TIMBER GROYNES
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1. Introduction

Timber has traditionally been used for the construction of a wide variety of coastal and fluvial structures including groynes, jetties, lock gates and riverbank protection. As a renewable resource it 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:

- Relatively lightweight, with a good strength / weight ratio and easily handled because of its weight.
- Good workability allowing on site repairs and recycling.
- High tolerance of short duration loads.
- Attractive appearance and (to a greater or lesser extent) natural durability.

There are many applications where it is still an economic preposition to use timber for construction purposes. Timber groynes are a good example of this. These are fence-like structures, built perpendicular to the coast with the aim to trap and retain beach material.
A permeable solution can be obtained by one or more rows of timber piles driven directly into the beach at relatively sheltered locations.
An impermeable structure may be constructed using a combination of materials. A double row of timber sheet piling can be filled with sand, gravel, earth or stone with the top layer consisting of rock or rubble preventing washing out of the smaller material.
Impermeable timber groynes have been constructed at many gravel beaches in the UK, but little is known about best practice design or structure detailing.
This note is based on the work of Perdok (2002), Crossman and Simm (2004) and Van Rijn (2010).

2. Functioning and dimensions of groynes

2.1 General

Beaches constantly change as they respond to natural processes including waves, currents and the wind. These processes can result in material being transported from the beach, which if not replaced by material from neighbouring areas, will result in erosion. Groynes are constructed more or less perpendicular to the shoreline to restrict the movement of sediment along the shore.

A groyne system is made up of a number of individual groyne structures, usually of similar length and spaced at regular intervals along the shoreline. Groynes usually work in two ways, diverting or intercepting longshore currents (which may be caused by tides or waves) and often also providing a physical barrier to the movement of the beach material. The shore between the groynes will orient itself more or less parallel to the approaching wave crests.

Groynes only interrupt the longshore drift and cannot prevent cross-shore transport. Often the erosion problem is simply moved to a location downdrift of the groyne field.

Two main types of groynes can be distinguished:

- ***impermeable, high-crested structures***: crest levels above +1 m above MSL (mean sea level); sheet piling or concrete structures, grouted rock and rubble-mound structures (founded on geotextiles) with a smooth cover layer of placed stones (to minimize visual intrusion) are used; these types of groynes are used to keep the sand within the compartment between adjacent groynes; the shoreline will be oriented perpendicular to the dominant wave direction within each compartment (saw-tooth appearance of overall shoreline);
- ***permeable, low-crested structures***: crest level between MLW and MHW lines to reduce eddy generation at high tide; pile groynes and open timber fences are used; permeability can increase due to storm damage; these types of groynes are generally used on beaches which have slightly insufficient supplies of sand; the function of the groynes is then to slightly reduce the littoral drift in the inner surf zone and to create a more regular shoreline (without saw-tooth effect); groynes should act as a filter rather than as a blockade to longshore transport.

Timber groynes are fence-like structures, and can often provide substantial advantages over other forms of groynes. These include the ease with which the level and profile of the groyne may be adapted (by adding or removing planks), ease of maintenance and their appearance.
At many places “pile row groynes” are still used, consisting of a row of timber piles, with a spacing of approximately their diameter.

The main function of a groyne system is to stabilise a stretch of beach against erosion by:

- prevent or slow down the alongshore drift of material;
- build-up material in the groyne due to cross-shore transport.

This is achieved by:

- intercepting wave induced currents;
- deflecting strong tidal currents away from the shoreline;
- serving as a barrier, to enable a beach section to reorientate itself.

2.2 Length

Most longshore transport takes place in the surf zone, between the breaker line and the shoreline. The length of a groyne determines the trapping effectiveness of the system, depending on how far across the surf zone it reaches. The location of the breaker line, and thus the width of the surf zone, varies with wave height and tidal stage, therefore the relative groyne length also changes.

Shorter groynes will allow sediment to bypass the groyne immediately after construction, which may be desirable to minimise erosion along downdrift beaches. The mild slope of a sandy beach requires a much longer groyne than a steep shingle beach. A large tidal range leads to a longer groyne than a small tidal range. A shorter length has effect on the spacing of the groynes too, leading to a smaller spacing.

From an economic viewpoint, a groyne is preferably constructed above the mean low water mark, as building in the water is a costly matter. However for the functional design of a groyne system, they are only effective if they reach far enough into the surf zone. If the groyne is too short at the landward end, outflanking may occur.
For tidal situations the breaker line changes with the tide level, for a given wave height. In practice it has proven to be effective to construct groynes beyond the breaker line of a summer wave climate at mean high water tide level. The reason for choosing the summer wave climate is because this is the wave climate when beaches are built up again.

2.3 Height

The height of a groyne controls the sediment movement over the groyne and determines the amount of sheltering from waves to the nearby beach. Factors such as the amount of construction material to be used and wave reflections from the groyne are influenced by the height. The height of a groyne, above beach level, may vary over the groyne's length, and differs for the summer and winter beach profiles. The groyne profile is built to approximately the desired post-project beach profile, see **Figure 2.1**.
High groynes are likely to create rip currents, and flows at the head of the structure, sometimes leading to erosion channels, which will transport beach material out of the groyne bays.
Sand beaches are most sensitive to the height of a groyne and can best be adjusted to protrude only 0.5 m or two plank widths above the seasonal beach profile. On shingle beaches, greater groyne heights are permissible and practical.

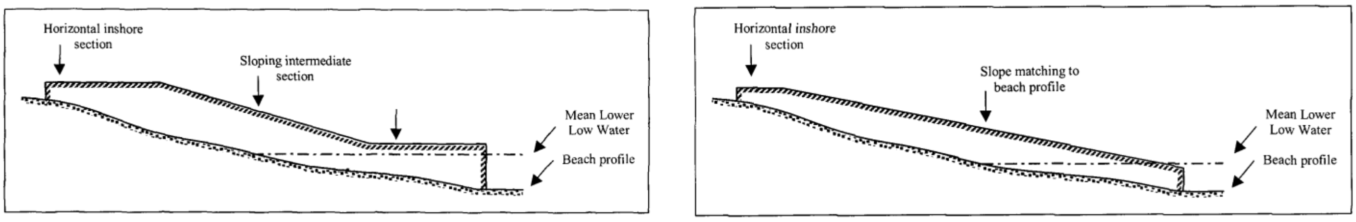


Figure 2.1 *Typical groyne profile*

In practice it will be uneconomic to continuously adjust the groyne height, but attempting to keep the groyne height at a level approximately two to three plank widths above beach level will improve the functioning of the groyne.
A groyne profile matching the beach profile will reduce near shore longshore currents (wave and tidal induced), but minimise the increase of flows around the structure by letting water pass over the structure too.

2.4 Spacing

The spacing of groynes is usually given in terms relative to the length of individual groynes, generally in the order of two to three groyne lengths. The groyne length is specified as the distance from the beach berm crest to the groyne's seaward end. Steeper beaches or a small tidal range require shorter groynes and therefore the spacing is smaller too. When designing a groyne system, the spacing is determined by an analysis of the shoreline alignment that is expected. This alignment will approximately correspond to the crest of the dominant incoming waves. The shoreline alignment is a function of the wave-, and longshore transport environment at a site.
When the waves make an angle with the shoreline, closer groyne spacing is required. In case of varying wave direction and transport rates, the shoreline alignment near groynes will also vary, and the spacing is generally chosen to be relatively small.

2.5 Permeability

Groynes are either permeable or impermeable, depending on whether sediment can be transported through the groyne. The idea of permeable groynes is that they reduce alongshore currents, and thus reduce sediment transport. Permeable groynes have several advantages such as their relatively low cost and a smaller tendency to produce rip currents and currents round the end of the groyne. Another advantage is that permeable pile screens don't create such severe erosion downdrift, as sediment is transported through the groyne.
Permeable pile screens deserve serious consideration as a first flexible and cheap phase in combating coastal erosion.

2.6 Orientation

Generally groynes are constructed perpendicular to the coastline. To minimise wave impacts, groynes could be aligned into the predominant wave direction. However, to provide the most effective control of littoral movement they should be angled slightly downdrift. Because wave and drift directions may vary, the most practical solution is chosen: aligning groynes transverse to the coastline.

2.7 Summary of design rules

Basic groyne design rules are:

1. long impermeable groynes should only be constructed along coasts with recession rates exceeding 2 m/year and dominant longshore transport processes; small permeable groynes can be used at sheltered coasts; groynes cannot stop erosion, but only reduce erosion;
2. groyne length (L) should only extend over the inner surf zone at sandy beaches (up to the landward flank of the inner bar trough) and crest levels should be relatively low to allow sufficient sediment bypassing so that lee-side erosion is reduced as much as possible; groyne spacing S should be in the range of S = 1.5 to 3L; groyne tapering can also be used (reduced lengths at downcoast end of groyne field);
3. groynes should be constructed from downcoast to upcoast;
4. groyne cells should be filled to capacity immediately after construction;
5. groynes made of rock should have a smooth cover layer of armour units (no rip rap or rubble mound) to minimize visual intrusion;
6. timber groynes are effective at sheltered beaches and at moderately sheltered gravel/shingle beaches.

3. Overall stability and construction

3.1 General

The stability of a groyne structure is determined by its ability to withstand loads exerting a moment on the structure. Usually evenly spaced 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 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.

3.2 Planted posts

The simplest way of constructing a groyne is by placing (either planting or driving) posts 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, see Figure 3.1 A. 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.

Prefabricated elements consisting of hardwood wooden posts in a concrete foot (see Figure 3.1B) can be used in sections just landward and seaward of the waterline and/or at places where in-situ casting of concrete is problematic. Plankings can be attached after placement of the prefabricated elements. A permeable groyne can be made by using posts only and small spaces between the posts (about 10 to 15 cm).

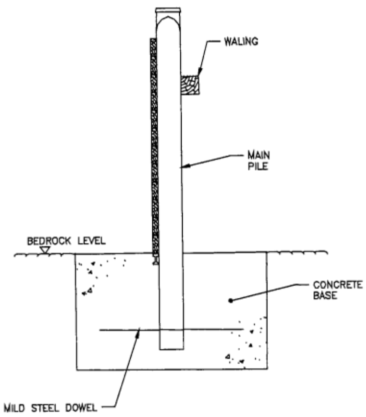


Figure 3.1A *Planted post in concrete foundation and in sand beach*

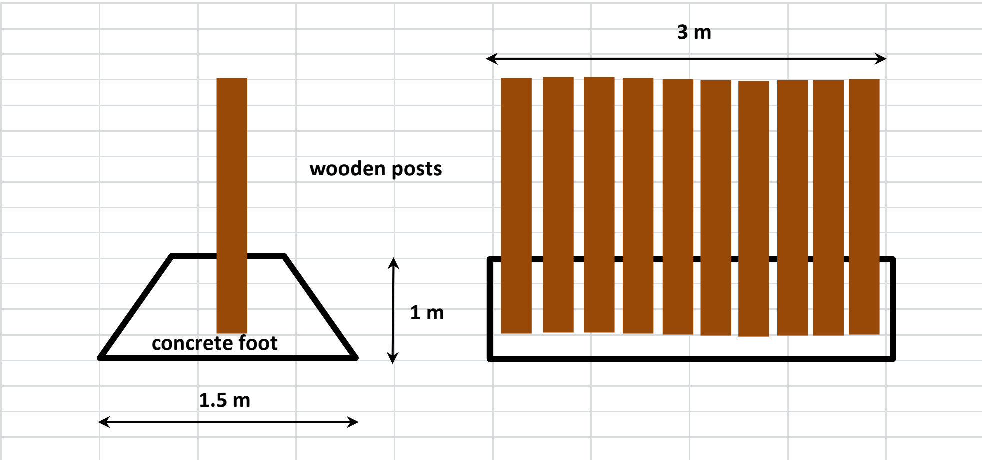


Figure 3.1B *Prefabricated wooden posts (piles)*

3.3 Buried panels

This method consists of excavating between the main piles and fix horizontal in-fill panels, such as planking. The planking (**Figures 3.2** and **3.3**) extends below the lowest anticipated beach level. Buried panels are mostly used in conditions with shingle or sand. Vertical sheetplanks are preferred in a clay substrate.

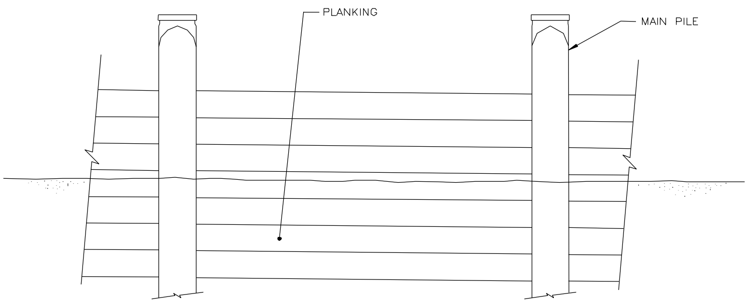


Figure 3.2 *Buried panels*

Figure 3.3 *Planking*

3.4 Props

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. In **Figure 3.4** a prop arrangement is illustrated. In this case the whole structure is founded in a concrete filled trench, in the siltstone bed.

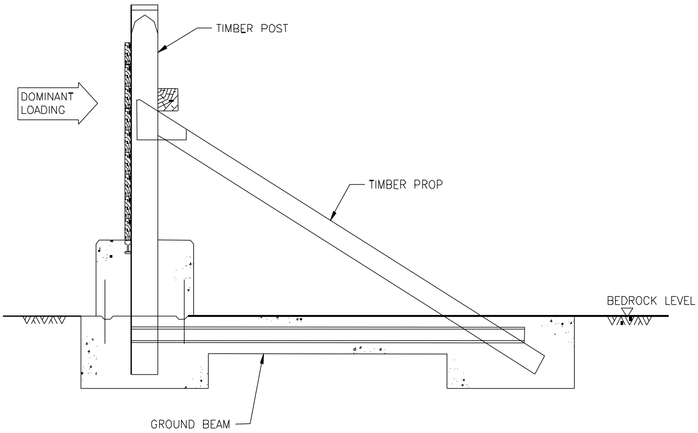


Figure 3.4 *Prop arrangement*

3.5 Ties

Ties (working in tension) can be used to support the main piles. This system (**Figure 3.5**) is superior to the prop structure, because lee side erosion may uncover the prop, exposing it to abrasion and possibly undermining the prop. Ties or props can be made of whole logs and will require an anchorage system such as secondary piling, illustrated below. Ideally the whole tie will permanently remain under beach level.

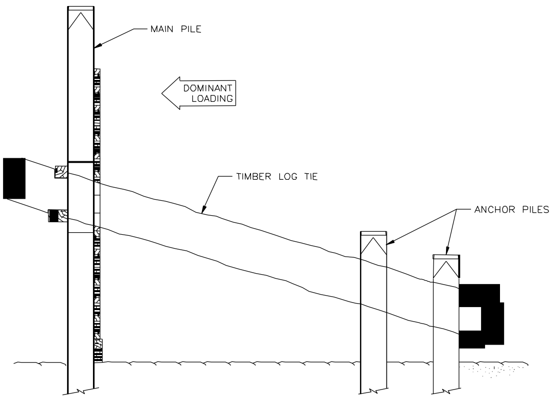


Figure 3.5 *Timber log tie*

3.6 Members and connections

The key issue for members and connections (**Figure 3.6**) is keeping the structure arrangement uncomplicated with as few connections as possible. Members and their connections should be designed and developed together. 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.

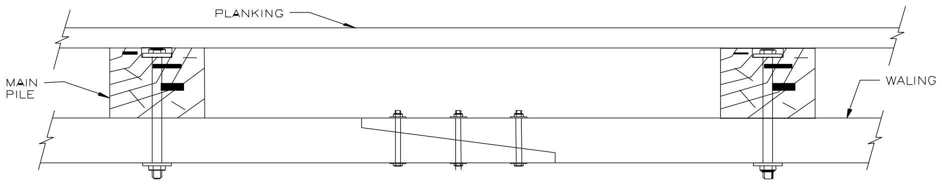


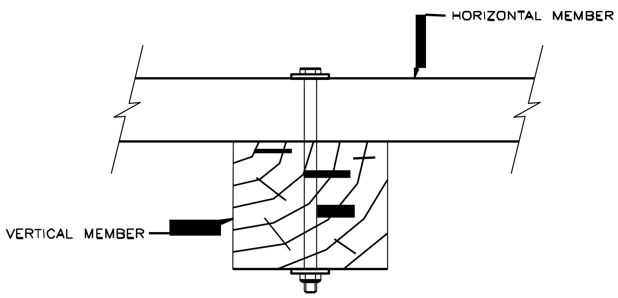
Figure 3.6 *Connections typically used in a groyne*

3.7 Connections

When configuring the arrangement of connections within a structure, first preference should be given to designing with connections that work in compression.
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 (**Figure 3.9**).
The third preference should be for tension connections where the main load path is via fixings working in tension.

A. Overlap connection

This is the simplest type of connection and involves two or more members passing across each other, **Figure 3.7**. Examples are the connections between main pile and waling, between waling and sheeters, and between main pile and planking.



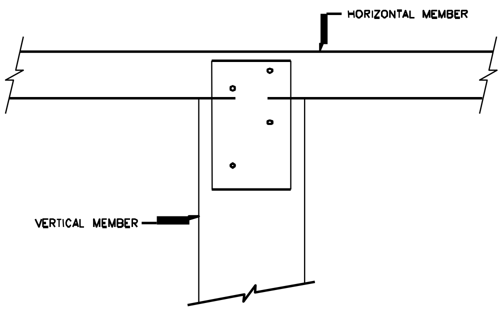


Figure 3.7 *Overlap connection*

Figure 3.8 *Butt connection*

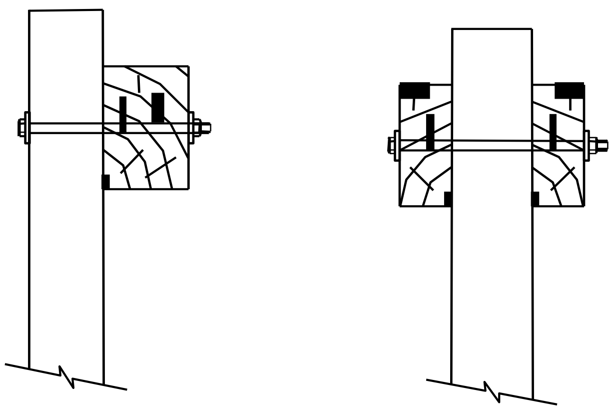


Figure 3.9 *Single and double shear connection*

B. Butt joint

This connection involves two or more members converging to a single point, **Figure 3.8**. 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.

C. Scarf joint

This connection usually involves a splice connection for the in-line extension of a member. Usually this joint is carried out with steel plates on both side sides of the members (**Figure 3.10**).

D. 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. This connection is more vulnerable to rot.

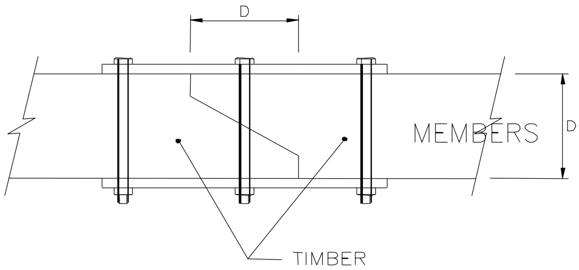


Figure 3.10 *Scarf connection*

3.8 Fixings

The potential types of fixing for use in connections are as follows:

A. Bolts

For most situations this is the preferred method. Bolts (20 to 25 mm) 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. Close attention should be paid to the edge distances between the boltholes and the timber faces and the spacing between bolts. Bolts used as tightened fasteners should have washers under any heads or nuts, which are in contact with the timber.

B. Coach screws

These are normally limited to fixing cladding such as planking and decking. They 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.

C. Dowels

Timber dowels can be used but are rare due to the high standards of workmanship required. Their main advantage over steel is their ability to expand, contract and deflect in harmony with the surrounding timber members. For these reasons such connections often remain tighter for longer periods of time and can be particularly appropriate for structures experiencing high impact loads such as mooring jetties.

D. Nails

Heavy-duty nails may be used in limited situations such as for decking timbers. However, compared with coach screws they have two main disadvantages, they are unsuitable for resisting tensile loads and they cannot be easily removed if the need arises.

E. Shear plates

Shear plates (Figure 3.11), split ring connectors, etc. are rarely used due to corrosion and the difficulties associated with forming connections in situ, especially in hardwoods.

F. Steel flat plates

Again these are normally used with bolts. The main purpose of plates is to increase the capacity of the connections in their ability to transfer load from one member to another. Usually they are used in butt joints and scarf joints.

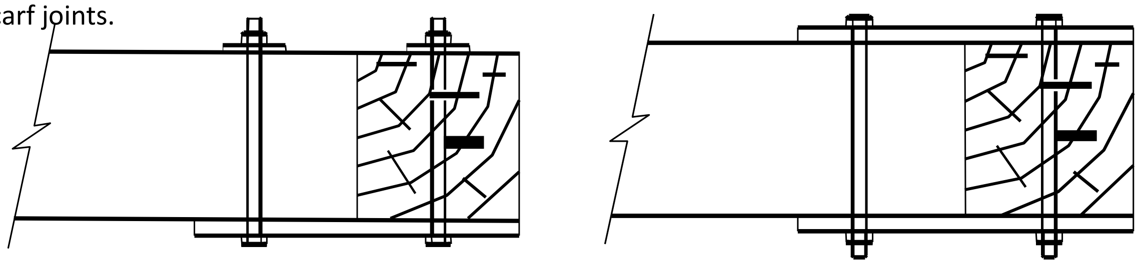


Figure 3.11 *Single and double steel plate connection*

G. Steel angles

Their application and detailing are similar to flat plates except that they are mainly, but not exclusively, used in overlap joints (**Figure 3.12**).

H. Steel straps

These are broadly similar to plates and angles except more versatile in as much as they can be bent to various shapes including curves. Also they lend themselves to being wrapped around members thereby reducing the number of positive bolt or coach screw fixings required.

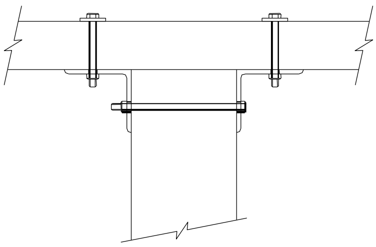


Figure 3.12 *Steel angle connection*

3.9 Finishes and fittings

All fixings on groynes are exposed to severe wear and oxidation, due to the aggressive marine environment. Therefore as few bolts, as possible should be used, these never being placed 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 finishes and fittings should be kept as simple as possible and as few as possible. Stainless steel fittings and bolts are strongly recommended.
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. Pile rings and shoes can be fitted to protect the head and toe of the piles. Finishes can include construction facilities such as steel strips on the top planking of a groyne, to allow plants to drive over the groyne. Finishes and fittings of this nature need to be properly sized for their function, and carefully fitted.

4. Timber as a construction material

4.1. Timber

Wood is made of organic matter. The basic building block of timber is the wood microfibril, which may be described as a fibre composite, where the fibre element provides strength to the composite while the matrix provides stiffness and transfers stress from fibre to fibre. The microfibril is made up of cellulose, which provides strength, and the hemicellulose and lignin act as the matrix that stiffens and bonds the cellulose fibres.

Other chemicals may be present in the timber, which may be classified as extractives. Examples of extractives are gums, oils, tannins, latex, resins, silica and calcium deposits. Large quantities of silica may cause blunting of cutting tools but are also responsible for giving greater resistance against attack by marine borer. The make up and distribution of extractives varies from species to species and is thought to play an essential role in providing durability against biological attack.

The commercial division of timbers into hardwoods and softwoods has evolved from long traditions when the timber trade was dealing with a limited range of species. Nowadays, this division has no relation to the softness or hardness of the timber. The terms “softwood” and “hardwood” can be confusing as some softwoods are harder than some hardwoods. Both groups contain timbers that vary in density, strength and resistance to biological attack, i.e. natural durability.

4.2 Degradation

Over the course of time and the influence of the external environment, timber structures, like all other structures, experience a loss in performance. Degradation is both inevitable and undesirable. At best, degradation is limited to the surface layers of the timber structure. However, given the right conditions, degradation will eventually affect the whole structure, particularly in terms of mechanical performance, strength and durability. The rate of degradation is usually specific to the particular timber species and the specific conditions. Hardwoods have lifetimes of 30 to 40 years
Timber in the marine and fluvial environment will in most cases remain permanently wet. Where those timber elements are out of contact with surrounding water, they will probably be exposed to conditions that will result in them being vulnerable to irregular attack. For fungal decay to occur, four conditions must be present: food, adequate moisture, suitable temperature and oxygen. In most circumstances, lack of moisture is the limiting factor that restricts fungal activity. However, low levels of oxygen, limited nutrients and low temperatures also decelerate or even inhibit fungal activity. The timber itself or the cell contents provide the necessary nutrients. Oxygen is usually available under service conditions except when the timber is totally under water. Practically all fungal activity ceases at or below freezing point and is very slow just above it.

The following types of biological attack may occur in fresh water:

- Bacterial, mould and sapstain attack. Mould and sapstain fungi are lower fungal organisms that are best described as “scavengers”, they feed upon readily available cell contents but do not cause decay of the timber structure.
- Soft rot attack occurs in ground contact and in marine and fluvial environments. Soft rotters are also lower organisms.
- Dry rot attack is by far the most important destructive fungus in buildings.
- Wet rot attack is by far the most important group of fungi to consider in terms of timber structures serving in the marine and fluvial environment.

If used in fresh water, the moisture content of the timber will exceed the decay threshold of 20% and it is highly probable that fungal decay will occur. Aggressive fungal decay above the water level may occur, principally by wet rot type fungi. In addition, insects may also attack wet timber above water level. However, below water level only fungal decay of the soft rot type may occur.
Soft rotting type fungi erode the outer layers of the timber components at a relatively slow rate. The outer surfaces are typically dark and soft in texture. The depth and rate of penetration of the fungi is largely regulated by the timber's density. However, the affected timber may also be exposed to currents. The combined effects of the soft rot fungi and faster erosion of the decayed outer layers of timber may accelerate the deterioration of the component.
Gribble and shipworm are present at many locations. Research has demonstrated that geographical features such as changing water temperatures influences overall distribution of the organisms.

4.3 Durability and preservation

Wood is naturally a durable material, which is resistant to most biological attack, provided it remains dry. However, prolonged wetting leads to a risk of decay by wood rotting fungi, though susceptibility varies according to the wood species. This varying susceptibility is categorised by the timbers' natural durability classification. Durability may be a natural feature of the timber or it may be imparted by the use of preservative treatments.
Timber is a variable material and its natural durability to various forms of biological attack is affected by many factors. Natural durability may be defined as the resistance of the timber to biological attack. It is important to recognise that the term natural durability only refers to the heartwood of timber species.
Timber species differ distinctly in their resistance to biological attack. The heartwood of some species, e.g. Greenheart, will last for decades in ground or marine contact whereas that of European redwood will suffer destruction in a comparatively short period of time. Historically, natural durability was recognised through experience of working with various species. However, in the nineteenth century field tests provided specifiers more reliable test data. The durability ratings are summarised in **Table 4.1**.

Durability	**Approximate life in ground contact**	**Examples**
Class1 Very durable	> 25 years	Jarrah, Greenheart, Iroko, Ekki
Class 2 Durable	15 - 25 years	Oak, Chestnut, Balau
Class 3 Moderately durable	10 - 15 years	Pitch Pine, Douglas fir, Larch
Class 4 Slightly durable	5 - 10 years	Redwood/Whitewood
Class 5 Not durable	< 5 years	Beech, Sycamore and Ash

Table 4.1 *Classification of natural durability*

Historically wood has been treated with a wide range of wood preservatives prolonging the service life of timber. However, some of these compounds have been banned from use whereas others are being restricted. The principal reason for the banning and restriction of certain compounds is their reported eco-toxicity. Greater environmental awareness and the need to develop environmentally friendly preservatives has driven preservation research and many new chemicals and products have been tested for their effectiveness. Some commercially available treatments are still being appraised for their long-term performance.
Pressure treatment is the most effective method of application for the majority of wood preservatives, although by itself pressure treatment is absolutely not a universal solution to increase the durability of non-durable timber species in hazardous environments.
Three types of preservative treatment may be considered appropriate for non-durable timber that is expected to serve in a marine or fluvial environment. These are water borne salts/oxides, tar-oil preservatives and light organic solvent preservatives (LOSP's).

5. Example cases

5.1 Bournemouth, UK

The Bournemouth coastline along the English channel at the south of the Uk is composed of sand, gravel, clay and rock. At Bournemouth the beaches consist mainly of fine sand, this changes at Southbourne (eastwards) to coarser material. The last part of the beach up to the Long Groyne at Hengistbury consists of gravel and cobble size material. Most areas of cliff have been protected from sea erosion by seawalls and groynes for over 90 years and have been regraded to a more stable angle.
Longshore drift is considered to be the main cause of sediment depletion in Bournemouth. Sediment accumulations at Studland, Hengistbury Head Long Groyne, Mudeford Spit and Hurst Spit are results of the predominantly eastwards direction.
The beach near Hengistbury Head Long Groyne is mostly unprotected from long fetch Atlantic waves. The longest fetch English Channel waves come from a south-easterly direction with exposure increasing to the east therefore, wave height is slightly higher at Southbourne than Boscombe. Winds from the west or south-west are more frequent and stronger than winds from the east so, Southbourne also receives the most powerful winds. The (small) tidal range hasn't caused any problems except when at spring tide combined with the channel surge in extreme conditions.

From 1915 until 1969, 45 concrete groynes, 3 steel groynes and 1 timber groyne protected the Bournemouth coastline in combination with a seawall.
In 1970, when the existing groynes were in a dangerous condition, a review of the coast protection policy was done and led to the new policy of beach replenishment with timber groynes to hold the fill in place. A change to timber was made because of the difficulty of maintaining concrete in the aggressive marine environment. In 1991 the "Groyne building programme" was completed, with in total 51 new timber groynes (**Figures 5.1** to **5.3**). Now Bournemouth has a field of 52 timber, 3 concrete and 10 rock groynes.

The earliest of the 51 new groynes were built with a high profile at the outer end. Later groynes were built with the planks at a lower level as an economy measure to reduce costs. The Greenheart piles were placed to the same level leaving the possibility of raising the groynes at a later date. Either horizontal planking or vertical sheeters were used. Five different experimental designs had been used between 1971 and 1975, including a permeable type of groyne. This design was not repeated as they suffered severe abrasion and members were lost. Additionally an aerial survey was done and identified these permeable groynes as being ineffective (at an exposed coast). Another type was introduced with a low profile, thinner planking (75 mm) and joints in planks at the piles to increase strength. By 1996 all five types of groynes had been demolished and replaced by the type proven to be best, with some additional improvements.

In 1987 an experiment was done using 5 different timber species for the planking on several adjacent groynes. All groynes had Greenheart piles, which showed gribble attack when inspected in 2000. The Greenheart planking showed the worst wear and Ekki planking least.

Monitoring beach levels within the groyne bays assesses the performance of the groynes. This has led to several improvements in both the profiles and positions of the groynes. The improved and currently used design consists of 300 x 100 mm sheeters and planking attached to 305 x 305 mm piles with stainless steel bolts. At the upper end lof the 9 m long piles 300 x 200 mm waling supports the structure. The profile was made steeper to match better with the beach profile. At the seaward end the level is low to reduce turbulence. A higher level at the seawall avoids transport of sand over the groyne. Plywood panels have been fixed to the downdrift side of the groynes to prevent the gaps between the planking from opening up, which led to considerable problems on earlier designs. The panels have to be replaced with time, but are efficient in that they reduce damage to the planks. Joints and fixings have also been reviewed. Planks are joined with butt joints at the piles (having previously been between the piles to make best use of the lengths of planking available), which are easy to construct and provide the groyne with greater strength.

Figure 5.1 *High quality groyne at Bournemouth*

Figure 5.2 *Stainless steel fixings and pile rings; plywood panels avoid transport of sand between planking*

Figure 5.3 *Planting posts in trench*

The Bournemouth Borough Council maintains and replaces the 51 timber groynes along their coast in a rolling programme. The groynes have a life expectancy of 25 years so two groynes are replaced each year. The present construction cost of each groyne is approximately £195,000 (around 2002), which is in part due to the small tidal range and the large length of the groynes, which necessitates considerable temporary works (a steel platform is constructed to provide access for a crane). The hard underlying strata necessitate pre-boring for the piles with high-pressure water lances.

5.2 Eastbourne, UK

More than a century ago a concrete seawall was constructed along Eastbourne's coastline (English channel, south coast, UK). Additionally oak groynes were installed in order to bring the dropping beach levels to a halt. Until the late 1980's these groynes were reconstructed and maintained when necessary.

In the late 1980's and early 1990's several storms caused permanent damage to Eastbourne's sea defences, leaving the town at risk of serious flooding. The sea front consists of a shingle upper beach with a flat sandy area uncovered at low tide. By the end of 1991 some areas were scoured out to bare rock and the beaches failed to recover. The exposed sea wall was regularly under attack of storm waves, and the groyne field in front of it severely damaged because of the extreme conditions. Broken timbers, high wave loadings and marine borer attack mainly caused damage. With the increased levels of attack and waves reflecting from the sea wall, the shingle beach had no chance of recovering at all.

After having evaluated numerous options, it was recommended a closely spaced hardwood timber groyne field to be constructed (**Figure 5.4**), controlling a new and wider beach. To determine the minimum beach volume required and the beach profile response to storm conditions, HR Wallingford carried out a flume study. The results were used for a wave basin physical model, to determine the optimal spacing and configuration. Finally the most advantageous design consisted of a replenished beach controlled by 94 groynes and further specific extra works on three locations.
The construction of the coast protection scheme was launched in 1995 and completed in 1999. The £30 million scheme included the construction of 94 new timber groynes, rock revetments at particularly vulnerable areas of the beach and extensive beach nourishment. The average cost of one timber groyne was about £95,000 (around 2000). Massive groynes were constructed, being designed to retain a 3 meter differential across them. In order to realise a beach width of 20 meter and a slope of 1:9, in total over 780,000 m^3 of shingle was pumped ashore after completion of the groyne field.


Figure 5.4 *Timber groynes Eastbourne, UK*

Each groyne was constructed with ties, consisting of entire Oak logs, attached to every fourth pile. The 230 x 75 mm planking and single 230 x 230 walings have been attached to the king piles (305 x 305 mm) using hot dipped galvanised coach-screws and bolts. The hard pile driving meant in some cases that the piles were stopped high and driven to the required depth after two to three tidal cycles. A gate was used to ensure that piles were square on the planking. In areas where the chalk platform made pile driving impossible, the posts were planted in a concrete filled trench. Sheeters below the planking were used where ground conditions allowed them to be driven.
In order to justify the decision to use ***Greenheart timber***, the consultant and council investigated its sustainability.
The Eastbourne groyne profiles runs under a slope, and protrudes only about a plank's width above the beach at the head. This has a positive effect on the sandy lower beach, as currents will remain limited and cause no significant scour. At the upper end of the beach, plant access bays have been constructed, consisting of

doubled piles at a wide spacing with extra thick planking spanning the entire width of the bay. When necessary the planking can be removed and plants can pass through the groyne. Especially in case of low beach levels, such as during construction this may come in handy to provide an exit for equipment operating on the beach. The high planking level over the entire length of the groyne provides no possibility to add planking. At some locations along the groyne's length it seems as if some planking may be better to be removed, to match the beach profile.

5.3 Tankerton, UK

The Canterbury City Council is responsible for the 16 km of coastline between Seasalter and Reculver along the Thames Estuary coast (North Kent, UK). The primary defence system of Tankerton is the shingle beach, which is controlled by timber groynes, see **Figure 5.5**. Just behind the shingle beach a seawall holds and protects a grass slope. The seawall was initially constructed in 1911 and has been refurbished several times since. In February 1996 a storm event removed a great deal of the shingle beach and undermined the seawall partially. An extensive survey was carried out for the beach level and wall condition.
The old timber groynes were constructed between the 1950's and mid eighties and their lengths, spacing and state varied considerably. The net littoral transport along the coastline is from east to west, with an estimated annual loss of shingle of 15,000 m^3. Until 1991 every two to three years the beach was recharged, allowing a five-year beach drop till the 1996 storm event took place.

Figure 5.5 *Ekki timber groyne*

The eroded beach exposed the underlying clay and the toe of the seawall in some areas, but in other areas the beach reached till the top of the seawall. Emergency works were carried out, filling the space beneath the toe with concrete and placing temporary fencing along the top of the wall.

The survey compared a number of alternatives for the Tankerton coastline and finally recommended the scheme with a beach and timber groynes. From mid 1998 works were carried out along the Tankerton frontage. A groyne field consisting of 36 timber groynes was constructed, and other groynes were refurbished. Additionally in total 122,000 m^3 of shingle was supplied to the beach.

The groynes are constructed with Ekki piles (230 x 230 mm) and planking (76 x 230). Some hardwood (Greenheart or Balau) was re-used from the demolition of the existing groynes, for sheeters, piles and struts. Both cantilevered as strutted piles have been used in the design, using Y-shaped raking struts as shown in **Figure 5.6**. The bottom planking acts as a waling with bolts countersunk in order to attach the sheet piles to them. At the landward end of the groynes, steel plates are attached to the top planking for plant access, together with cutting one pile flush with the planking. Other piles reach 300 to 530 mm beyond the highest planking, leaving the possibility to add one plank.

Figure 5.6 *Y-shaped raking struts (courtesy to HR Wallingford)*

5.3 Calshot, UK

New Forest District Council has renewed mixed softwood and recycled hardwood groynes and revetments over the last five years along the sheltered Calshot coastline. Calshot is situated along the Solent (south coast, UK) on a natural shingle spit with a large shoal area just offshore. The Isle of Wight protects the shore against large waves. This allows the existence of low-lying marshy areas along the Solent's shorelines, sometimes with a small shingle beach.

The New Forest District Council uses a maintenance-based approach for their shore protection structures at Calshot. Short zigzag shaped groynes (**Figure 5.7**) have been constructed using reused hardwood king piles with 2 meter long treated softwood piles between them. The neighbouring privately owned coastline of Lepe uses entirely Douglas fir groynes. The locally grown Douglas fir softwood erodes fairly rapidly and needs regular maintenance, and replacement after approximately 10 to 12 years. At the landward end the Calshot groynes connect to a timber breastwork, constructed with the same timbers and a geotextile to hold fine material in place. On either side of the king piles Greenheart waling is attached, leaving enough space for the round softwood piles to be placed between them. Pins are driven in a hole through the waling into the Douglas fir. The hardwood piles and waling are left in place when the softwood needs replacing.

Figure 5.7 *Low cost groyne at Calshot, UK*

5.5 Pevensey Bay, UK

Pevensey Bay's sea defences is situated along the English channel at the south coast of the UK.
The option of soft engineering by regular shingle nourishments is favoured for Pevensey Bay. Since 2002 the shingle embankment has been managed to a defined minimum width. As storms have eroded beach material and moved it east by longshore drift, it has either been recycled back to rebuild narrowed defences, or replaced by annual beach nourishment. This is achieved by dredging similar sediments from the sea bed and pumping them onto the beach. The advantages of this method are: minimum impact on the environment and much less expensive than hard engineering options. However, it requires constant maintenance.

Timber groynes are not being replaced at Pevensey Bay. The reasoning is that in recent decades advances in machine technology has meant that there are now different techniques that can be used, and as we become more aware of man's impact on our natural environmental, sustainability too is a major consideration.

Tropical hardwoods typically used for groyne construction take about 100years to grow and then probably only last 30-40 years. They grow in small groves and hence a lot of jungle is cleared when only a few trees are harvested. These days planning consent is unlikely to be granted for a timber groyne scheme, and there has been a move towards rock groynes, as at seen at Bulverhythe and Shoreham.
A well-constructed timber groyne is not cheap. For instance those at Eastbourne constructed 15 years ago cost £100,000 each.

Nourishment has advantages. Dump trucks used today carry 40 tonnes at a time. So in a single day each can shift significant quantities of beach from accreting to eroding areas. If undertaken regularly, keeping haul distances low, beach can be moved for less than £2 per m^3. Spending money on recycling shingle rather than groyne building allows resources to be mobilised as soon as there is a problem. In this way protection of "at risk" areas can be achieved more effectively, whilst retaining the flexibility necessary to target any and every area that needs repair.

Figure 5.8 *Pevensey beach shingle beach with old timber groins*

5.6 Summary of timber groyne data

Location	Type of beach	Type of groins	Length (m)	Spacing (m)	Tidal range (m)	Wave climate
Hurst castle; south coast along English Channel, UK	shingle	Timber	30	40	2 to 3	Moderate (swell)
Bournemouth; south coast along English Channel, UK	shingle/sand	Timber	80	170	2 to 3	Moderate (swell)
Shoreham; south coast along English Channel, UK	shingle/sand	Rock	60	100	4 to 5	Moderate (swell)
Eastbourne; south coast along English Channel, UK	shingle/sand	Timber	70	70	4 to 5	Moderate (swell)
Pevensey Bay; south coast along English Channel, UK	shingle/sand	Timber	60	60	4 to 5	Moderate (swell)
Calshot; south coast along English Channel, UK	shingle/sand	Timber	10	20	4 to 5	Sheltered behind Island of Wight
Tankerton,Thames Estuary mouth, UK	shingle/sand	Timber	40	40	2 to 3	Moderate

Table 5.1 *Summary of timber groyne data*

6. Summary and conclusions

The available options of shoreline management to deal with erosion problems, are:

- to accept retreat in areas where beaches and dunes are wide and high;
- to maintain the coastline at a fixed position (to hold the line) by hard structures and/or by soft nourishments;
- to bring the coastline at a more seaward position by reclaiming land from the sea.

If there is a substantial loss of sediment over a period of 5 years or so, it may considered to nourish the area with a sediment volume equal to the observed volume loss. Nourishment is the mechanical placement of sediment in the nearshore zone to advance the shoreline or to maintain the volume of sediment in the littoral system. It is a soft protective and remedial measure that leaves the coast in a more natural state than hard structures and preserves its recreational value. The method is relatively cheap if the borrow area is not too far away (<10 km). Beachfills are mainly used to compensate, local short-term erosion in regions with relatively narrow and low dunes (in regions of critical coastal safety) or when the local beach is too small for recreational purposes.
Although nourishment offers an attactive solution in terms of coastal safety and natural values, it may not be the cheapest solution because of the short nourishment lifetimes involved (regular renourishments every 2 to 5 years). In regions where sediment is not easily available, it should be assessed whether hard structures may offer a more cost-effective solution to deal with chronic erosion, particularly if rock is available at nearby locations.

Generally, hard coastal structures such as groynes, detached breakwaters and artificial reefs are built in urban areas to significantly reduce coastal beach erosion and to maintain a minimum beach for recreation.

Hard structures (groynes, detached breakwaters) require relatively high capital investments plus the continuous costs of maintenance works (storm damage, subsidence, scour problems, redesign, etc.) and costs of supplementary beach nourishments to deal with local erosion problems (opposite to gaps and along the downdrift side). Indicative figures are given in **Table 6.1**.

The construction costs of a short permeable timber groyne (pile screens only) with a length of 50 m (spacing of 75 m) is about 0.1 million Euro. Adding interest and maintenance costs, this will be about 0.2 million Euro over a lifetime of 30 years or about 50 to 100 Euro per m coastline per year.
The construction costs of a short impermeable timber groyne (with horizontal planking) with a length of 50 m (spacing of 75 m) is about 0.15 million Euro. Adding interest and maintenance costs, this will be about 0.3 million Euro over a lifetime of 30 years or about 100 to 150 Euro per m coastline per year.

The construction costs of a rubble-mound groyne with a length of 200 m (spacing of 600 m) is about 1 million Euro. Adding interest and maintenance costs, this will be about 3 to 5 million Euro over a lifetime of 50 years or about 100 to 150 Euro per m coastline per year.

Type of structure	**Construction + maintenance costs; 30 to 50 years (in Euro per m coastline per year)**
Short permeable timber groins (pile screens)	50 to 100 (30 years)
Short impermeable timber groins (horizontal planking)	100 to 150 (30 years)
Straight long rock groynes	100 to 150 (50 years)

Table 6.1 *Investment cost of timber and rock groynes*

7. References

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