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DEVELOPMENT OF NEW TIMBER PRODUCTS

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KENYA,

Technical Report: Construction of Timber Jetties for Small Boats*

Prepared for the Government of Kenya
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

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United Nations Industrial Development Organization
Vienna

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GLOSSARY

Every endeavour has been made to avoid the use of specialized engineering or nautical jargon. Technical words in English do not have the same meaning all over the world and conversely different words are used in different countries to mean the same thing. In this glossary the word used in the text is given first then equivalent words in brackets followed by a brief explanation of the meaning as used in the text.

Beam: (stringer, girder, joist) A long horizontal member carrying the deck.

Cap: (cross cap, waling) A horizontal single or double member fixed at the top of a pier.

Deck: (floor) Horizontal boards covering a boat or jetty.

Fender: A cushion made of old car tires, rope or other soft material placed between a structure and a boat to prevent damage to the boat.

Jetty: (pier, wharf) A structure built out from land to water.

List: Of a ship, to tilt or heel to one side.

Pier: (trestle, bent) A structure of two or more piles connected by caps and bracing.

Pile: (post, stake) A timber driven or fixed into the ground.

Pontoon: (float) A moored floating structure.

Spring Tide: The highest of high tides, occuring once a month.

Wharf: A structure built along the water's edge so that boats may lie alongside for loading and unloading.

1. Introduction

Water transport and fishing from small boats are important factors in many rural areas of developing countries. An important part of cargo transport is the land to water connexion. Sometimes a convenient beach or rock shelf is available, but in many cases, particularly in tidal waters or in lakes subject to seasonal variations in water level, a long tramp through mud at the water's edge severely limits the ease of the journey and the amount of goods which can be handled.

Construction of a jetty which gives easy access from the water to dry land can be an important factor in local development.

Although timber is an excellent and versatile material for most construction purposes, few species are naturally resistant to marine borers (or shipworms) 1/.

Treated timber, however, is an excellent material for the construction of jetties since it is:

- Resistant to marine borers;
- Resistant to fungal decay;
- Economical;
- Easy to work with simple tools;
- Easy to transport.

Care must be taken, however, in selecting the preservative since certain species of borer are tolerant to some substances under certain conditions and not to others.

This manual describes simple jetty construction in sheltered waters using treated timbers and also goes into the construction of floating pontoon landing stages.

Although written primarily for conditions prevailing in Kenya it should be applicable to other countries where small fishing industries

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1/ See Annex 1 for species list. Marine borers comprise 3 genera of molluscs - Teredo, Bankia and Martesia - and 3 of Crustacean - Limnoria, Sphaeroma and Chelura.

are being developed. A minimum of engineering knowledge has been assumed and the designs included should be capable of being built by a competent carpenter.

If a jetty is required in deep water, or where high waves or strong currents are encountered, expert engineering advice should be sought.

2. Siting and Design

Frequently a jetty will be built as an improvement to an existing landing place. In this case the navigational requirements will be satisfactory to the boatmen and the land access tracks and steps will be well established. Then only if there is some very good reason, should the site be varied by more than a few metres.

In this case where a completely new site is chosen, the following points should be considered.

- Suitability of water access at high water (consider choppiness of water).
- Speed of current at mid-tide, both flow and ebb.
- Mooring depth at low water. Can the boats in use safely lie on the bottom? Will construction of a jetty encourage boats of deeper draught to come in? In that case, are the approaches adequate?
- At the landward end, is the road/track system adequate? Are the ground conditions suitable for construction of roads/tracks/steps in the cliff side?

The national or local harbour or water authority may have jurisdiction over marine or inland water structures, and appropriate approval for construction should be obtained in writing.

Decisions must be made on:

(1) What depth of water is required at low water, and

(2) How far above high water the deck should be?

Question (1) on the previous page determines how far out the jetty should go and is determined by the type of boat which will use the jetty and the acceptability of occasional grounding.

Question (2) is a matter of user convenience. On the one hand it is desirable that the deck is dry under all conditions, but this increases its height, adds to costs and makes its use under average conditions more difficult. As a compromise, it is suggested that the deck should be built at the level of High Water, Ordinary Spring Tides. On a few occasions each year the deck will then be entirely submerged for a few hours.

To determine these levels, observations of high and low water should be made at around spring tide time. Then by reference to tide tables, published by the nearest Hydrographic Office or Ports Authority, adjustments to the measured heights can be made. Permanent reference points should be established, either by reference to a bench mark if surveyor's level and staff are available, or otherwise by stout pegs or marks carved in rock. It may be that construction will not start for some time after the survey is done and temporary reference points are easily lost. (See Annex II.).

In many situations a straight jetty is satisfactory. This is the case in a lake of uniform depth where boats may lie on either side. In a river or a tidal channel with strong currents, boats are preferably moored parallel with the current. If the lake or sea bed shelves very steeply, then it may not be possible to get enough length of jetty over deep water before construction becomes impossible. In coral formations, vertical underwater cliffs 20m deep may be encountered just one meter beyond low water mark.

In such cases the end of the jetty is finished with a wharf lying parallel to the shore. Such a wharf may be either 'T' or 'L' shaped in plan. The 'T' shape is rather more complicated to construct but is more convenient in use. The framing layout for both types is shown on Sheet 2 of the drawings. If necessary, the length of the wharf may be increased by adding extra bays.

A wharf will be subjected to heavier loads than the rest of the jetty and consequently should be built more strongly. This may be achieved by either:

(a) Using shorter span bays of only 3m as shown in the drawing of the 'T' head jetty.

(b) Increasing the number of beams in a 4.8m span as shown in the drawing of the 'L' head jetty.

In either case 20cm piles should be used for wharf structures.

The strength of the supporting structure must be adequate to carry the loads imposed. The jetties shown in the drawings are not intended for motor traffic. A crowd of people weighs about 390 Kg per square meter and the head of the jetty should be built to carry this load. On a long jetty it is most unlikely that a crowd will assemble over its whole length and a loading of 290 Kg per sq. metre should be adequate. A jetty of this strength will also carry loaded handcarts or donkeys.

The designs shown in the drawings will carry these loads. They will NOT carry motor vehicles. If there is any possibility of motor vehicles trying to drive on, a notice should be posted 'NO MOTOR VEHICLES'. Preferably a barrier of stone or concrete which they cannot negotiate should be erected.

3. Foundations

The most difficult part of jetty construction is the foundations. The bottom can range from deep soft mud to rock. Either extreme is easy to cope with and the most difficult situation arises when rock is overlaid by soft material which is insufficiently deep to support foundations, but which prevents dry access to the rock. In such cases, resiting the jetty may be necessary. The designs in this Manual are based on the use of round timber piles of 15 to 20cm in diameter which may be either driven using simple drop hammers or cemented into holes cut into the rock.

3.1 Pile Driving

Driven piles will be required in mud or sand. Small piles can be driven by hand. It is tiring work and as much depth as possible should be gained by excavation before resorting to driving. In this case, excavated holes should be back filled with granular meterial, well compacted.

Ideally, specialized equipment should be used, but this is expensive to hire and difficult to transport into remote areas. The simplest hand driving equipment consists of a shear legs with a block to hoist the hammer. The hammer should weigh at least 100 Kg, and consist of a length of steel bar 15 to 20cm in diameter with a 4cm hole bored through its long axis. One or two lifting loops are welded at the top end. The hammer is shown in Figure 1. The guide for this consists of a piece of steel bar about 1.5m long driven into the butt of the pile. Figure 2 shows the equipment in use. Initially the pile must be guided by at least three ropes attached near the butt or upper end which should be chamfered or banded at the top to avoid splitting.

If a winch is available it will generally have too much friction and inertia to run freely with such a relatively light hammer. In this case a tripping hook (Figure 3) should be used to let the hammer fall freely.

In dense sands and gravel, driving may be eased considerably by jetting. This consists of pumping water at high pressure down a pipe nailed to the side of the pile, as illustrated in Figure 4. The water loosens the soil round the pile tip and can permit driving in otherwise impossible ground. Jetting also lowers the bearing capacity of a pile very greatly and must be discontinued 30 or 40cm above the desired final level, after which the pile is driven without jetting. Even if the pile does not move after jetting has ceased, about 20 blows should be given to consolidate the soil around the pile by vibration.

Pile driving over water can be done from a pontoon about 3m x 5m constructed of timber and oil drums. (See Figure 5). At least two drums should be used at each corner of the pontoon. Heavy anchors

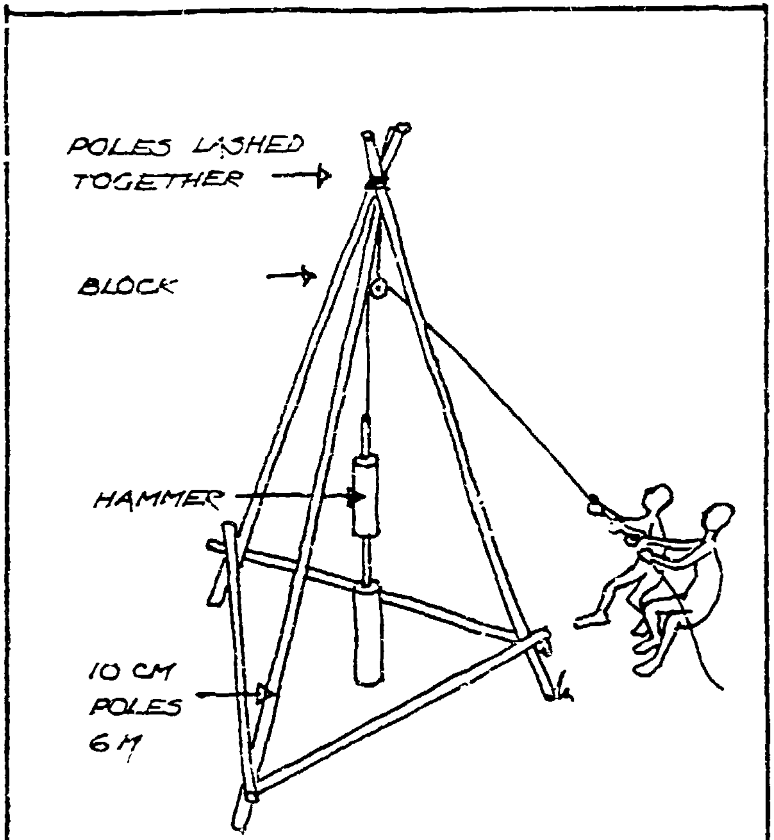


FIG 2

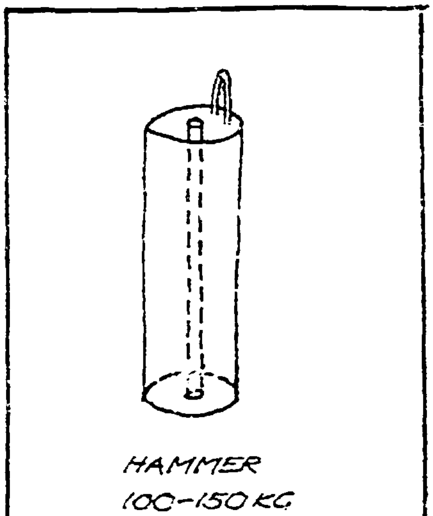


FIG 1

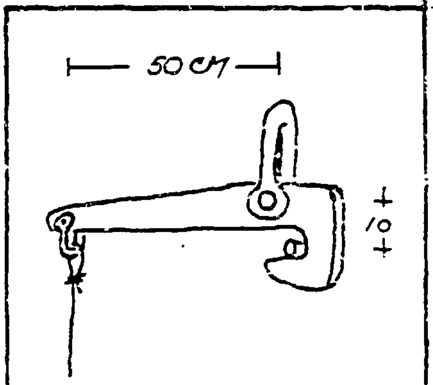


FIG 3

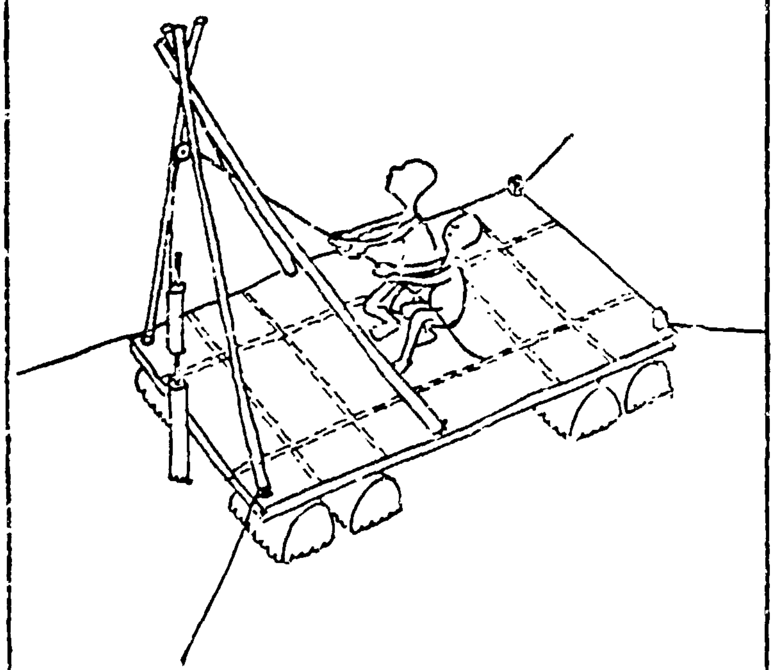


FIG 5

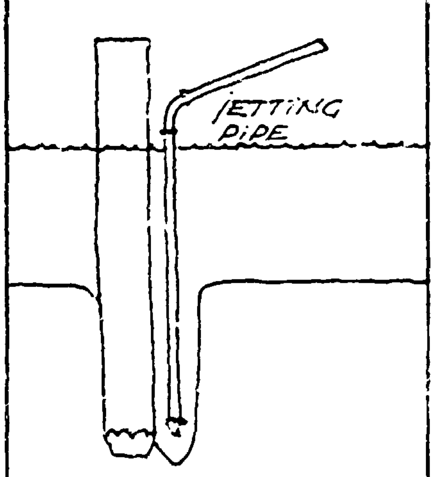


FIG 4

are required for accurate positioning and adequate cleats on the pontoon for easy manouvering.

Pile driving may be daunting to those who have never undertaken it, but it is quite a simple job even with primitive equipment. A foreman who can control the workmen is essential for an effective team effort and for the tricky first few blows when the pile is not adequately held by the soil.

3.2 Bearing of Piles

The maximum load on any pile in the designs shown is 1750 Kg and piles should be capable of taking this load.

If a pile is driven to refusal on solid rock, or cemented into a pocket out into rock, then its bearing power will be the area of the pile multiplied by the allowable end grain compressive strength of timber provided the pile is well supported laterally. In the case of 15cm softwood piles in even the weakest species this will be about 10 tons, which is ample for these jetties.

In the case of driven piles not founded on rock a fair estimate of bearing power can be made from the Engineering News formula:

$$P = \frac{164\ W\ H}{S + 25}$$

Where
- P = safe bearing power, kilogrammes
- W = weight of hammer, kilogrammes
- H = height of drop of hammer, metres
- S = average penetration per blow of last 10 blows, millimetres

The maximum allowable "set" S required should be calculated for the hammer and height of drop being used from:

$$S = \frac{164\ WH}{1750} - 25$$

and driving should be continued until this value is reached. Remember, a set smaller than the calculated value is looked for, which indicates hard ground and high bearing power. If not too much more driving is involved, the pile should then be driven to its final level to avoid cutting off the heavily impregnated butt and exposing untreated wood.

If the required set cannot be achieved a decision must be made whether to:

(a) Drive another pile in each pier, making it a three-pile pier;
(b) Reduce the span of the beams, thus reducing the load;
(c) Relocate the jetty on firmer ground.

In mud, it may be impossible to get anywhere near the set required by the formula, but the Engineering News formula does not apply in mud in any case. If several metres of pile have been driven in mud, and it shows no sign of slowing down, it should be left for a day or two. Frequently the mud will harden up around the pile. A few blows will show if this has happened or not. If the pile cannot be started again all is well. In doubtful cases, an engineer experienced in foundations should be consulted.

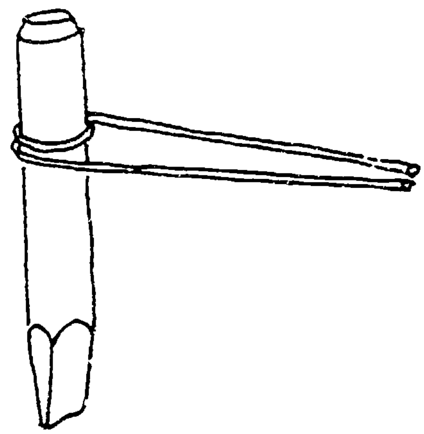
Generally, pile driving should start at the landward end of the jetty where working is easiest, and proceed towards the water. In this way the locally recruited assistants will be somewhat experienced when more difficult conditions in water are encountered.

3.3 Rock Foundations

In rock, including coral, all that is necessary to hold the pile is a pocket into which the pile is cemented using a sand-cement grout. The pocket should be about 10 to 15cm greater in diameter than the pile and about 30cm deep in solid rock, 50cm deep in soft or fissured rock.

A compressor and pneumatic rock drills are the easiest way of working rock, but for thousands of years rock has been cut by hand tools.

Heavy tools are best. Hammers should weigh at least 3 Kg, and chisels should have a blade about 3 or 4cm wide. Chisels should be held by an assistant with a gad, that is a handle made from 10mm rod wrapped completely round the chisel (Figure 6 shown hereunder).



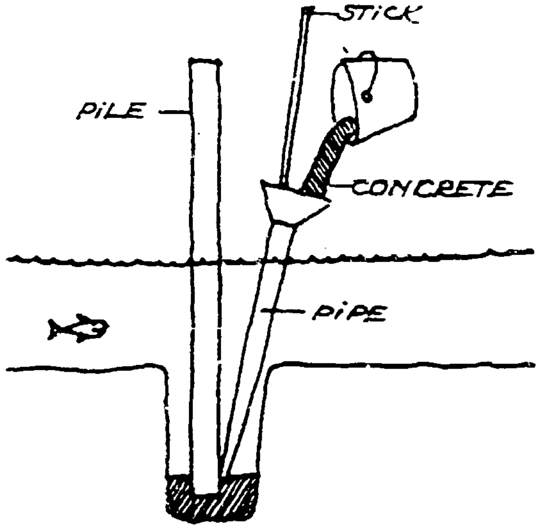
GAD - Figure 6

A blacksmith should be available locally for sharpening and tempering chisels and for grinding off mushroomed chisel heads. Mushroomed heads are dangerous and have caused the loss of many an eye. Masons should wear eye protection - PLASTIC lensed sunglasses are better than nothing if proper impact resistant spectacles are not available.

When placing piles, the holes should be carefully cleaned of any mud which may have settled, and baled out dry. The pile is placed butt down, the opposite of a driven pile and wedged in position with stones. The top should be braced temporarily so the pile is upright. Then 3 to 1 sand-cement grout is tamped into the hole, and the pile left alone for at least a week before any carpentry work is done on it. If this work is done at low tide and there is a possibility that the pile may float at high tide, then the pile should be tied down with wire to rocks or other weights placed near its base.

If the mortar must be placed under water, then a richer mortar, about 2 1/2 to 1 should be used, and it must be poured through a pipe into the bottom of the pocket (Figure 7 shown on the following page). In this way, the cement is not washed out of the mortar. The pipe can be a piece of 10cm rain water down pipe, with a funnel soldered to its upper end for easy filling. The bottom end may be flattened slightly to fit into the space between the pile and the wall of the pocket.

Figure 7



In use, the pipe is partly filled with mortar and one man stops this from falling out with his hand or a strip of sacking. The pipe is lowered into the bottom of the hole and the mortar is allowed to flow out. More mortar is poured down the pipe and worked out with a stick. The mortar is placed at the bottom of the hole without falling through water. This is most important. As the level of the mortar rises in the hole, so the pipe is withdrawn. The cement is not washed out of the mortar, which sets at its full strength. The freshly placed mortar should be protected by a few shovelfuls of stones carefully placed on top.

3.4 Bracing

Short piles firmly held at their base are quite stiff. Longer piles are more flexible and to stiffen the jetty in a sideways direction, diagonal bracing is required. Details of how this is fixed are shown in the drawings.

Although Drawing 2 states that no bracing is necessary for piles under 2 metres high, it may be found that piles driven into soft mud are too flexible, even though they are only 2m above the surface. In this case, bracing can be applied to stiffen the jetty up.

Wharf structures built at the head of a jetty will also require bracing. This should be applied to all pairs of piles the standard 1650mm apart, but it may also be necessary to brace in the direction of the wharf if large boats are constantly tying up as in the case of a ferry.

For most jetties there should be no need to apply any bracing in the length of the jetty. In the case of short very high jetties with long piles, these may move too much in a lengthwise direction. In this case, two more piles should be driven at mid-span of one bay preferably the end bay and a pier complete with cross caps built. This can then be braced to the existing piles on either side. (Sheet four of the Drawings).

It is highly desirable that all holes in piles and braces should be bored before the timbers are treated. This is not always possible where piles are driven, but where piles are cemented into rock careful measurements should allow the lower holes in the piles to be bored, and in any case the lower holes in the braces can be bored 200mm from one end of the timber. These holes should be the same size as the bolts, and the bolts are driven in, using a block of hardwood over the head to avoid damaging the galvanizing.

When applying bracing, put the brace in position and nail it. Then bore through the pile, using the pre-drilled hole in the brace as a guide. Place this bolt, then bore through the upper brace and pile in one operation. A short section of pile top, or two off-cuts from braces are used to pack the braces apart where they cross and these are also bored in one pass.

The upper ends of braces should be cut off neatly to give a workmanlike appearance.

4. Construction of Jetty

4.1 Carpentry

The designs have been made so that a minimum of skill and specialized tools are required. This is achieved by:

(1) Careful ordering of timber cut to length at the sawmill.
(2) Maximum use of lapped joints.

Nevertheless, some site cutting and fitting is required.

The following tools will be required:

- Several heavy (20 or 22 ounce) carpenters claw hammers
- Cross cut saw (a bow saw is satisfactory)
- 20cm try square and pencil
- 25mm chisel
- Adze or jack plane
- 60cm builders level
- 5m or 10m steel or fibreglass measuring tape
- 1m or 2m folding rule or steel tape
- String line
- Augers or brace and bits 14mm, 20mm, and 22mm
- Tool Sharpening Devices
- Saw Vice
- Saw set
- Triangular file
- Oilstone and oil

Sparpening of tools should only be done by the most expert carpenter.

Most of these tools are illustrated in Figure 8 on the following page. Step-by-step instructions are illustrated in Figure 9 of page 14.

Figure 6: Carpenters Tools

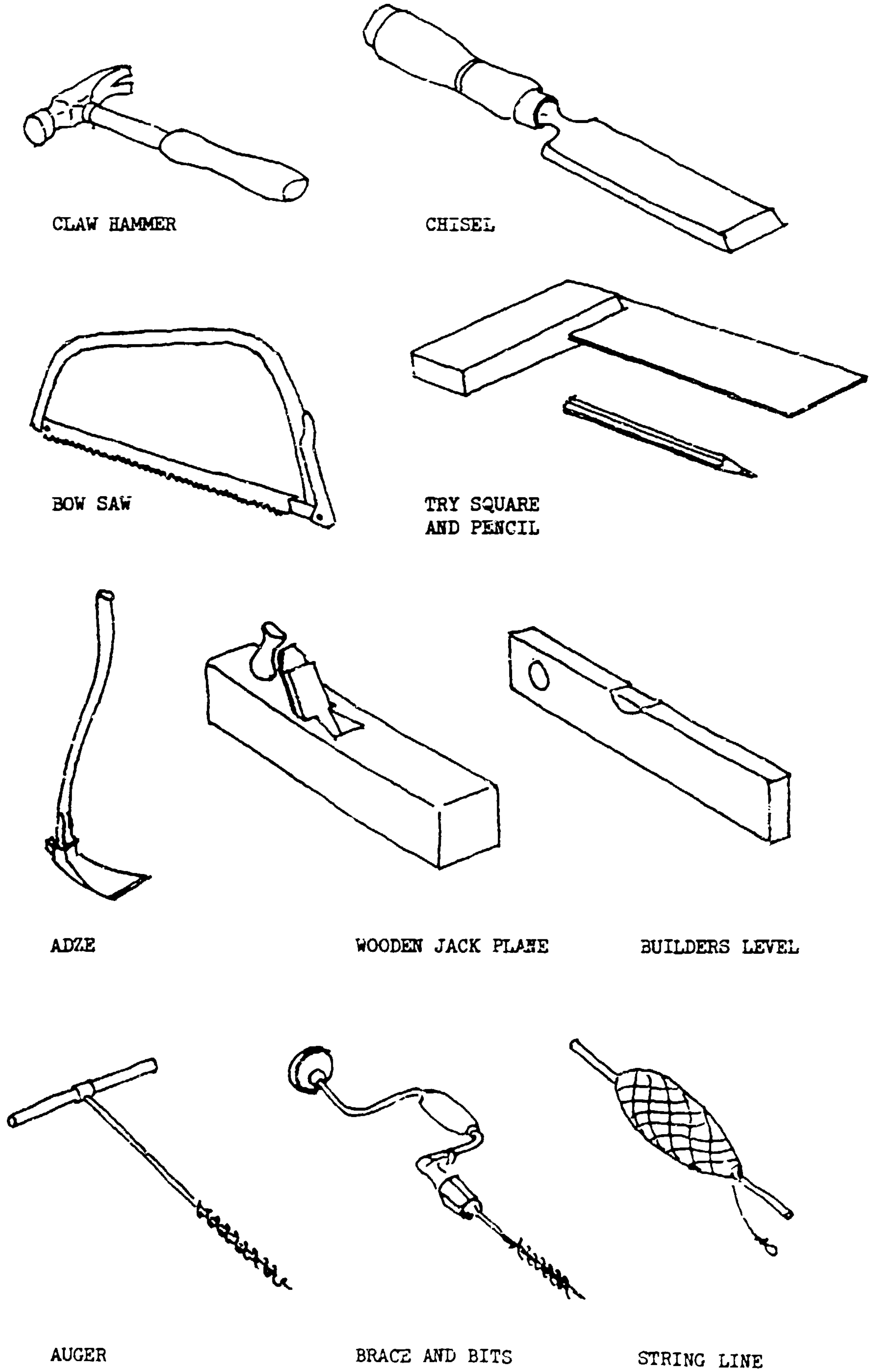
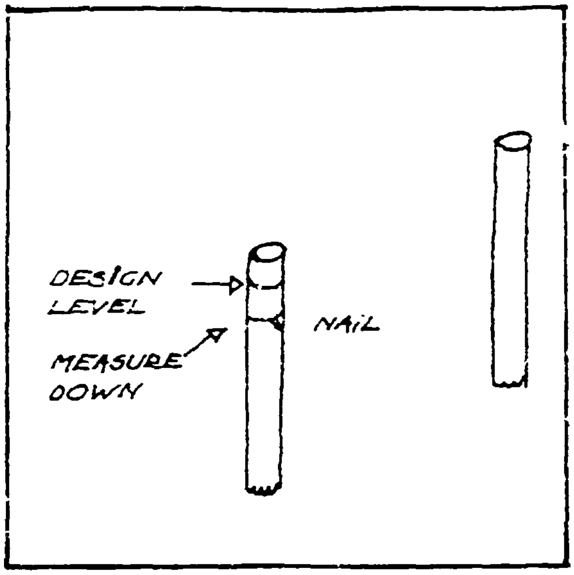
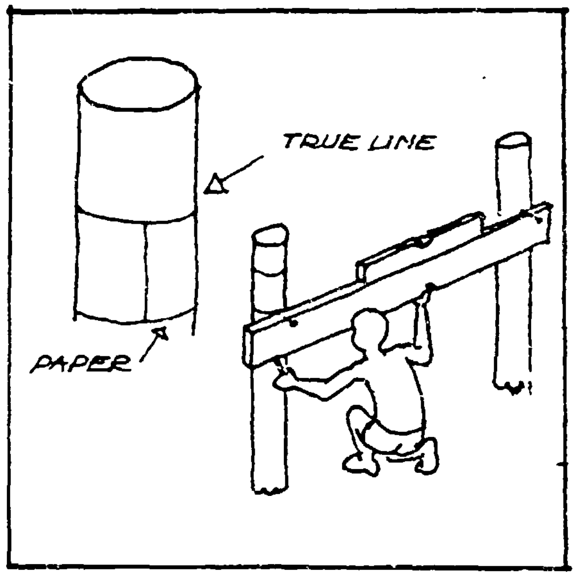


Figure 9: Construction Carpentry

1) Mark the design level of the deck on the pile. Measure down from this, the total of the thickness of the deck plus the depth of the beams.
Partly drive a nail at this point.



2) Place a cross-cap in position under this nail and level across to the other pile. Drive another nail. Mark the top and bottom notches from the cap. Mark around the surface of the pile by wrapping a piece of paper round, and mark along its edge to get a true line.



3) Temporarily nail a board across the two piles just under the lower marks. Using this as a guide, saw the bottom of the notches move the board up to the top marks and repeat. Make two or three more cuts in the notch to help removal of waste.

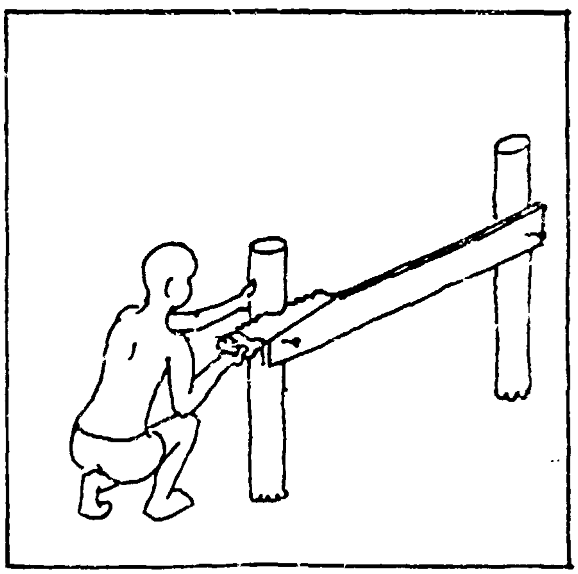
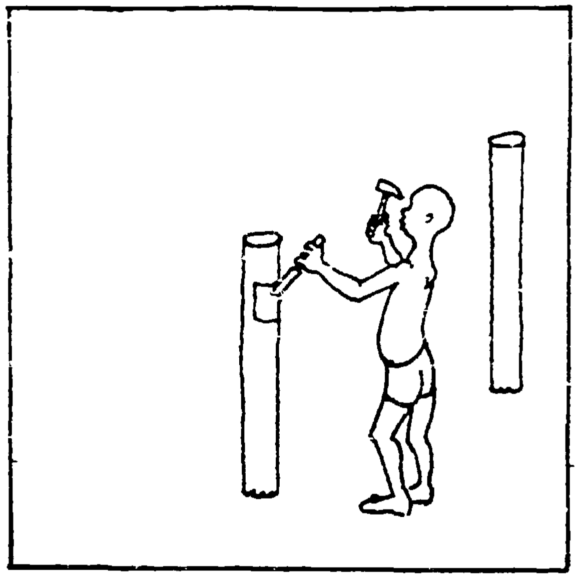
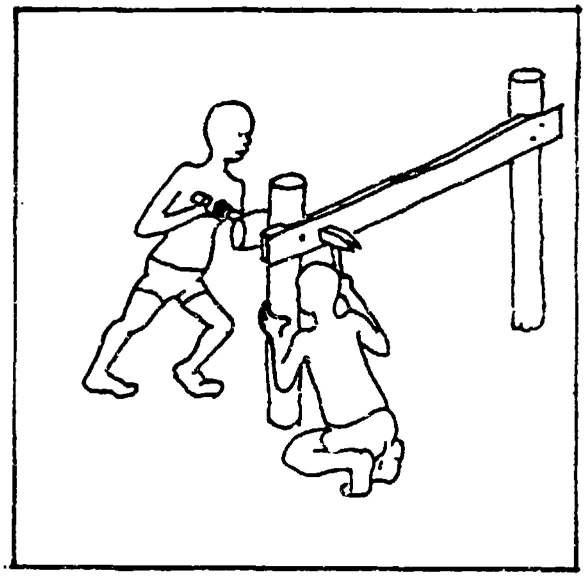


Figure 9 Cont.

4) Chisel out the waste wood, so the cross-cap fits neatly in the notches.



5) Partly nail in position, holding a heavy weight behind the pile to stop it bouncing. Place the second cross-cap in position, levelling it from the first one. Repeat the marking, sawing and chiseling. Nail both cross-caps in place. If the design calls for bolting, drill the bolt holes and place bolts.



6) Cutt off the pile tops about 2cm below the height of the beams (except if mooring cleats are to be fixed - See Figure 12).

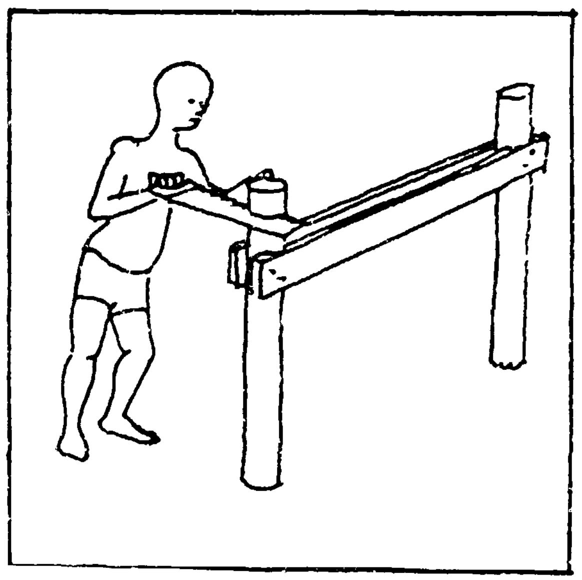
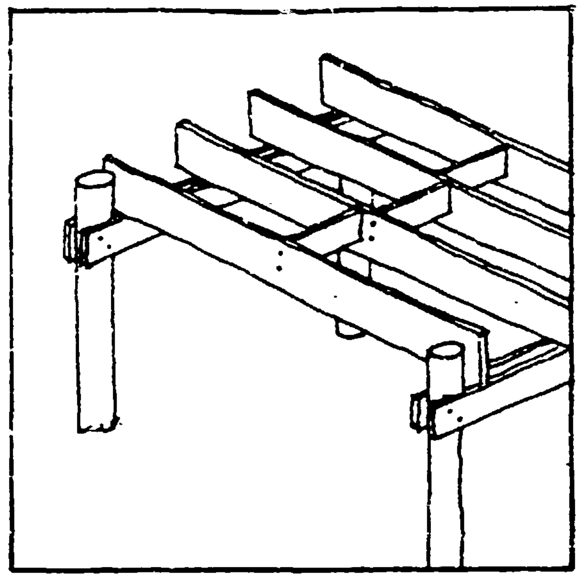
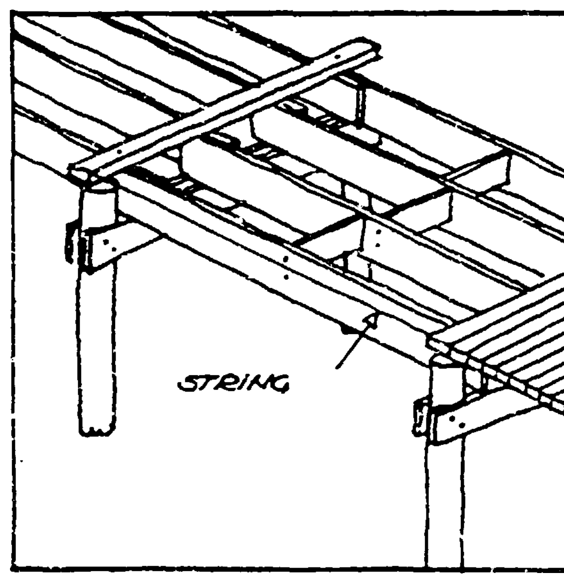


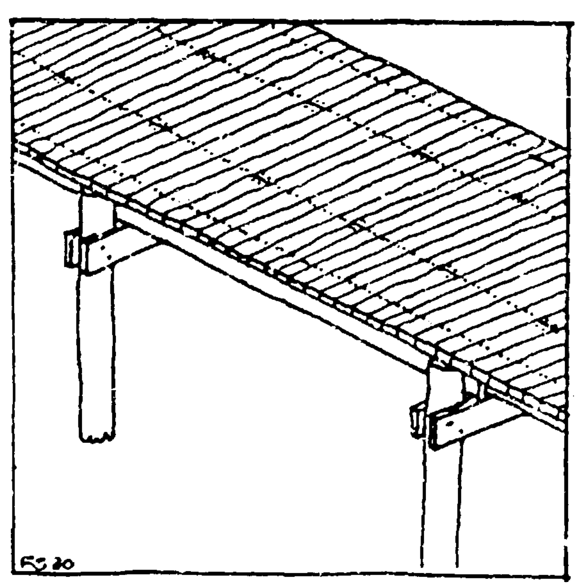
Figure 9 Cont.



7) Place the beams in position and nail. Measure the length of the blocking at mid-span. Cut acurately to length and nail in position. If there is any irregularity in the height of the beams where they rest on the caps, plane or adze them to level.



8) After three bays are completed start laying the decking. Temporarily nail a deck plank to the beams ahead, and use it to attach the string line. Line up the end of the decking to this.



9) Space the planks about 6mm apart (the thickness of a 125mm nail). Every third plank may be joined alternately on the centre beams. Saw off any irregular deck plank ends to a straight line. If required, nail or bolt down kerbs and erect hand rails.

4.2 Timber

The best timber for jetty construction is low density pine, heavily impregnated with copper-chrome arsenate (CCA) preservative salts. This timber has several advantages:

- It is generally readily available.
- It is not very expensive.
- It has a long proven life against attacks by marine borers and fungi.
- It is easy to work.
- Mechanical damage is easily repaired.

Alternative preservative treatments are frequently referred to, particularly creosote or oil impregnation. In practice these are not available outside industrialized countries. Treatments consisting of soaking or brushing are ineffective in marine environments and should not be considered under any circumstances.

Some moderately durable hardwoods are available in a few localities. However, these are heavy, expensive and difficult to work. Also, while these hardwoods may be relatively durable compared with untreated softwoods, their durability is with a few exceptions much less than that of properly impregnated softwoods.

The treatment recommended for marine work is vacuum-pressure impregnation by the full cell (Bethel) process. This can only be done in a commercial plant.

The specification required, for any of the major commercial CCA salts is the following:

Piles and other round timbers in salt water:

- 25 Kg dry salt per cubic metre of timber. Minimum penetration 40mm or 100 per cent of sapwood.

Sawn timbers submerged on every tide:

- 20 Kg dry salt per cubic metre of timber. Penetration as above.

Round and sawn timber in fresh water:

- 13.5 Kg dry salt per cubic metre of timber. Minimum penetration 30mm or 75 per cent of sapwood, which ever is greater.

Decking, beams etc. generally above water level except in spring tides, in salt or fresh water:

- 10 Kg dry salt per cubic metre of timber. Penetration 10mm all round and complete sapwood penetration.

The preservation log sheets should be made available to the purchase, and the case of piles, every single piece of treated timber should be bored with a hollow borer at about mid-length and the penetration of the preservative checked by means of a colour test for copper penetration. The hole should then be plugged with a tightly fitting dowel, impregnated to the same retention.

Wherever possible, all timbers should be cut to length before treatment. The designs shown in this manual allow for a minimum of cutting to length on site. Where this in unavoidable, for instance in blocking pieces between beams, these should be cut only silghtly over length before treatment, so that a minimum of heavily impregnated end grain is removed in cutting to exact length.

4.3 Timber Grade

The grade of the timber used has an important effect on the strength of the final structure. Where grading is rigidly enforced, timber may be ordered with confidence with no allowance for pieces which do not meet grade requirements. Where this is not the case, additional quantities of timber may have to be ordered to allow for pieces under grade. This applies particularly to beams. This under grade timber need not be wasted, but can be cut to shorter lengths for use as caps, blocking and decking. Although the drawings show 200 x 75 timber for caps, 300 x 50 may also be used.

Note: Working stresses used in the design were 1200 p.s.i. and 800 p.s.i. for "second" and "third" grade sawnwood (roughly 8.3 and 5.5 N/mm^2). The grading rules described here are considered suitable for the purpose considering the nature of the structures and with the simple precautions, described later, taken. They are a condensation of the Kenyan Standard Timber Grading Rules and are very similar to the Australian Structural Grade No. 3 and several American rules for medium quality grades.

The grades required are:

Piles:

Minimum tip diameter 150mm or 200mm as specified. Knots exposed on surface: One fifth of diameter where the knot occurs.

Straightness: The maximum sweep allowed shall be one half of the tip diameter, measured as the distance between a string stretched from the tip to the butt and the surface of the pile.

Figure 10 illustrates these defects.

Beams:

Second strength grade. This allows for:

Edge knots - half thickness (25mm). Margin knots - one quarter width (75mm). Centre, Splay and Cluster knots - one third width (11mm).

Slope of grain - one in eight.

Pith may be allowed provided it occurs only in the centre third of the face. (This is normally not allowed in official grading rules but is acceptable for this purpose).

(Figures in brackets refer to 300 x 50mm timbers).

Figure 11 illustrates these defects.

Caps and Bracing:

Third strength grade. This allows for:

Edge knots - three quarters thickness (56mm). Margin knots - one third width (67mm). Centre, Splay and Cluster knots - one half width (100mm).

Slope of grain - grading rules do not normally restrict this but for this purpose it should be no steeper than one in six.

(Figures in brackets refer to 200 x 75mm timber).

Blocking and Decking:

These pieces are not highly stressed and a lower grade even than third may be used provided some discretion is used by the carpenters as to the location of the worst defects. Decking pieces may be tested by supporting them as they will be in the jetty and jumping hard on any suspect defects. This sounds crude but is very effective.

Beams and caps should be placed with the largest knots on the top side. Also, the best quality pieces should be reserved for the end of the jetty where loads will be heaviest, and lower grade pieces used away from the end where crowds are not likely to gather.

Figure 10: Maximum Allowable Defects in Piles

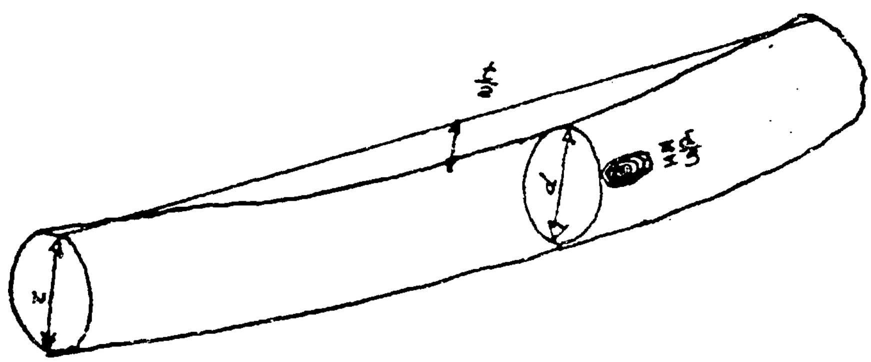
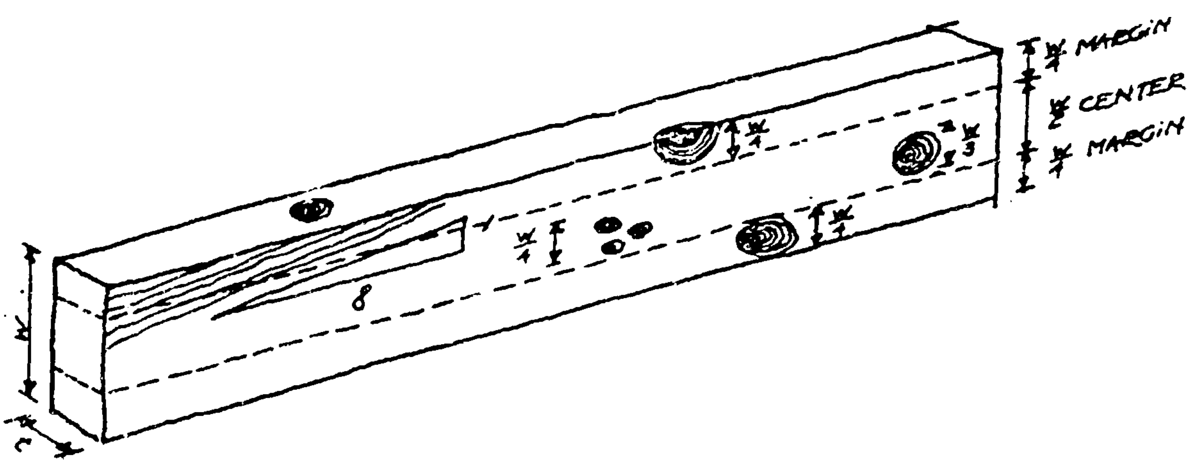


Figure 11: Maximum Allowable Defects In No. 2 Stress Grade



4.4 Hardware

Damp, salt laden air is highly corrosive to steel, and without protection steel fastenings will rust away to nothing in a very short time. The most common and highly effective protection is Hot Dip Galvanising. This consists of dipping the chemically cleaned steel into a bath of molten zinc. For even more protection double galvanising, that is two dips, may be used.

Galvanising may be applied to nails, spikes and bolts, also to steel straps, brackets and other fabricated parts. In all cases it should be the last operation done to the steel. In the case of bolts it will be necessary to undercut the threads before galvanising otherwise it will be impossible to screw the nuts on. 1/

Care should be taken with galvanised steelwork not to damage the coating of zinc by bending or bruising the steel. The use of ring or socket spanners is advised for nuts and bolts since these bear on all six faces and are much less damaging than ordinary wrenches.

Galvanised steel is highly resistant to corrosion so long as there is no movement against it. Therefore a short time after erection, a check should be made over the whole jetty for any loose joints and these must be tightened.

In the case of moving parts such as in pontoons and link spans, extra thickness of metal must be provided, or non-corrodible metals such as stainless steel or bronze (not brass) should be used. These metals are expensive but some enquiry may turn up worn out stainless steel pump shafts which can be used as hinge pins, axles etc. Scrap stainless pipe from chemical or food processing plants is also frequently available and if flattened can be used for straps subject to chafing on pontoons.

Alternatively, durable hardwoods of appropriate size will frequently give a longer life than unprotected or even galvanised steel.

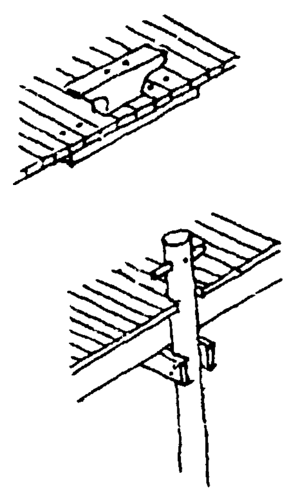
1/ Calculated undercut is 0.4mm on diameter but no exact guidance can be given due to differences in alloy, bath temperature and local engineering tolerances.

Cast iron, while subject to rust, is more resistant than steel to rusting.

4.5 Mooring Cleats, Handrails and Ladders

The drawings show jetties without any extras. Generally a few mooring cleats will be useful. Cleats can be carved from timber and bolted to at least two deck planks with a reinforcing piece beneath to further spread the load. Where the tidal range is large, cleats bolted onto the piles at about mid-tide level are also useful. A good cleat can be made by leaving a pile to extend about 20cm above the deck, and boring it to take a piece of 25mm galvanised water pipe 10cm above the deck. The pipe should be about 30-35cm long.

Figure 12: Mooring Cleats



Kerbs are a safety feature and can consist of 10cm x 5cm timber supported on blocks of the same size. They should be fitted wherever the height of the jetty exceeds 1.5m, where handcarts are used or where animal traffic is expected.

Handrails should be fitted on all high jetties where passenger traffic is expected. They must be substantial if they are to be of any use. They may be omitted if a jetty is used purely for fishing or other industrial purposes.

If the jetty is more than about 1m above low water, steps of some sort will be required for access from boats. These can take the form of vertical ladders or inclined steps.

A ladder may be constructed between two piles by nailing horizontal lengths of 10cm x 5cm to the piles. The timber chosen must be of the best grade available. It can be selected from the decking planks. (See figure 12A)

5. Pontoon Landing Stages

If the tidal range is high, there is some advantage in having a floating pontoon which boats can lie alongside. There are several advantages in this:

- Mooring is easy at all stages of the tide.
- Unloading and loading of passengers and cargo is simple and quick.
- Fender problems are small.
- Mooring lines to boats alongside do not have to be constantly adjusted.

This construction, however, has its own problems:

- Moving parts need maintenance.
- A long link span must be provided to avoid excessive slope at low water.
- The pontoon is expensive to build, maintain and repair.

A general arrangement of a pontoon landing stage is illustrated in Figure 13 with details on Sheet 3 of the drawings.

Ladder- Figure 12A

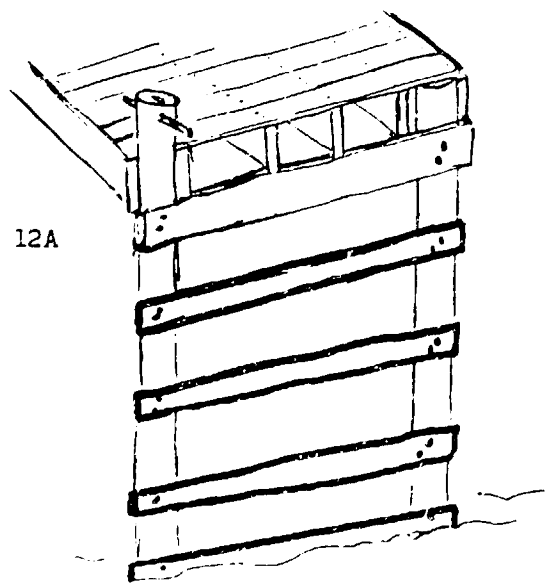
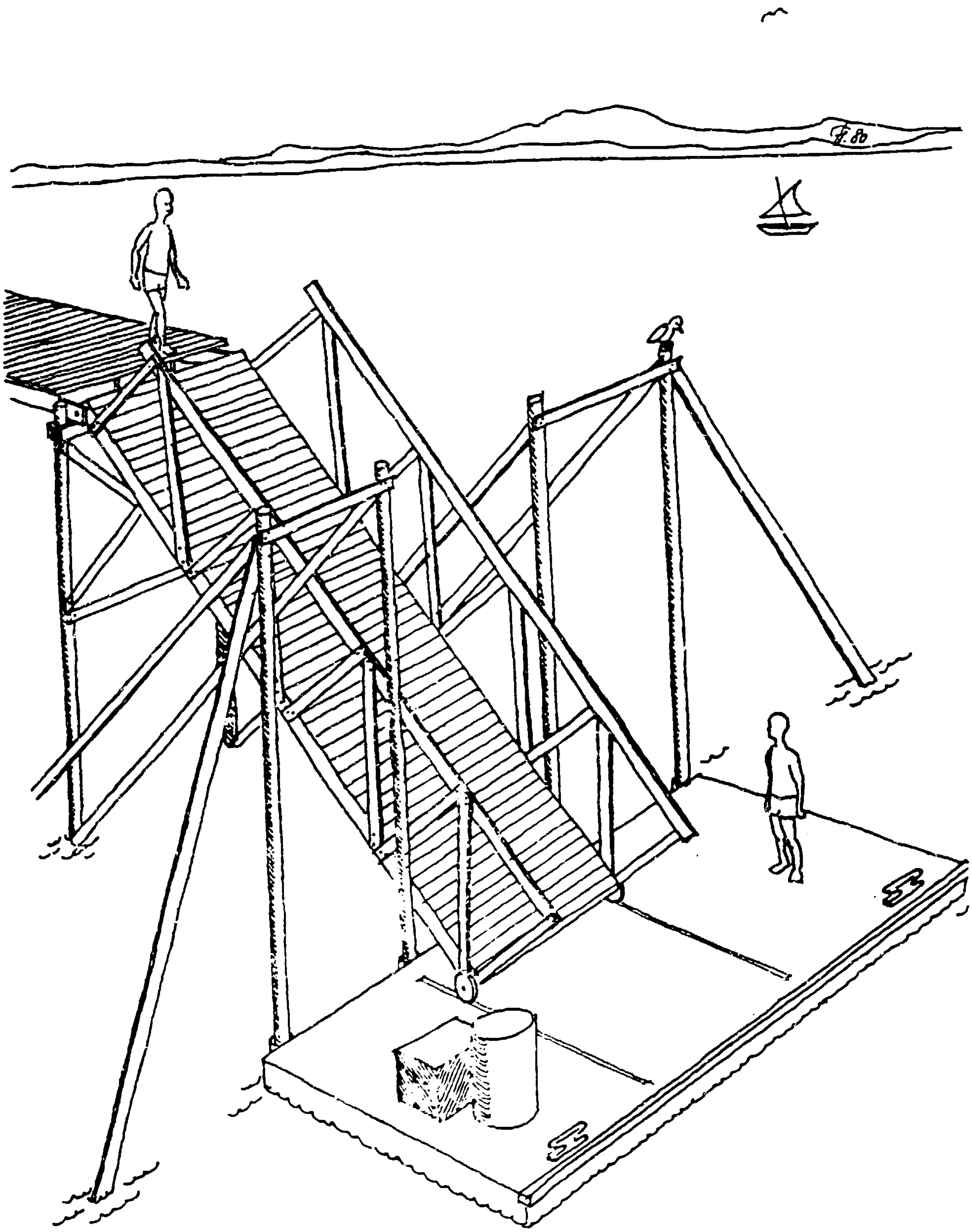


Figure 13: Pontoon Landing Stage



5.1 Pontoon

Probably the cheapest way of providing a pontoon is to obtain an old boat which is no longer seaworthy but is still sufficiently sound so that it can be made watertight. Alternatively a wooden or concrete hull must be built. Construction of hulls is outside the scope of this Manual. For construction of concrete hulls reference can be made to "Boats from Ferro-Cement", ID 85, United Nations, New York 1972, Sales Number E. 72 II B 23.

Fibreglass or steel floats can also be used if available and economical. Steel must be at least 6mm thick and has to be regularly maintained. Old oil drums are not thick enough for a permanent pontoon in salt water and will quickly rust through.

The pontoon should be at least half the length of the longest boat which will come alongside, and in any case not less than 6m. It should be fairly beamy (wide), about 3m, so that loads placed at its seaward edge where most activity takes place will not cause it to list too much. For this reason a flat bottom is preferred to a round bottom. Also it must be wide enough to allow the link span to move over its full range. Where the link span runs the deck should be specially strenghened.

The pontoon should be equipped with mooring cleats and fenders on its seaward side and both ends. A heavy timber rubbing strake covered with old car tires split open and nailed to the strake is satisfactory.

If the pontoon is completely decked, then a hatch must be provided for inspection and bailing out.

The pontoon is moored to four piles by loose fitting rings. These allow it to ride up and down the piles with the tide. The piles should be at least 20cm in diameter and driven or grouted deep into the ground. They must be absolutely straight and free of any bumps which could cause the mooring to bind. Also they must be absolutely vertical. The tops should be braced back to the ground to take the force of the pontoon when the current in the channel is running. Braces should be both endways and sideways.

The straps holding the pontoon should be about 10cm bigger than the diameter of the pile. For a 20cm pile the straps should be 30cm inside measurement. If the straps are made of steel they should be heavily galvanised and made of thick steel to allow for corrosion. A section of 75mm x 20mm minimum should be used. Alternatively, hardwood bolted together as shown is also suitable (See sheet 4 of Drawings).

5.2 Link Span

The hinged link span serves as the connexion between the floating pontoon and the fixed end of the jetty. It is hinged to the jetty and has wheels at its lower end which run on the deck of the pontoon. This portion of the deck must be heavily reinforced.

The hinge can be made from a piece of 50mm shafting working in hardwood blocks bolted to the beams of both the jetty and the link span. Besides the vertical tidal movement some lateral movement must be provided to allow for the movement of the pontoon. The holes in the bearings should be bored 10mm over size to allow for this. For 50mm shaft bore 60mm holes.

The link span should be as long as possible to give not too steep a slope at low water. At high water it will be more or less horizontal, but if it is too short, at low water it may be too steep to climb. For example with a 4m range of tide a 6m long span will slope at 42°; steeper than most flights of steps, but a 9m long span will slope at only 25°.

The deck of the link span must be heavily ribbed to allow people to climb it without slipping. A suitable method of decking is to lay two 10cm x 4cm timbers on their flat, then a 7.5cm x 5cm timber on its edge and so on.

The link span must have substantial handrails since they will be used by people to haul themselves up and should be braced lengthways as well as sideways. Handrails should be provided on both sides as negotiating the steep slope is the most difficult and dangerous part of the journey from land to water.

The wheels at the bottom of the link span should be about 25 cm in diameter. They can be made of hardwood, provided this is a type which does not split easily, or four layers of 25mm softwood nailed together with the grain of alternate boards at right angles.

Designs for 6m and 8m link spans are shown in the drawings, sheet 3.

6. Maintenance

All structures require periodic inspection and maintenance. Correctly treated timber needs less than most other materials, but trouble may be experienced in metal fastenings.

In a structure owned by an industry, there will be an officer responsible for buildings, repair and maintenance. In a communally owned structure, particularly co-operatives, there is often no person responsible for repairs.

In a community project formed to construct a jetty a particular person should be nominated to inspect the jetty and report on any necessary repairs to the local authority chief. Depending on what is required, appropriate action can be taken. The person nominated should be a frequent user of the jetty, as he is in the best position to observe defects developing. The senior boatman of the community would be a good choice.

In a special inspection of a jetty, which should take place once a year, every item of the structure should be checked. Two people should do the work, one inspecting and one taking notes. As each defect is found, an estimate of the materials required should be made, so that the total requirement can be worked out.

6.1 Maintenance of Jetty

Checking a jetty of the types shown should include the following procedure:

- Shake every pile to check that it is still firmly embedded;

- Check all bolts for tightness. If any are loose, see if they are so corroded that they need to be replaced;
- Check the tightness of seating of caps on piles. Probe timber joints with a knife or screwdriver for signs of softening and decay;
- Check the deck planks for any which are broken or weak;
- At the jetty end, check mooring cleats and fenders to see that they are firmly attached;
- Jump on every rung of the ladder;
- Where there are piles permanently under water, put on a diving mask and check the soundess of each pile;
- Scrape away any accumulated barnacles and oysters which can damage boats and cause injuries.

If a few tools are taken along minor jobs can be done on the spot.

Regular inspection and maintenance can keep a jetty sound for years. Complete neglect will result in any structure becoming dangerous, useless and derelict. This can become so extreme that complete rebuilding is necessary.

6.2 <u>Maintenance of Pontoons and Link Spans</u>

These being moving structures, wear is higher and maintenance more frequent than in fixed jetties. It is vital for the continued functioning that a person be in charge.

- The pontoons should be sounded for leaks and baled out at least weekly;
- The hinges, pins and wheels should be inspected and greased once a week;
- The pile straps and braces should be checked for wear and tightness;
- The link span and handrails should be checked for loosness in any place and tightened up as necessary. For the fixed part of the structure, inspection as described in the preceeding section will be enough.

ANNEX I

USE OF ALTERNATIVE TIMBERS

Piles in Salt Water

The principal requirement for piles is resistance to marine borer attack. The following species are some of those which have a relatively high natural resistance.

South America

1)	Greenheart	*Ocotea rodiaei*	Guyana, Suriname
2)	Basralocus, Angelique 1/	*Dicornia guianensis*	Guyana, Suriname
3)	Anaura, Marish, Kauta, Grigri	*Licania macrophylla* *Licania spp.*	Brazil, Suriname
4)	Manbarklak	*Eschweilera spp.*	Central America, Guyana, Brazil, Suriname, Venezuela

Africa

5)	Okan, Edum Denya, Adoum	*Cylicodiscus gabunensis*	Ghana, Nigeria, Cameroon, Gabon, West Africa
6)	Ekki, Azobé Bongossi, Kaku	*Lophira alata*	West Africa
7)	Sougué Pembe Mbura	*Parinari excelsa* *P. holstii*	Ivory Coast, Equatorial Guinea, Angola, Zaire
8)	Afzelia, Doussié	*Afzelia spp.*	West and East Africa
9)	Iroko	*Chlorophora excelsa*	West and East Africa, Angola

Asia and the Pacific

10)	Teak	*Tectona grandis*	Burma, Thailand, Indonesia, India
11)	Pyinkado, Irul Deng, Sokram Cam-Xe	*Xylia dolabriformis* *X. xylocarpa*	Burma, India, Thailand, Vietnam
12)	Thitka, Melunak	*Pentace burmanica*	Burma, Malaysia
13)	(Pink) Kanazo Sundri, Dungun, Cui	*Heritiera littoralis* *H. fomes*	Burma, India, Indonesia, Malaysia, Vietnam

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1/ Angelique gris is particularly resistant.

ANNEX I Cont.

Asia and the Pacific

14)	Belian, Billian, Onglen	Eusideroxylon zwageri	Malaysia, Indonesia
15)	Turpentine (bark left on)	Syncarpia laurifolia S. glomulifera	Australia
16)	Jarrah	Eucalyptus marginata	Australia
17)	Ironbark	Eucalyptus spp.	Australia
18)	Blue Gum	Eucalyptus globulus (and others)	Australia

It is the heartwood of these timbers which is resistant to attack (except Turpentine) and consequently they will be used in sawn sections. A few mangrove species are resistant to attack but only local experience will tell if they are resistant to local borers.

Use of Alternative Timbers - Decking, Beams, Caps and Piles in Fresh Water

The primary requirement for these timbers is durability against fungal attack. The stresses are relatively low, being the following:

Beams	1250 p.s.i. -	8.6 MPa
Caps	800 p.s.i. -	5.5 MPa

Almost any naturally durable hardwood will have allowable stresses in excess of these figures.

Other timbers may be used provided they reach these strengths and also provided they are capable of being impregnated with CSA salts. The local Forests Department and timber preservers will be able to give advice on these matters.

Being continuously in a damp environment the timber in a jetty is at extreme risk of failure by fungal attack. The use of timbers which are not of known high natural durability or which are resistant to pressure treatment is not recommended.

ANNEX II

SPRING TIDES AND SITE MEASUREMENT

Once each lunar month the level of high tide will be at its highest for the month, and low tide will be at its lowest. Twice a year the level of spring tides are greater than at any other time and twice a year they are at their lowest.

Tide tables give the times and heights of high and low tide and detailed examination of these is of great help in deciding the height to build a jetty.

The extract from a set of tide tables (seen below) shows the dates and heights of the monthly spring tides.

19Jan.	17Feb.	18May	15April	14May	13June
3.8m	3.8m	3.9m	4.0m	3.9m	3.8m
28July	26August	26Sept.	25October	23Nov.	22December
3.7m	3.8m	3.9m	4.0m	4.0m	3.9m

The heights for ordinary spring tides are 3.8m. Going through the tables for the year, the number of days that tides reach each level can be counted. Using the same table as above, the following data was calculated:

Height	No. of times in a year	No. of times tide reaches or exceeds height
4.0	6	6
3.9	9	15
3.8	17	32
3.7	18	50
3.6	27	77

With these figures, and remembering that half of these tides will occur during darkness, a balance can be drawn of inconvenience through the jetty being flooded at high tides against the deck being high above low

ANNEX II Cont.

tide and so, therefore, the cost of attaining a dry jetty for most of the year.

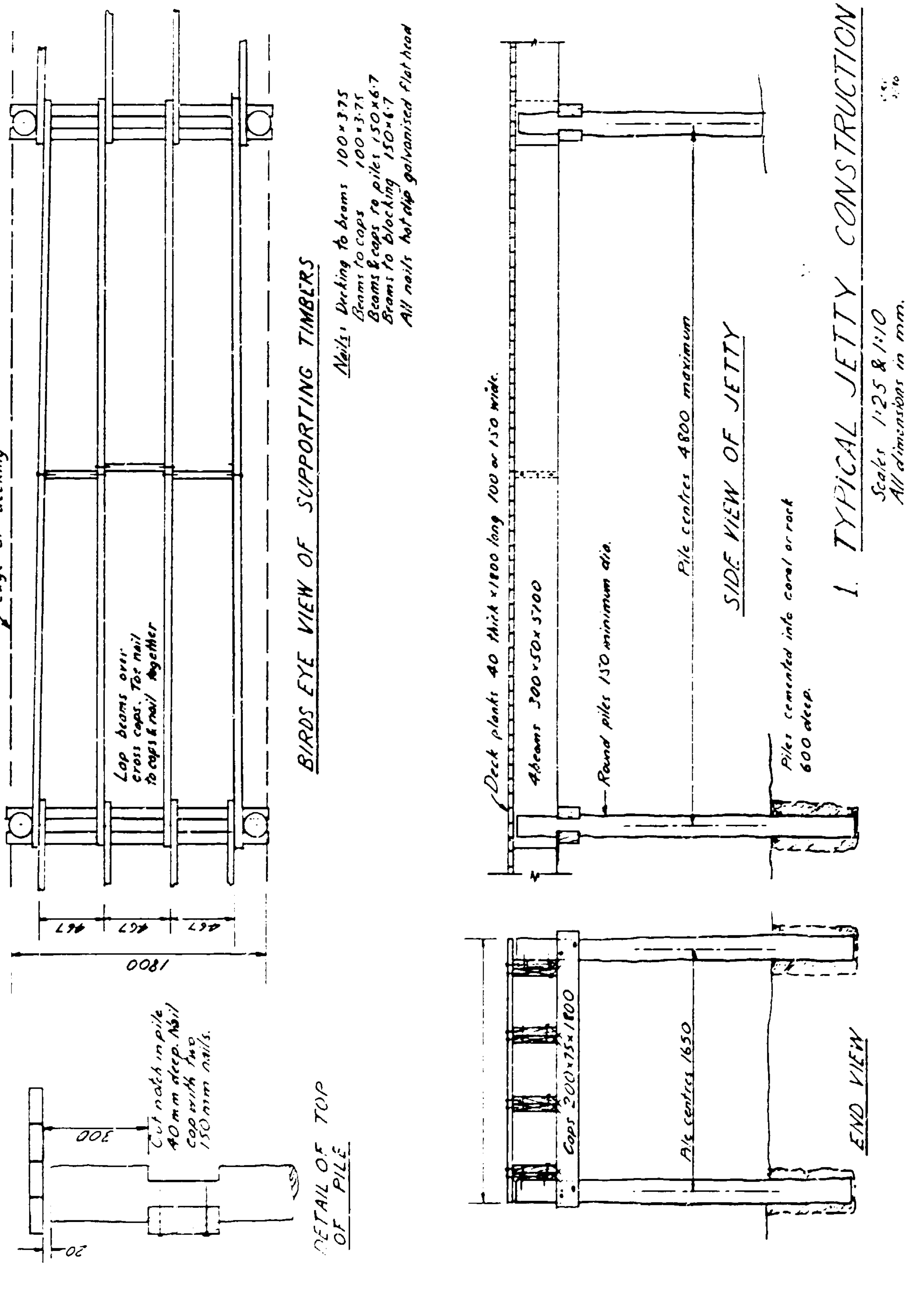
To relate these tide table heights to a particular site, a reference must be established. This can be a vertical cliff face well submerged at high tide or a vertical board fastened to a mangrove tree. This should have a scale of metres and tenths carved or painted on it. Then at each high tide for a number of days around a spring tide the water level should be recorded and noted against the tide table height thus:

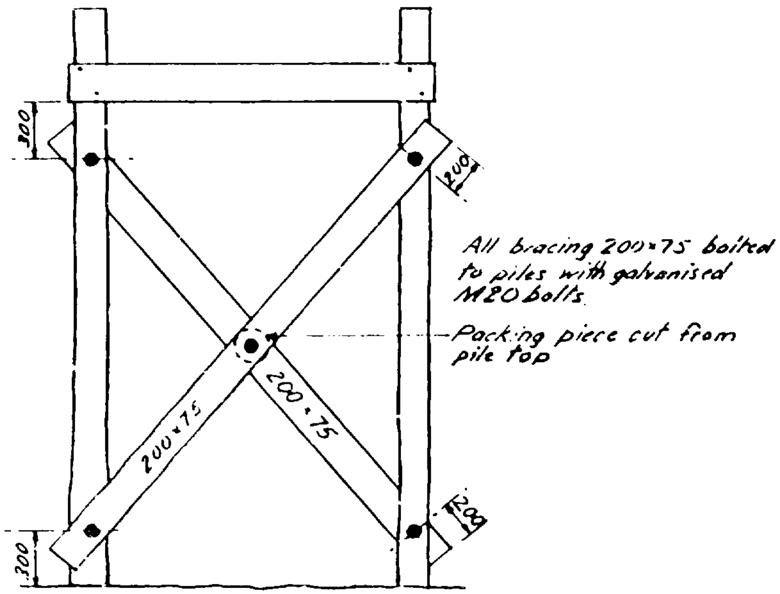
	Date	Tide table height	Observed height	Difference
Aug.	21	2.6	1.1	1.5
	22	2.8	1.4	1.4
	23	3.1	1.6	1.5
	24	3.4	No observation	-
	25	3.6	2.1	1.5
	26	3.8	2.2	1.6
	27	3.8	2.3	1.5
	28	3.7	2.5	1.2

The observation for the 28th does not tie in with the others probably due to an error in reading, so it is disregarded. The average of the differences is 1.5 so we can safely conclude that 3.8m in the tide table corresponds to 2.3m on our local gauge, and the jetty can be built accordingly.

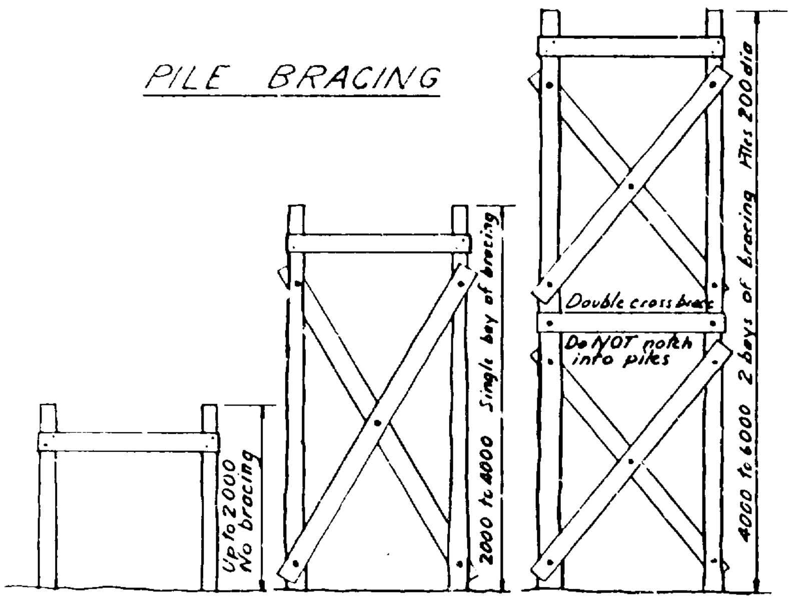
SHEET 1

TYPICAL JETTY CONSTRUCTION

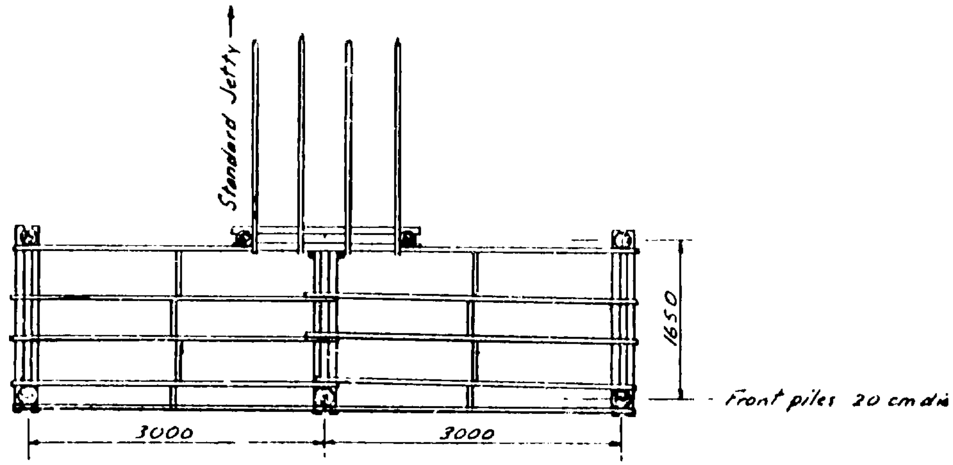




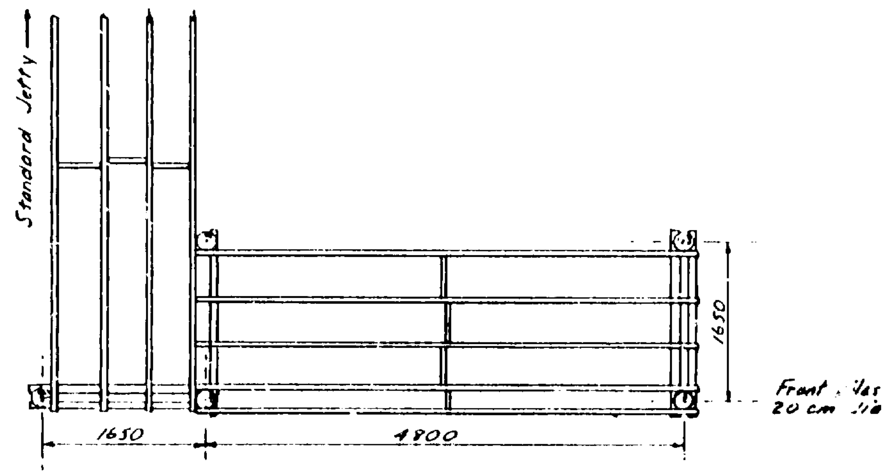
PILE BRACING



BRACING FOR VARIOUS PILE HEIGHTS



T HEAD WHARF



L HEAD WHARF

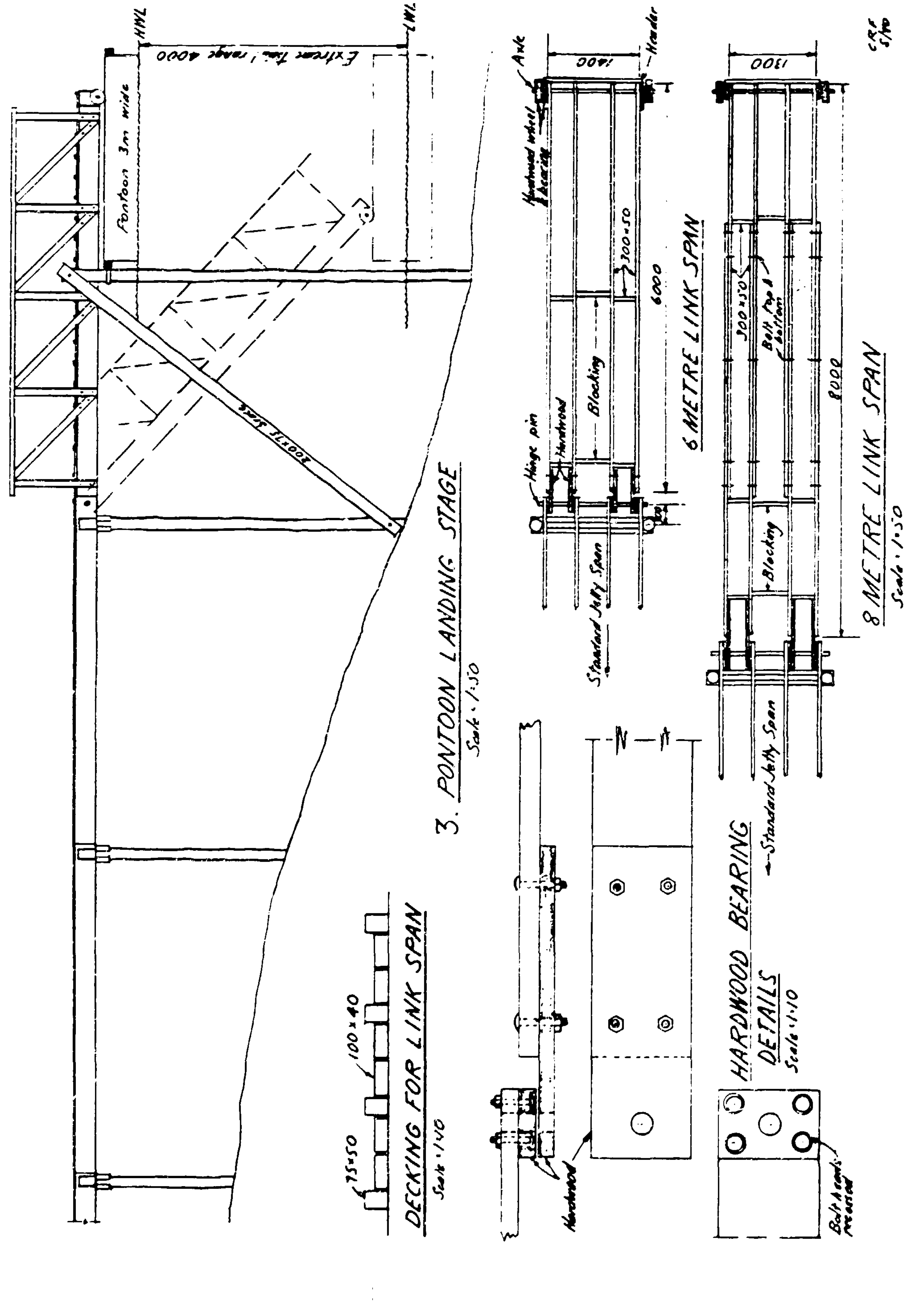
2. BRACING & WHARF DETAILS

Scales 1:25 & 1:50
All dimensions in mm

- 35 -

SHEET 3

PONTOON LANDING STAGE



SHEET 4

BRACING AND STRAPPING DETAILS