration as a

first and cheap phase in combating coastal erosion (Bakker, 1984). Impermeable groynes should be constructed with precision, as local abrasion can be very high as beach material is funnelled through gaps in the groyne.

Overall stability of structure

The stability of a groyne structure is determined by its ability to withstand loads exerting a moment on the structure. Usually evenly spaced cantilevered main piles with buried in-fill panels of vertical sheet piles or horizontal planks achieve overall stability. The stability of a groyne can be affected by scour and undermining of the foundations. The means of attaining sufficient stability is dependent on the beach type and substrate type in which the groyne is to be founded. In coastal engineering the loadings are often dynamic and irregular. A random wave front approaching the shoreline at an angle does not exert a steady, sustained load over the full length of a groyne. Instead, at any given point in time it impacts certain lengths whilst others are left relatively unaffected. For this reason it is necessary to design structures with the ability to spread localised areas of high loading. This can then be taken into account when calculating the overall stability of a structure. The design of a structure, including its foundation, should be kept as simple as possible. If at all, possible props and ties should be avoided due to the problems of abrasion from beach movement, and extra complexity of the structure. If they are unavoidable then ties are preferable because they are located on the updrift side of the groyne where beach levels tend to remain higher for longer periods, thereby reducing abrasion.

Cantilever piles The simplest way of constructing a groyne is by placing (either planting or driving) piles in the ground, with planking between the piles. Where the ground conditions are too hard for the piles to be driven sufficiently far into the ground, holes or trenches can be excavated after which timber posts inserted and the excavations backfilled with the beach material or imported fill such as concrete. Posts planted in concrete can also be used in situations where piling would otherwise be possible but the required lengths of timber are unavailable. Shorter lengths of timber set in a concrete base can potentially match the performance of longer driven piles. However, to use a concrete foundation the substrate must be able to carry such heavy loads, to avoid cracking of the concrete or even instability in its whole.

Contiguous piles A different method, to help support the main piles is to drive sheet piles in the ground close to the posts and attaching them to a waling (see Figure 1). In soft ground conditions the sheeters will help the piles to resist rotation. The sheet piles are bolted or coach screwed to the waling, after which the sheet piles can be cut flush to the waling. Directly above the waling planking will be placed to the appropriate level. Under normal conditions the vertical sheeters won't be visible, as they will remain under the beach level. This method can only be used in relatively soft ground, to make driving of sheeters and piles possible. In order to make driving of the sheeters easy, the bottom end is cut at an angle to ensure that the driven sheeter is forced against the previously

placed. A tongue and groove in the sheet piles will keep the piles in line and make the panel impermeable. Without tongue and groove the sheeters can be driven using accurate machinery, or fixed to two walings keeping them in the correct place and assuring a tight fit. In the latter case the sheeters can be driven as a panel, instead of individually.

Buried panels An alternative arrangement to the contiguous piles described above is to excavate between the main piles, as explained for the planted posts, and fix horizontal in-fill panels, such as planking. When backfilling a trench with beach material the planking level must lie well under beach level, to provide extra resistance against rotating and to avoid seepage under the structure, as piping may form a threat. The planking extends below the lowest anticipated beach level. Buried panels are often used instead of contiguous piles when most of the necessary excavation is in a non-cohesive material, such as shingle or sand. With a clay substrate, the contiguous pile system has preference.

Props or ties Where the main piles are unable to resist rotation on their own, props (working in compression) can be used. They will require their own anchorage arrangement. Instead of, or in addition to, the prop structure, ties (working in tension) can be used to support the main piles. This system is superior to the prop structure, because lee side erosion will uncover the prop, exposing it to abrasion and possibly undermining. Ties or props can be made of whole logs and will require an anchorage system such as secondary piling. Ideally the tie will permanently remain under the beach level.

Members and connections

The key issue for members and connections is keeping the structure arrangement uncomplicated with as few connections as possible. Members and their connections should be designed and developed together. Connection details will often influence the design of the members, and vice versa. The number of connections should be kept to a minimum and in relation to this, individual members should be kept as long as possible. The arrangement of members and connections should be designed to allow for the distribution of localised loads, such as wave impacts, into the structure. Permissible stresses can generally be increased for short-term loading conditions. From a design perspective, connections typically fall into one of the following four categories:

Overlap connection This is the simplest type of connection and involves two or more members passing across each other. This connection can pass large forces, and depending on the section sizes, and number of fixings moments too. Examples are the connections between main pile and waling, between waling and sheeters, and between main pile and planking.

Butt joint This connection involves two or more members converging to a single point. The members are usually within the same plane. This arrangement demands a higher degree of fit than the overlap connection. Butt joints are usually carried out using steel plates, overlying the entire connection. Depending on the steel plates, this connection may resist high loading. Butt joints are sometimes used when in-line planking meets at a main pile. In this case only small forces are transmitted through the joint.

Scarf joint Usually this connection involves a splice connection for the in-line extension of a member (see Figure 2). The joint is generally carried out with steel plates on both side sides of the members, and thus can transfer some loadings (moments and forces). The first plate has close fit boltholes and the second has oversize holes to allow for drilling tolerances through the timber. Pairs of plates are more efficient than single plates (due to the advantages of double shear) but their installation demands higher standards of workmanship. Also, the greater the number of bolt holes the more difficult the installation. Plates are typically in galvanised mild steel and of the order of 12 mm thick.

Notch connection This connection involves cutting a notch in one timber member in order to receive a second member. This requires precise workmanship, or can be done by machinery, for example for the tongue and groove of sheet piling, which is a type of notch connection. Although this connection can resist high forces in certain directions, it is not used very often, as the connection is complex, costly and may result in thin sections.

When configuring the arrangement of connections within a structure, first preference should be given to designing with connections that work in compression. Namely, where the main load path is from timber to timber and the fixings (e.g. bolts) play only a secondary role. The second preference should be for shear connections where the main load path between timbers is transmitted via the fixings working in shear. Double shear connections are more efficient than single shear connections and should only be incorporated in a design when loads are high. The third preference should be for tension connections where the main load path is via fixings working in tension. The fixings will usually be carried out in steel, and is discussed below. In general a design should always use as much staggered connections as possible within a structure to avoid lines or planes of weakness.

Fixings

All fixings on groynes are exposed to severe wear and corrosion, due to the aggressive marine environment. Therefore as few bolts, as possible should be used, these never being placed too close in the same grain line of the timber. Galvanised steel fixings are commonly used but stainless steel fixings have the advantage that the groyne can be dismantled or refurbished more easily and the fixings can be reused. The arrangement of

fixings and joints should be kept as simple as possible and as few as possible, in order to minimise the need for cutting, drilling and shaping. The potential types of fixing for use in connections are as follows:

Bolts For most situations this is the preferred method. Bolts have hexagonal or square heads and threaded shanks, and provide a robust connection and are relatively straightforward to fix. Galvanised, coarse threaded, mild steel bolts are usually the most cost effective solution but other types such as stainless steel cannot be ruled out. Where bolts pass through the timber they should be a tight fit. Holes should only be drilled from one side of the timber member. Within a connection, bolts should not be designed to bridge an air gap. The length of bolt between the head and nut should be fully enclosed. Close attention should be paid to the edge distances between the boltholes and the timber faces and the spacing between bolts. Where possible, nuts should be located on the more sheltered side of the connection. Bolts used as tightened fasteners should have washers under any heads or nuts, which are in contact with the timber. As a general rule in coastal engineering large diameter bolts are to be preferred. For most situations 20 mm and 25 mm diameter bolts tend to be suitable. Larger diameter bolts have the advantage in terms of exerting lower secondary stresses on the timber and coping better with corrosion. Timberwork washes should have a diameter of at least 3 times the diameter of the bolt and a thickness of 0.3 times the diameter to provide full bearing. In selecting the position of bolts in a connection consideration should be given to ease of installation and removal, and also to protection of the head and nut. To use the bolt in a countersunk hole so that the head or nut does not protude above the surface of the timber member is not recommended as this in some cases will result in accumulation of water, and reduces the effective depth of the timber. However, where connections coincide countersinking can be useful.

Coachscrews These are suitable for multiple lightweight connections, but installation requires a higher degree of workmanship than bolts. Typically they are galvanised mild steel, for example 16 mm in diameter with a 25 mm square head. In situations where it is likely to be necessary to remove fixings for operational or maintenance purposes, coachscrews are less suitable than bolts. Their heads are less robust than bolt heads and their grip within the parent timber is susceptible to deterioration through repeated fixings. For locations where the members may stay connected throughout the life of the structure, such as sheeters or lower planking they are convenient. It is not useful to use washers with coachscrews, as their working loads are lower than for bolts, and allowing the head to embed themselves slightly is functional.

Due to the often aggressive environment in which coastal structures operate, the range of practical finishes tends to be limited. As a general rule timbers are left in their original as-sawn or planed condition. However there is a tendency for timber fibres to separate (broom) at both the head and toe of the pile during heavy driving, resulting in a loss of

structural strength, and ability to drive the pile. Pile rings and shoes can be fitted to protect the head and toe of the piles. The head of the pile should be carefully shaped in order to ensure good contact between the timber and pile ring. After fixing the pile ring the top of the pile must be trimmed where necessary to ensure the driving face will be horizontal. The pile shoes must be fitted symmetrical, and firmly fitted onto the suitably shaped end of the pile, ensuring a maximum possible contact area between the shoe and the pile in order to avoid overstressing during driving. Other finishes can include construction facilities such as steel strips on the top planking of a groyne, to allow plant to drive over the groyne. Finishes and fittings of this nature need to be properly sized for their function, and carefully fitted. Poor workmanship can result in such fittings becoming a hindrance rather than a help.

Construction and maintenance

Construction stage Minimising in situ working and simplifying fixing, handling and lifting operations should be incorporated in the design and planning of a contract. Prefabrication of sheet pile panels can largely reduce the amount of in situ work, which often is carried out on unstable surfaces. Normally the construction of a groyne necessitates working between high tide periods. The contractor should be aware of this and provide sufficient beach access routes, in order to leave the beach safely in time. This requires a strict planning of the work, and keeping machinery in a good condition. Particular measures that can be taken include the following:

- Recognise and facilitate dimensional, constructional tolerances for installing members, depending on the working conditions. Use planted posts instead of driven piles where closer positioning tolerances are required. Be aware of significantly larger tolerances for hewn piles than sawn piles.
- Simplify the structure to facilitate difficult working conditions (e.g. at extreme low tide or with very poor access).
- Minimise the need for long slender boltholes where there is a risk of deflection of the drill bit.
- Facilitate prefabrication to reduce the amount of in-situ working. Prefabrication of elements such as panels of sheet piles, fixed near or below low water, can increase safety and improve the quality of construction. Prefabrication may also enable the use of preservative treated timbers, and minimise waste.
- Line up one side of all main piles, to obtain a straight planking line.
- Make sure bolts are “locked off” once in place, by destroying the thread, welding the nut or bending up locking washers.

Operational stage Designers must be aware of the fact that the public shall use the beach along the groynes. Therefore trip hazards and dangerous protruding bolts must be avoided in the design. Misuse of the structures must be discouraged too. To facilitate maintenance operations, plant access bays with a sufficient width may be designed within a groyne scheme to provide a safe exit route for machinery at work on the beach.

Maintenance of timber structures involves repairing or replacing damaged elements of the structure as well as adjusting the structure to perform in the most efficient way. During this stage of the life cycle, wastage arising from the use of timber in construction has potentially the largest impact on the environment. Particular measures that can be taken include the following:

- Members such as planking, which may need replacing within the lifespan of the structure, should be relatively easy to access and disconnect (fixings should be accessible and the need to remove other members should be avoided).
- Allowance should be made where reasonable for the possibility of adding new members within the scope of the structure at a later date.
- Avoid the use of paint on hardwood, as this will possibly cause the member to rot under the paint film, due to the excess of moisture under the paint.

Pile extension Groynes should be adjusted to the optimal height, matching to the changing beach profile, possibly several times throughout their lifetime. In some cases extending groynes to the preferred height may be an attractive solution instead of rebuilding an entire groyne (see Figure 3). On the other hand, when constructing a groyne, an allowance may be provided in the pile length for extra planking.

Rubbing pieces To protect piles from abrasion, softwood or recycled timber rubbing pieces can be attached to the piles at critical levels. Extending planks beyond piles may also reduce wear, increasing the life of the pile. Members should be sized with an allowance for wear and the connections carefully chosen. Maintenance will require regular inspection of the structures and replacing of worn rubbing pieces.

Timber and the natural environment

As a renewable resource timber has the potential to be an environmentally responsible material option, if recycled or obtained from sustainable managed forests. However, negative publicity surrounding logging (particularly of tropical forests) and an increasing reliance on alternative materials has led to a belief that the practical, environmental and aesthetic advantages of timber are not being fully exploited. There are a number of characteristics that make timber an attractive choice of construction material, including the following:

- Relatively lightweight, with a good strength / weight ratio and easily handled because of its weight.
- Good workability allowing on site repairs, adjustments and recycling.
- High tolerance of short duration loads.
- Attractive appearance and (to a greater or lesser extent) natural durability.
- Possible lower whole life costs, due to small quantity of material used.

Sustainable procurement As a natural material, the efficient utilisation of timber is dependent on some form of selection and grading. An understanding of the

characteristics and properties of timber as a raw material will enable the designer or user to ensure that timber is used to best effect. One advantage which timber has over almost all other materials is that trees are a living, renewable resource. Good land management and thoughtful felling regimes are recognised as essential issues of the timber trade that will help to secure the long-term availability of certain timbers. Many organisations are now implementing timber specification policies. Having a policy about timber specification is a good way of ensuring that everyone working on a project is clear about what timber is acceptable for use. When procuring durable timber, species of timber from sustainable sources should be specified and possibly allowance made for a range of timber species in order to spread demand.

Recycling of timber Recycling and reusing timber can obtain an enormous reduction of the need of new timber, although reuse of timber is not necessarily cheaper in terms of construction costs due to issues of selection, handling and workability. Timber that has been used in a structure under beach level will hardly suffer any loss of quality, and thus can excellently be used again. Piles can possibly be placed upside-down back in the ground, leaving the abraded section under the ground. If the pile is severely damaged above beach level the useful remaining part can be used as a shorter pile elsewhere. Old planking or sheeters can well be reused as sheeters or rubbing pieces because these elements require limited section lengths.

Minimise waste During the design, construction and maintenance stages the quantity of waste can be reduced in a number of ways. Member section sizes and lengths should be matched with the optimum available from the original logs, and some flexibility must be allowed for, in accommodating variable lengths and sizes. Ideally lengths and sizes are standardised as much as possible, preferably ordering in both metric and imperial unit lengths. By specifying careful storage of timber on site the likelihood of warping and end damage can be reduced, especially for smaller section sizes.

Durability by design Particular measures that can be taken to make a design durable include the following:

- Use planking and other tertiary members to contribute to the overall stability of the structure thereby reducing the total timber requirement.
- Use rubbing pieces at locations of anticipated high wear and tear.
- Assure that the gaps between planking, or other members is minimal, to prevent them from widening as a result of abrasion.
- Main piles should be designed with an over height to make adjustments possible in the future.
- Use oversize members at locations of anticipated high wear and tear, and extend planks beyond piles.

- Avoid local traps, passageways and other configurations, which might encourage high wear and tear through the channelling of water and/or water borne sediment.
- Avoid connections, which are reliant on single fixings.

Conclusions

Timber groynes have proven to be an excellent system to control a coastal area under certain circumstances. As beaches constantly change as they respond to natural processes, a flexible structure is required to retain the beach. Removing or adding planking to a groyne can obtain an optimal profile throughout the entire lifetime of the structure. An adequately designed, constructed and maintained groyne provides a physical barrier to the movement of the beach material and diverts longshore currents away from the beach.

In many cases timber may offer lower whole life costs and environmental advantages over alternative materials, due to the relative ease of construction and small quantities of construction material. To be an environmental responsible material it is necessary that the timber is either recycled or is obtained from sustainable managed forests. Reuse and recycling of timber can substantially reduce the need for new timber, and should be incorporated in the design and maintenance of structures. The durability of a structure is largely determined by design details, such as the spreading of loads and connection details.

When designing a groyne system it is important to understand the processes that take place in the near shore area, before and after construction of the groyne field. Preferably the designer has both practical experience and knowledge of coastal engineering, as no two beaches are the same and consequently, there is not a groyne design that is universally effective. Because groynes have been constructed for hundreds of years, almost every possible mistake has been made. By studying several structures before simply replacing an existing groyne, an optimal system can be attained. The key issue is to keep the whole design as simple as possible to facilitate a fast and effective construction, and easy accessible maintenance.

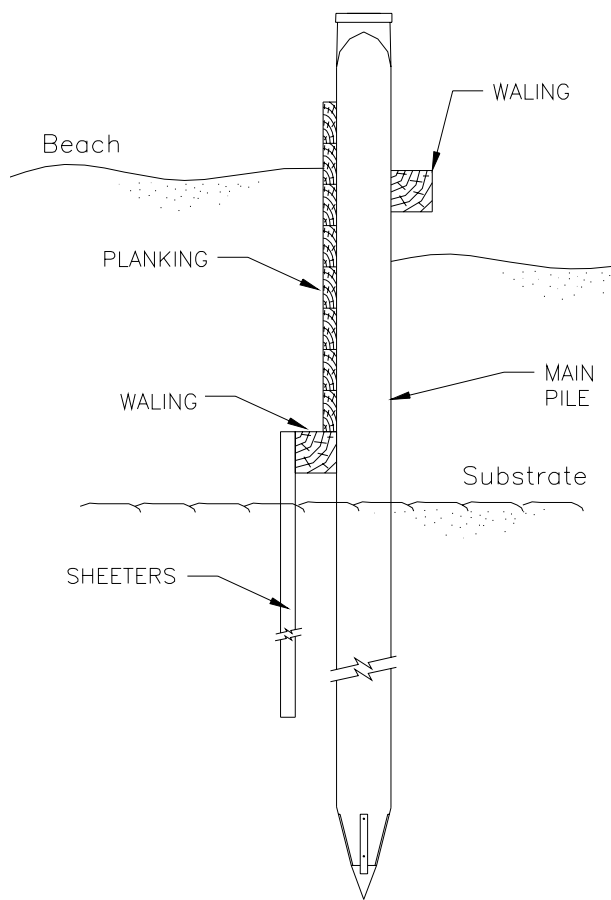


Figure 1. Contiguous piles

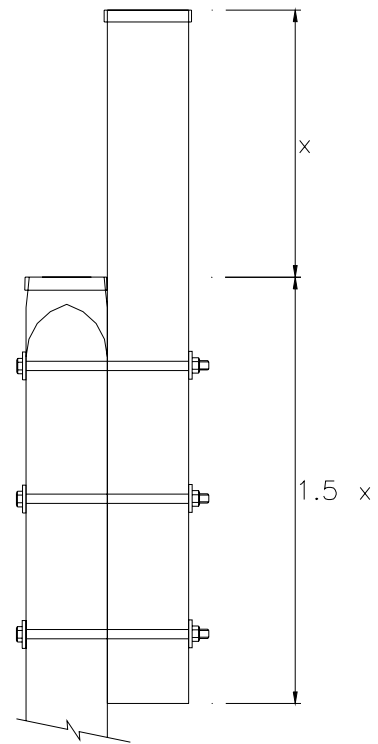


Figure 3. Pile extension

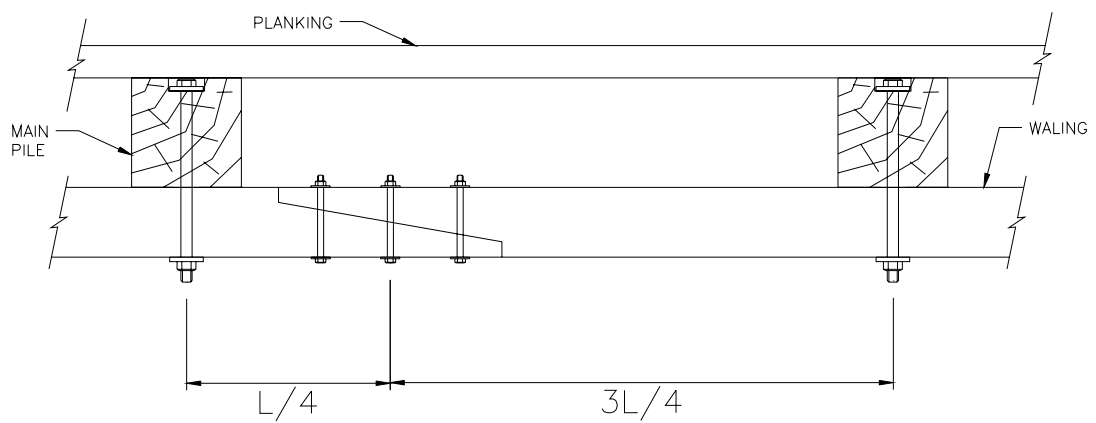


Figure 2. Scarf joint

Acknowledgements

A consortium including HR Wallingford and industry partners have prepared a manual on the use of timber in coastal and fluvial engineering, which will be published in early 2004. The manual will provide general and structure specific guidance, based on the knowledge and experience of consultants, contractors, timber specialists and suppliers. The manual addresses a number of issues not discussed in detail in this paper, including:

- The selection and procurement of sustainable and durable sources of timber material, taking account of the current international sensitivities associated with the procurement of tropical hardwoods.
- Structure-specific guidance for a wide range of other timber structures for use in coastal engineering

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