



ArcelorMittal

Steel Sheet Piles

Installation



INSTALLATION OF STEEL SHEET PILES

With the compliments of



PROFILARBED S.A.
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1. General

This manual provides an introduction to the methods of installing sheet piling, based upon the common experiences of the European Sheet Piling Producers.

A knowledge of the characteristics of the steel and the section are not enough to guarantee good results prior to installation.

The aim of this document is therefore to briefly describe the practical information to be considered to ensure proper product installation.

It aims to show the importance of predicting the drivability of pile sections after full evaluation of the ground conditions.

This is followed by an inventory of the existing driving systems, from impact hammers to vibratory pile drivers and special systems.

The manual then provides a description of driving methods, ancillary equipment, including guide frames, and guideline procedures to assist in providing good practice when installing sheet piles.

Finally some common installation problems are illustrated and special aspects of driving briefly outlined.

Please note: Care has been taken to ensure that the contents of this publication are accurate but TESPA does not accept responsibility for errors or for information which is found to be misleading. Suggestions for or methods of working are for information and guidance only and TESPA accepts no liability in respect thereof.



2. The Soil

2.1 Site conditions

For the successful driving of sheet piles, it is essential that a good knowledge of the site conditions is available to enable an accurate assessment to be made of the topographical and geological conditions.

Topography describes the particular environment of the site, and details working restrictions such as noise and vibration. Each site will be subject to its own unique set of restrictions which varies according to the proximity and nature of neighbouring buildings, road category, underground services, power supplies, material storage areas etc.

Geological conditions refer to the vertical characteristics of the soil strata.

In order to achieve the required penetration of the sheet piles, site investigation of the soils together with field and laboratory tests can aid installation by providing information on:

- a) stratification of the subsoil;
- b) particle size, shape distribution, uniformity coefficient;
- c) inclusions;
- d) porosity and void ratio;
- e) density;
- f) level of the groundwater table;
- g) water permeability of the soil;
- h) moisture content;
- i) shear parameters, cohesion;
- j) dynamic and static penetrometer test results and results of standard penetration or pressuremeter tests.

Generally only the results from section a), e), i) and j) are available.

2.2 Soil characteristics

The following table shows the density in relation to penetrometer and pressuremeter-test results for **non-cohesive soils**:

DPH ₁	SPT ₂	CPT ₃	Pressuremeter Test		Density
n ₁₀	n ₃₀	q _s	pl	E _M	
		MN/m ²	MN/m ²		
	< 4	2,5	< 0,2	1,5	very loose
3	4 to 10	2,5 to 7,5	0,2 to 0,5	1,5 to 5,0	loose
3 to 15	10 to 30	7,5 to 15	0,5 to 1,5	5,0 to 15	medium dense
15 to 30	30 to 50	15 to 25	1,5 to 2,5	15 to 25	dense
> 30	> 50	> 25	> 2,5	> 25	very dense

1 Dynamic probing heavy

2 Standard penetration test (dynamic)

3 Cone penetration test (static)

The consistency of **cohesive soils** in relation to SPT, CPT and pressuremeter-test results is as follows:

SPT	CPT	Pressuremeter Test		Consistency	Undrained shear strength
n ₃₀	q _s	pl	E ^M		
	MN/m ²	MN/m ²			kN/m ²
< 2	< 0,25	< 0,15	1,50	very soft	20
2 to 4	0,25 to 0,5	0,15 to 0,35	1,50 to 5,25	soft	20 to 40
				soft to firm	40 to 50
4 to 8	0,5 to 1,0	0,35 to 0,55	5,25 to 8,25	firm	50 to 75
				firm to stiff	75 to 100
8 to 15	1,0 to 2,0	0,55 to 1,0	8,25 to 20	stiff	100 to 150
15 to 30	2,0 to 4,0	1,0 to 2,0	20 to 40	very stiff	150 to 200
> 30	> 4,0	> 2,0	> 40	hard	> 200

* SPT values are not normally used for evaluating clay layers. NOTE: 1 MN/m² = 10 bar.

The correlations between the different methods of soil tests are not based on any standards.

Each method gives its own specific classification of the subsoil.

The tables serve only as an aid to the user to complement their own experience.

2.3 Driving characteristics of various soils

The different types of soil with the various parameters listed in section 2.2 present various driving characteristics, a brief description of which are given here.

Method: Impact driving

Easy driving may be anticipated in soft soils such as silts and peats, in loosely deposited medium and coarse sands and in gravels without rock inclusions.

Difficult driving may be expected in densely deposited fine, medium and coarse sands and gravels, hard clays and soft-to-medium rock strata. Dry soils will give higher penetration resistance than those which are moist, submerged or fully saturated.

Method: Vibratory driving

Round-grain sand and gravel and soft soils are especially suited to vibratory driving. Angular-grain material or soils with firm consistency are much less suited.

It is also found that dry soils give greater penetration resistance than those which are moist, submerged or fully saturated.

If the granular subsoil is further compacted by the vibrations, then penetration resistance will increase sharply causing refusal.

For difficult soil layers it may be necessary to consult the driving aids described in Section 8.

2.4 Choice of sheet pile section for driving

With all civil engineering schemes, there is a need to minimise the cost of the work. It is important therefore that the most effective pile is selected for the task.

Wide, deep piles tend to be more cost effective as they provide the same bending strength at a lower weight per square metre than the comparable narrow sections.

Their increased width means that fewer piles are required to cover a given length of wall and installation costs can therefore be reduced.

The pile section chosen by the designer must be capable of being driven through the various strata to the required penetration depth.

The drivability of a piling section is a function of its cross-section properties, length, steel grade used, load applied and duration of this application and the method employed for installation. The cross-section properties of a pile are based upon the thickness of metal, depth and width of section and its designed shape.

The greater the surface area of the piling profile, the greater the driving force required. To avoid unnecessary deformation of the pile head, care is needed to ensure that the pile section chosen is compatible with the prevailing soil conditions. The geometry of the pile section may cause plugging of the piles in most cohesive and certain dense granular soil strata.

The driving force required is a function of the soil properties; therefore it follows that there is a definite limit to the drivability of a given pile profile and the steel grade being used. As the steel grade increases, the stress which the piles can withstand also increases and so, logically, the higher-yield steel piles are more resistant to head or toe deformation than the same section in a lower steel grade.

Consideration of the soil layers and appropriate parameters will enable the expected driving resistance to be assessed and hence a suitable section to be selected. The following table is based on a simple relationship using Standard Penetration Test results for cohesionless soil strata and a modular pile width of 500 mm, using impact hammers.

SPT minimum Dominant N value	Wall modulus (cm ³ / m)	
	Low-yield steel	High yield steel
0– 10	500	
11– 20		500
21– 25	1000	
26– 30		1000
31– 35	1300	
36– 40		1300
41– 45	2300	
46– 50		2300
51– 60	3000	
61– 70		3000
71– 80	4000	
81–140		4000

Where N represents the Standard Penetration Test value. "Dominant" means the average of the high values for the soils to be penetrated.

Where piles are to be driven only to a toe-hold in rock, the N value shall be divided by a factor of 4 for that stratum only.

It should, however, be stressed that the figures given in this table are for guidance purposes only. It is essential that good driving practice is adopted, combined with the use of the correct hammers, in good condition.

The table is based upon 500 mm, which is the average width of pile sections available; due allowance must therefore be made for piles of larger or smaller interlock centres.

The selection of a suitable pile section for driving into cohesive strata is a complex process and the section choice is usually based on previous experience.

However it is possible to assess the driving resistance using the surface area of the piling profile with the characteristics of the cohesive strata. This calculation will be altered considerably if a plug or partial plug will form across the profile at the toe. The end bearing resistance of the plugged profile will have to be included together with a reduction on the surface area of the pile profile.

For other driving systems refer to relevant chapters.



3. Driving Systems

3.1 General

The choice of a suitable driving system is of fundamental importance to ensure successful pile installation with due regard to safety.

Various categories of driving systems are detailed below:

3.2 Diesel hammers

A diesel hammer consists principally of a cylinder, a piston (ram) and an impact block at the bottom of the cylinder.

In single acting hammers the top end of the cylinder is open, but with double acting types it is closed. This double acting effect can also be achieved by using a vacuum chamber.

To start the single acting hammer, the piston is lifted to a preset height and automatically released. The falling piston compresses the air in the compression chamber and activates the fuel pump to spray fuel on top of the impact block. The impact of the piston on the impact block atomizes the diesel fuel, which ignites in the highly compressed air. This explosive energy throws the piston upwards thus driving the pile downward and re-starting the hammer cycle.

Diesel hammers perform especially well in cohesive or very dense soil layers. Under normal site conditions it is usual to select a ratio of ram weight to weight of pile plus cap of 1 : 2 to 1.5 : 1. Driving caps or flat anvil blocks are necessary to protect the pile heads during driving.

A penetration of 25 mm per 10 blows should be considered as the limit for the use of diesel hammers in accordance with the hammer manufacturer's recommendations.

Under certain circumstances a penetration of 1 mm per blow could be allowed for a short period of time. Longer periods of time at this blow rate would cause damage to the hammer and equipment.

Diesel pile hammers are operating as follows:

1. Raising of piston

For starting the Diesel pile hammer, the ram weight (piston) is raised by means of a tripping device and automatically released at a given height.

2. Injection of Diesel fuel and compression

While dropping, the piston will actuate the pump lever, so that a given quantity of Diesel fuel is sprayed on top of impact block. After passing the exhaust ports, the piston will start compressing the air in the cylinder chamber.

3. Impact and Explosion

The impact of the piston on the impact block will atomize the Diesel fuel in the combustion chamber. The atomized fuel will ignite in the highly compressed air. The resulting explosive energy will force up the piston.

4. Exhaust

While moving upwards, the piston will expose the exhaust ports. Exhaust gases will escape and the pressure in the cylinder will equalize.

5. Scavenging

The piston keeps jumping upwards and will draw fresh air through the exhaust ports for scavenging the cylinder, while also releasing the pump lever. The pump lever returns to its starting position, so that the pump will again be charged with fuel.

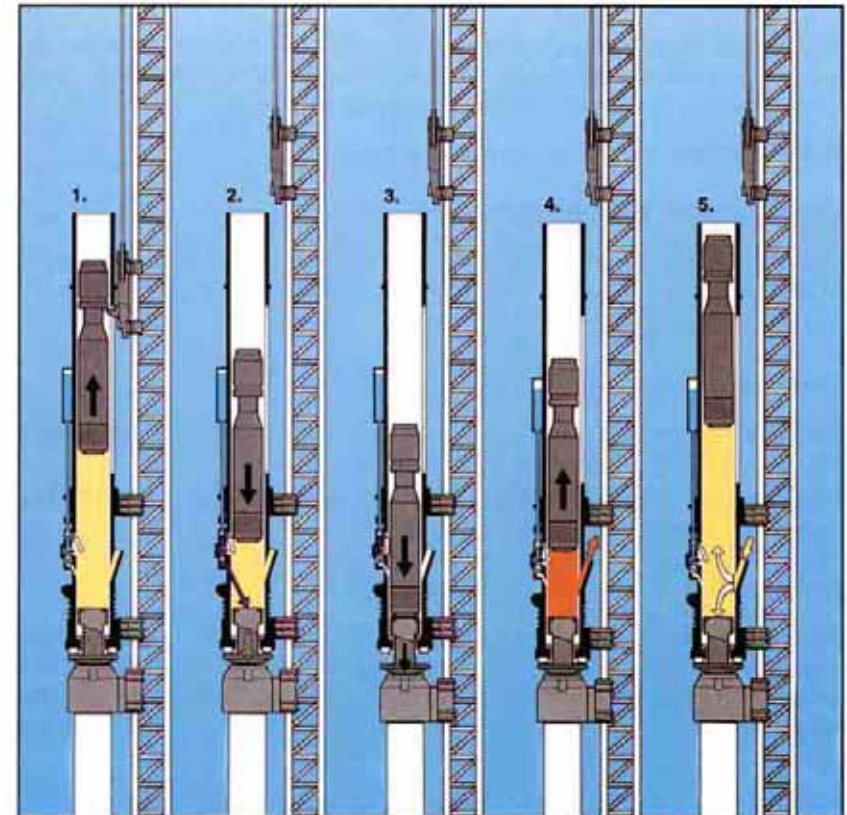


Figure 3-1: DIESEL PILE HAMMER

Reprint from DELMAG catalogue

3.3 Drop hammers

General

This hammer is easily adapted to drive any of the pile sections for all ground conditions eg. above and below the water table, and also adopts the same ram weight ratio and driving sets as described for Diesel hammers.

Ram weights up to 11 tonnes are available with a variable drop height of up to 1.2 metres. At maximum ram weight and stroke height a blow rate of 40 blows/minute can be obtained when used in automatic sequence.

It is always preferable to use a heavy ram, with short stroke to minimise pile head damage and noise emission levels.

The hammer controls are precise, and used correctly this hammer can achieve 75–80% of rated output energy. Data recording units simultaneously store the relevant driving information.

There are three main types of drop hammer:

Cable operated drop hammers

These consist of a machine lifted weight which is then allowed to free fall to drive the pile.

The falling height can be regulated by the cable winch.

Steam drop hammers

For these special drop hammers the cylinder represents the falling weight which is lifted by steam pressure.

A valve system interrupts the pressure and causes the cylinder to fall. The height can be adjusted to the given conditions.

Hydraulic drop hammers

This type of hammer consists of a segmental ram guided by two external supports; the ram is lifted by hydraulic pressure to a pre-set height and allowed to free-fall on to the anvil or driving cap. The weight and the height of drop of the ram can be varied to suit the piling section and the site conditions.

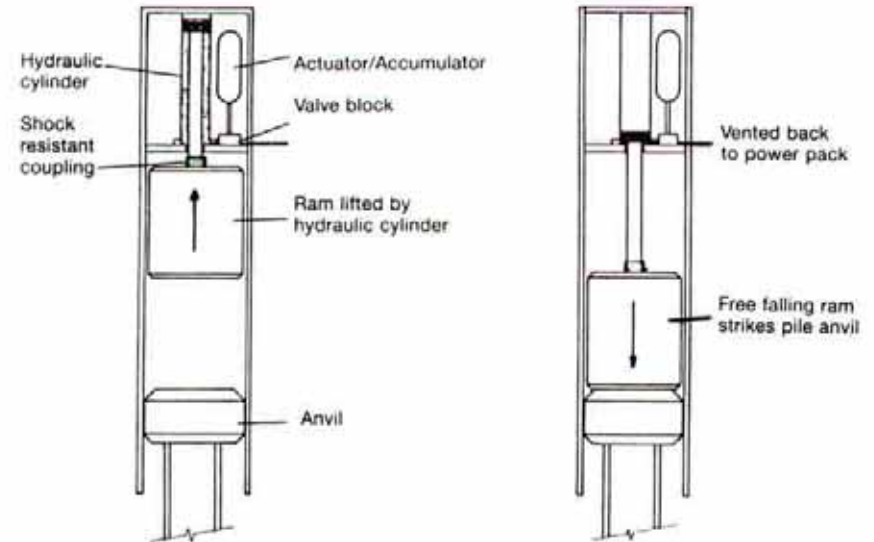


Figure 3-2: PRINCIPLE OF OPERATION



Figure 3-3:

3.4 Double-acting hydraulic hammers (hydrohammer)

This type of hammer consists of an enclosed ram which is lifted by hydraulic pressure. On the downward stroke, additional energy is delivered to the ram, producing an acceleration of 2 g. The maximum stroke of 1 metre thus corresponds to a free fall drop of 2 meters.

These hammers range from a maximum energy/blow of 35 kNm to 3000 kNm with a blow rate of 50/60 blows per minute. The electronic control system ensures optimum control of the piling process and the design enables a range of safety, monitoring and indicating devices to be incorporated. The net energy applied to the pile which is measured during every blow and shown on the control panel can be continuously regulated from maximum to less than 5%.

The hydrohammer can operate at any angles, above and below water-level and is suitable both for driving and extracting piles. Under normal site conditions it is usual to select a ram weight that is in the ratio of 1 : 1 to 1 : 2 with the weight of the pile plus driving cap. A heavy hammer with short drop is always preferable to minimise pile head damage and noise level emissions.

Up to the present time only hydrohammers from 35 kNm to 90 kNm energy per blow have been known to be used for sheet piling; hammers larger in capacity than these are considered to be too heavy.

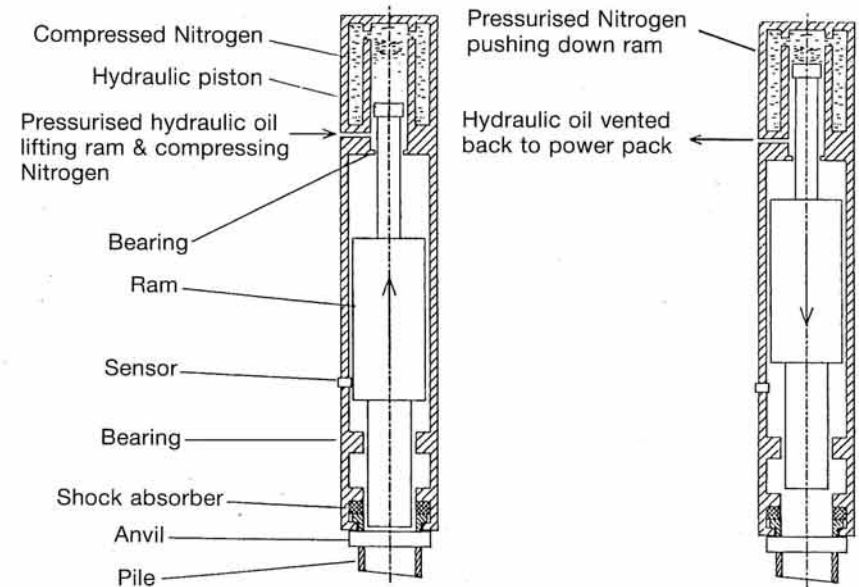


Figure 3-4:

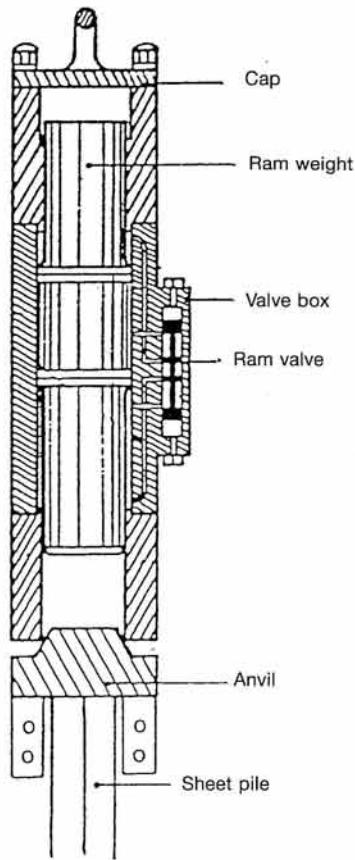


Figure 3-5: DOUBLE-ACTING AIR/STEAM HAMMER

3.5 Double-acting air/steam hammers (rapid blow)

With double-acting hammers the striking ram (piston) is driven by compressed air or steam when rising and falling.

The air or steam arrives under pressure in a valve box containing a slide valve which sends it alternately to each side of the piston, while the opposite side is connected to the exhaust ports.

When falling, the striking mass hits a flat anvil fixed to the cylinder resting on top of the sheet pile being driven. Then the pressure lifts the piston and allows it to be forced down again on to the anvil.

In comparison with drop hammers of the same overall weight the ram of the double-acting hammers is much less than that of the drop hammer. It is only 10–20% of the overall hammer weight but is effectively increased by the pressure (5–8 bar) on the upper end of the piston.

The hammers are designed to operate at maximum efficiency when used with standard sizes of compressors normally available. For such hammers, 90% of the available energy blow is derived from the action of the air or steam upon the piston.

The ram weight of the hammers which are generally used with steel sheet piles, ranges between 100 and 1300 kg and the drop height, which generally increases with hammer weight, varies from 110 to 500 mm. The total striking energy of the biggest double-acting hammer is around 30 kNm per blow, much less than the biggest single-acting or drop hammers. However, the striking rate of the double-acting hammers is higher, being about 100 blows a minute for the biggest machines and 400 blows a minute for the smallest. This striking rate usually leads to continuous movement of the pile which increases its penetration capacity in soils.

It is not advisable to insert a driving cap between the hammer anvil and the sheet pile being driven since this leads to an enormous loss of efficiency.

The double-acting hammers can also be equipped to operate under water and for the extraction of piles.

For continuous driving it is normal to limit the driving rate to 150 mm/min, but for short periods of time a driving rate of up to 50 mm per minute may be permitted.

A ratio not less than 1 : 5 between the ram weight and the weight of the pile is normally chosen.



3.6 Vibratory pile drivers

Vibratory pile drivers apply vibrations to the piles to enable them to penetrate certain soil strata.

The principle of vibratory driving is the reduction of friction between the pile and the soil. The vibrations will temporarily disturb the soil around the pile, causing minor liquefaction, which results in a noticeable decrease in resistance between soil and pile. This enables the pile to be driven into the ground with very little added load, i. e. its own weight plus the weight of the driver. The vibratory driver generates oscillations inside a vibration case in which eccentric weights are gear-driven by one or more motors. The weights turn at the same frequency but in the opposite direction, thus eliminating the horizontal components of the forces, leaving only the vertical components operational. The vibratory drivers can be powered by electric or hydraulic motors or a combination of both.

Hydraulically operated clamps mounted under the vibration case ensure a secure attachment and transmit the oscillating movements to the pile. The crane suspending the vibratory driver must be isolated from the vibration case by rubber cushions or spring elements. The variable speed features of hydraulic vibrators enable the frequency of the system to be matched to varying soil conditions and, because of the power source, such drivers are perfectly suited for working under water.

The vibratory pile driver is also a very efficient piling extractor. The decrease in resistance between soil and pile enables extraction to occur with a greatly reduced upward pull compared with the static extraction force which would be required to extract a similar pile.

The frequency of the standard range of vibratory drivers varies from 800 to 1800 RPM and the centrifugal forces go up to 5000 kN. The recently introduced higher frequency drivers give a range up to 3000 RPM. The high vibrations developed attenuate very rapidly, thus causing very few problems to adjacent properties. The penetration performance depends mainly on the soil conditions.

The best suited soils for vibration work are non-cohesive soils, gravel or sand, especially when they are water-saturated. With mixed or cohesive soils vibro-drivers can be used where there is a high water content.

Artificially dewatered sands, on the other hand, can be very resistant to vibratory driving.

As a guide to determining the size of a vibrator, the following formula may be used:

$$F = 15 \times \frac{(t + 2G)}{100} \text{ [kN]}$$

F = centrifugal force,
t = driving depth in m,
G = mass of the pile in kg.

It is generally recognised that a penetration rate of approximately 50 cm per minute be used as a limit. This is to be considered only as an indication for the control of possible vibration nuisance and careful monitoring is required if driving is continued past the limit.

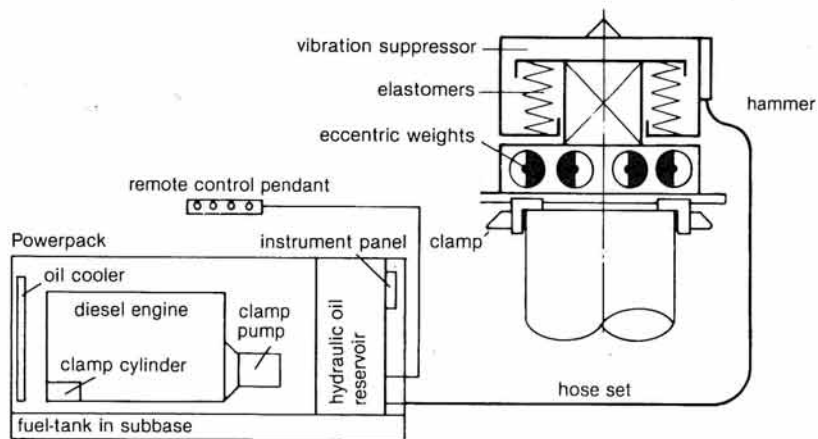


Figure 3-6: PRINCIPAL OF OPERATION

Reprint from ICE catalogue

3.7 Sheet pile presses

The elimination of the noise of sheet pile driving, which had for years been accepted as a nuisance to be tolerated, was the original purpose of the development of sheet pile presses as an alternative to the classical methods.

Originally developed to drive piles silently, the machines are also widely recognised for their vibration-free operation.

The machines, which are especially suited for use in cohesive soils, are hydraulically operated and take most of their reaction force from the friction of the previously driven piles. In the standard system, the engine consists of a crosshead containing hydraulic rams and the hydraulic power pack mounted on the crosshead.

Sheet piles are installed in a panel and the machine is set on the panel by means of a crane (Type 1).

The rams (hydraulic cylinders) are connected to the piles and by pressurizing two rams, whilst the others are locked, enables the piles to be pushed into the ground, two at a time, to the full extent of the rams. When all the rams have been extended, they are all retracted simultaneously causing the crosshead and power pack to be lowered and the cycle is then repeated to completion.

These presses can develop forces of up to 300 tonnes.

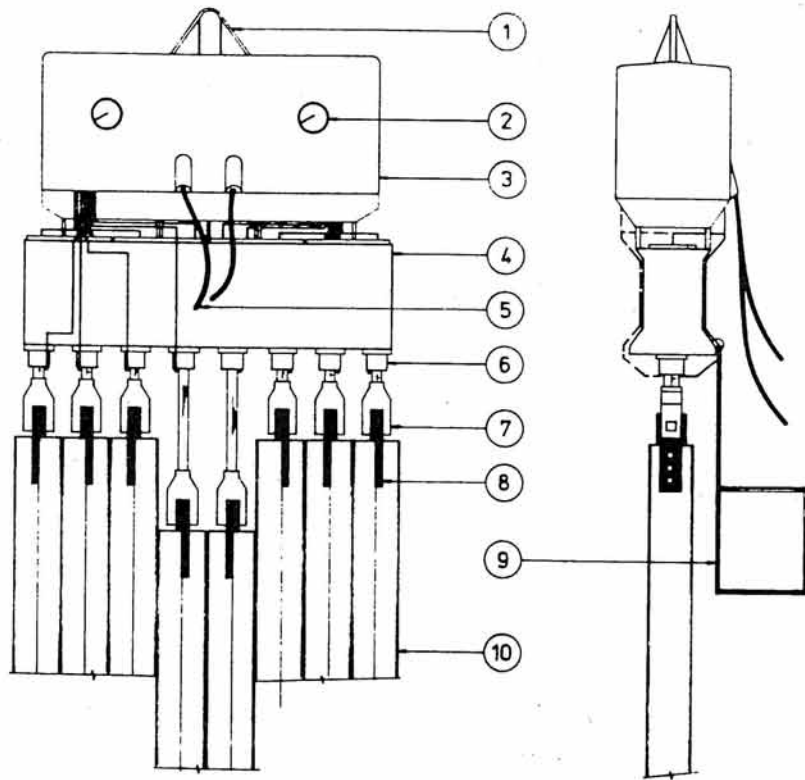


Figure 3-7: HYDRAULIC PRESS (Type 1)

- | | |
|----------------------------|-----------------------|
| 1 Lifting frame | 6 Hydraulic jacks |
| 2 Pressure gauges | 7 Pile connectors |
| 3 Power pack | 8 Friction plates |
| 4 Crosshead and guidebase | 9 Access platform |
| 5 Power and control cables | 10 Steel sheet piling |

Machine description

The press consists of a power pack mounted on an interchangeable steel crosshead containing eight hydraulic rams. The machine is fitted with a steel platform to give access to the pile connectors.

The machine is not suitable for driving into coarse sands and gravels. Pile extraction can take place in any soil conditions.

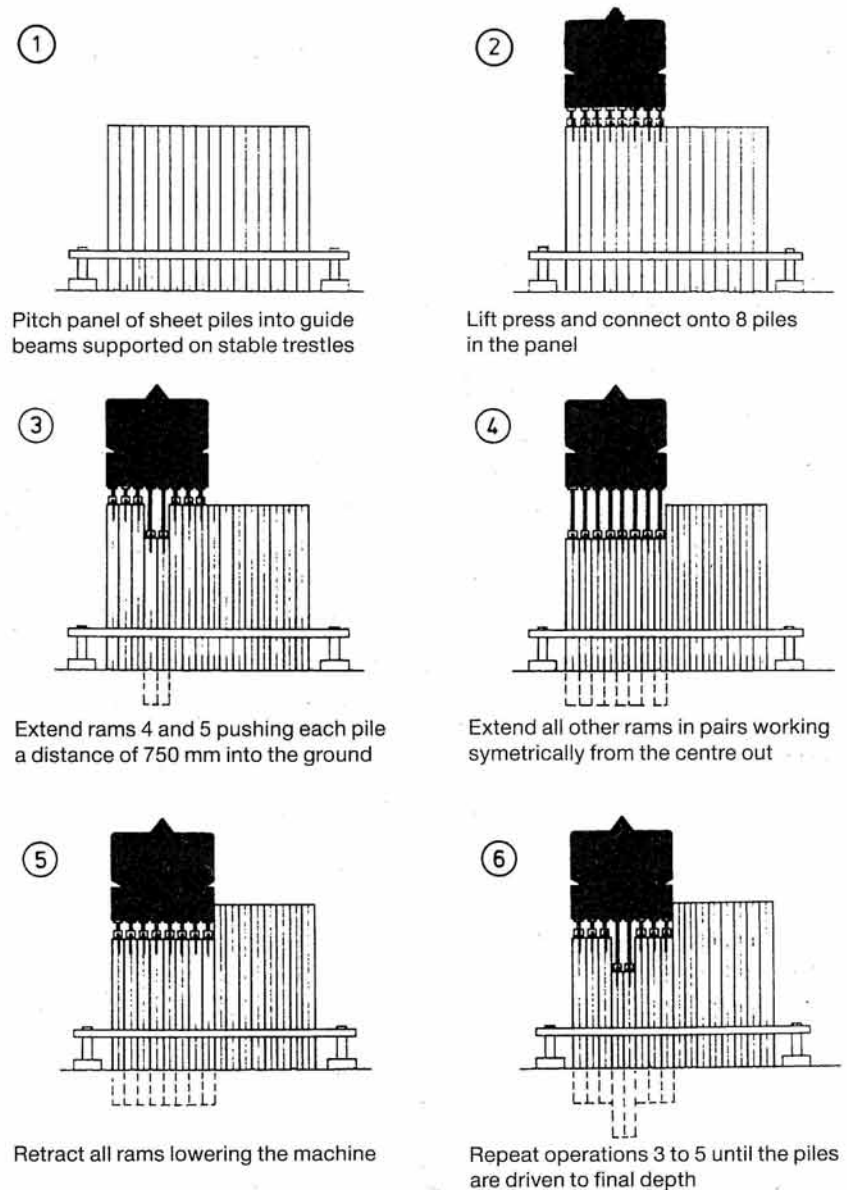


Figure 3-8: MACHINE OPERATION (Type 1)

Note: Piles are extracted using the reverse operation of the above sequence.

Another type of machine with similar features uses a moveable frame to hold the installed panel and to move from panel to panel, giving complete independence from a crane. In this system, pre-drilling loosens the soil during the press operation (Type 2).

A chain pull connected to a fixed point or to piles that have already been driven can provide supplementary press force.



Figure 3-9: SHEET PILE PRESS (Type 2)

Other kinds of presses jack one pile after another to the complete depth while walking on the previously set piles. These machines work completely independently from a crane, and also use the reaction force of the piles already set to operate. These machines can accommodate limited circular construction if required (Type 3).

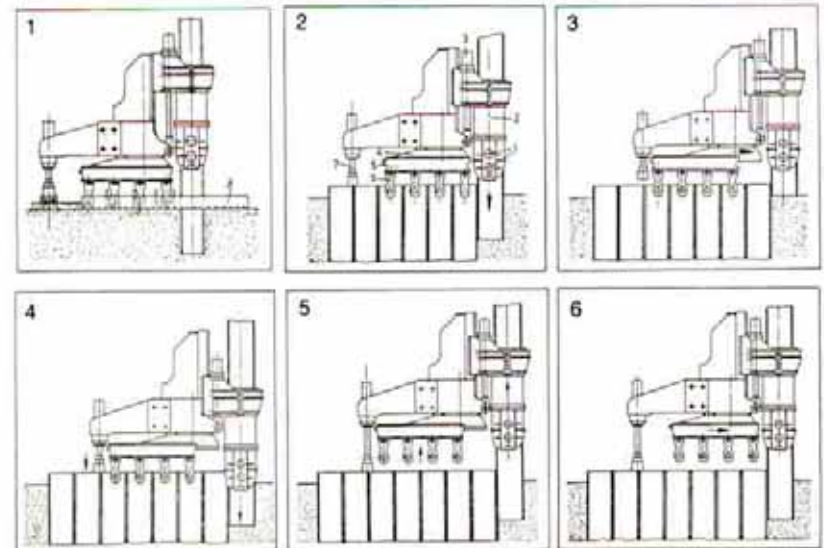


Fig. 3-10: MACHINE OPERATION (Type 3) SINGLE PILE PRESS

Reprint from MÜLLER catalogue

- 1 Setting of press and reaction table (6)
For the first pile supplementary weight can be put on to the machine.
- 2 In normal working, reaction force is taken from the already pressed piles.
- 3 Support (7) is lifted and press head moves forward.
- 4 New pile is pressed to give support.
- 5 Engine, sitting on pile and support (7), lifts the clamp unit (5).
- 6 Clamp unit moves forward to fix to installed piles again.

3.8 Special driving systems

Besides the common driving systems there are many special types designed for particular jobs or applications, these include:

- a) Impact hammers incorporating a special cushion system formed out of steel springs or inert gas to transmit the driving energy to the pile more smoothly and over a longer period of time.
- b) A driving system which vibrates and presses on sheet piles simultaneously.
- c) An impulse hammer operated hydraulically but with an extremely rapid sequence of strokes.
- d) A driving system which impacts and vibrates the sheet piles simultaneously.

It may be of benefit to use jetting or predrilling in conjunction with any of the above driving systems.



4. Driving Methods

4.1 General

Whilst it is recognised that, in common with most civil engineering projects, a measure of flexibility is desirable to meet site conditions, every precaution must be taken to maintain the necessary standards of safety whilst giving the required alignment and verticality of the installed piles.

The first sheet pile must be installed with great care and attention to ensure it is vertical in both planes of the wall.

It is essential that the following piles are interlocked sufficiently to the preceding pile before being released and the hammer applied. This can be achieved by a preliminary dug-out trench in the wall line which automatically reduces the driving length.

4.2 Pitch and drive

This method, where each sheet pile is driven to full depth before pitching the next one, is the simplest way of driving but can be practised only for loose soils and short piles. The free leading interlock is constantly in danger of deviation. For dense sands and stiff cohesive soils or in the case of possible obstructions, panel driving is recommended.

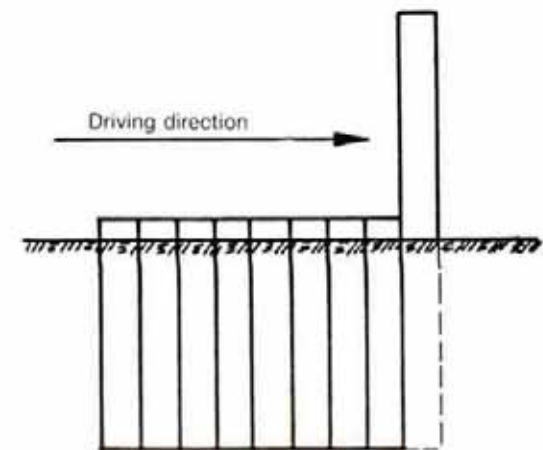


Figure 4-1: PITCH AND DRIVE

4.3 Panel driving

Sheet piles should be installed using the panel-driving technique in order to ensure that good verticality and alignment is achieved and to minimize the risk of driving difficulties or de-clutching problems.

This technique also enables greater control to be maintained on the nominal wall length.

Because a whole panel of piles has been pitched there is no need to drive all piles fully to maintain piling operations; if obstructions are encountered, individual piles can be left high without fear of disruption to the overall efficiency.

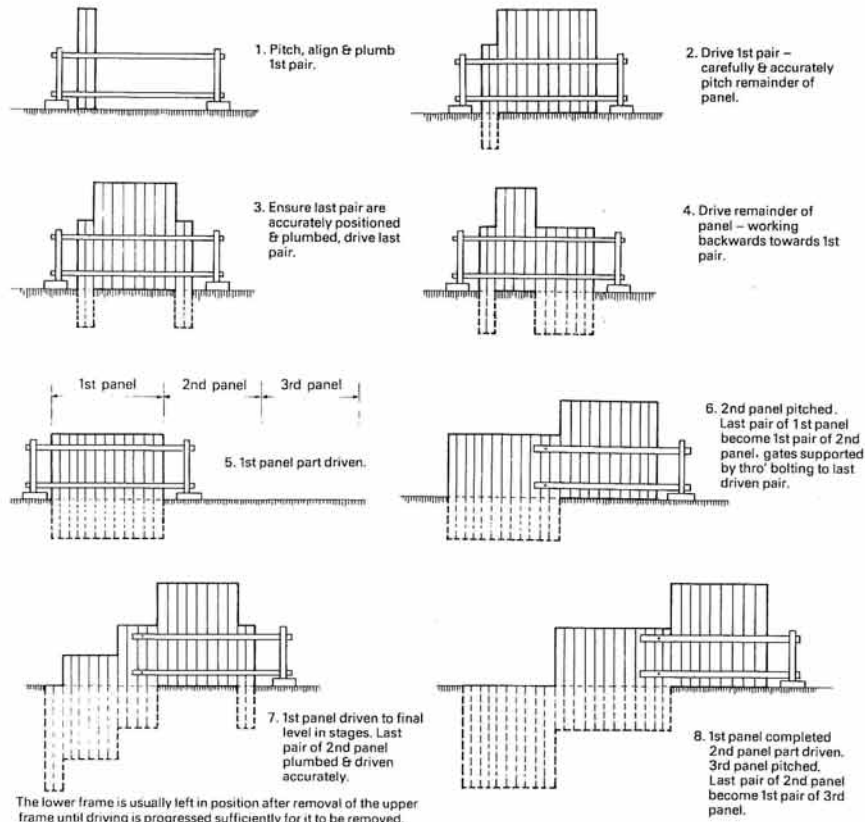


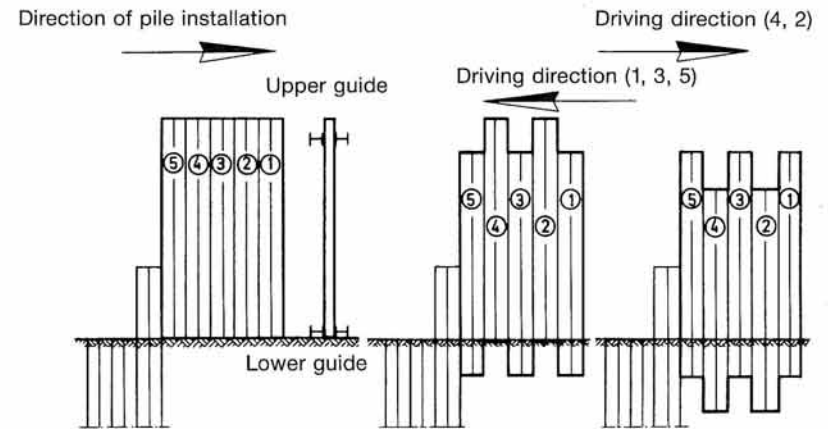
Figure 4-2: PANEL DRIVING

4.4 Staggered driving

In difficult soil conditions panel installation combined with staggered driving is recommended.

The piles are installed between guide frames and then driven in short steps as follows: piles 1, 3 and 5 first; then piles 2 and 4.

If the soil is very dense sand, gravel or rock, piles 1, 3 and 5 can be reinforced at the toe. In this case, these piles are always driven first and piles 2 and 4 in the second stage.



Only the reinforced elements 1, 3, 5 are pre-driven; the other 2, 4 . . . follow.

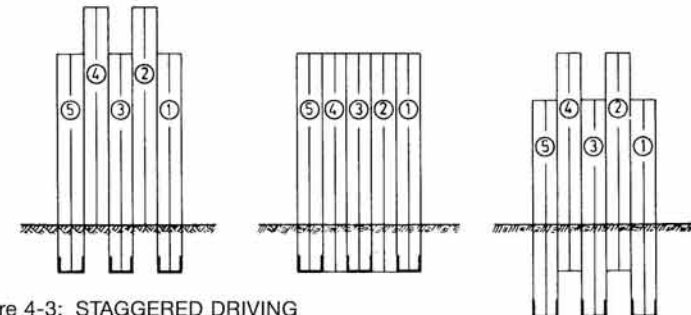


Figure 4-3: STAGGERED DRIVING

4.5 Driving of combined walls

Combined walls are piled walls which comprise high modulus components interspaced by much lighter sheet piles. The high modulus components known as king piles can be tubular, box, bearing or other types of fabricated piles.

It is essential that a stable, heavy, adequately rigid and straight pile driving frame adapted to suit the length and weight of the piles is provided.

The king piles are located in position in the frame by welded bracket guides which take into account width tolerances.

Driving of the king piles must be carried out with extreme care in order that they are embedded straight and vertical, or at a prescribed batter, ensuring that they are parallel to each other and at the required spacing.

The driving sequence of the king piles must ensure that the pile toe encounters compacted soil uniformly on its total circumference and never on one side only.

This is achieved by driving in the following sequence:

1 - 5 - 3 - 6 - 4 - 7 - 2 (large driving step).

At least however, the following sequence should be observed:

1 - 3 - 2 - 5 - 4 - 7 - 6 (small driving step).

In general all of the king piles should be driven in sequence to full penetration without interruption. Following successful completion of this the intermediate light pile sections can be pitched and driven. During the pitching and driving operations of the king piles a constant check should be made, using theodolites, of their alignment along and normal to the wall.

When the guide frames have been removed a final survey must be made to ensure the deviations in the distance between the king piles are within the acceptable tolerances, so as to allow the installation of the sheet piles. However, if the deviations are outside the specified or practical tolerances then either the intermediate piles have to be adjusted or the king piles extracted and re-driven.

To overcome difficult driving conditions it may be possible to use jetting, excavating inside the king piles or any of the ground pre-treatment methods normally adopted for sheet piling.



5. Enclosed Cofferdams

5.1 Rectangular

5.1.1 Panel Driving Method

The craneage available should have sufficient reach to enable each pile to be interlocked into the previously pitched pile, before driving commences adjacent to a corner pile.

Working around the perimeter, the final and closing panel, which should include a corner pile, must be pitched and interlocked with the partly driven first pair of piles, before driving is commenced. This is to ensure satisfactory closure of the cofferdam.

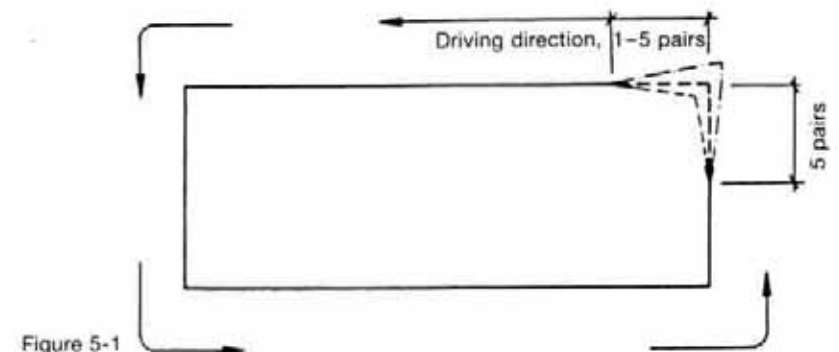
In small cofferdams it is advantageous to pitch all piles before commencing driving as this will alleviate probable difficulties in closing the cofferdam.

5.1.2 Pitch and Drive Method

Driving should commence and stop at 5 double piles from the final corner. Closure of the cofferdam is achieved by adjusting the alignment of the wall either inwards or outwards to suit the dimensions of the piles being used.

It is important that verticality of the piles is maintained during driving of the plain and corner piles; any tendency to lean must be corrected, if necessary by using taper piles.

If the cofferdam dimensions have to be strictly adhered to, then special fabricated piles will probably have to be provided.



5.2 Circular cofferdams

The length of the pile, straightness, and the soil pressed into the interlock during driving have a considerable influence on the achievable deviation of one pile from another. These deviations increase the friction in the interlocks considerably.

For small cofferdams it is prudent, where possible, to pitch and interlock all the piles around a driving template before starting to drive. Driving should progress in stages using a short lead of one pile to the adjoining pile.

In large cofferdams strict control on verticality must be maintained, preferably using panel driving techniques to facilitate closure of the cofferdam. It may be necessary also to re-arrange the final panel by increasing or reducing the radius of the cofferdam slightly, or by introducing a specially fabricated pile.

Cofferdams of small diameters may not be achievable with just interlock rotation, and therefore may require the introduction of prebent piles or fabricated special piles.



Figure 5-2:



6. Pile Driving Guides

6.1 General

It is particularly important that sheet piles are maintained in the correct horizontal and vertical alignment during installation. This is achieved by the use of efficient pile guides, which will also prevent lateral drift.

Each element to be driven must be guided in at least two levels (Fig. 6-1). The accuracy and effectiveness of the guides will be improved by maximising the distance between the two levels. Very long sheet piles may need intermediate guides to prevent flexing and other associated driving problems.

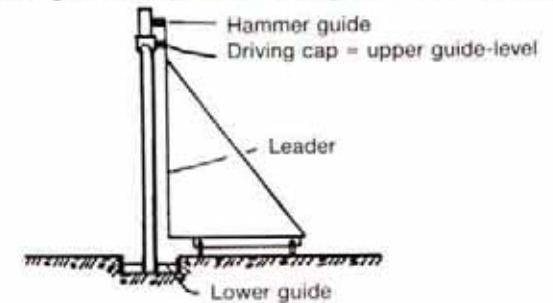


Figure 6-1

6.2 Upper guide

6.2.1 Driving with fixed leader

With this method both the hammer and the pile are guided by the leader. It is therefore important that the fixed leader is always vertical and that the hammer impacts its energy down the centroid of the pile profile.

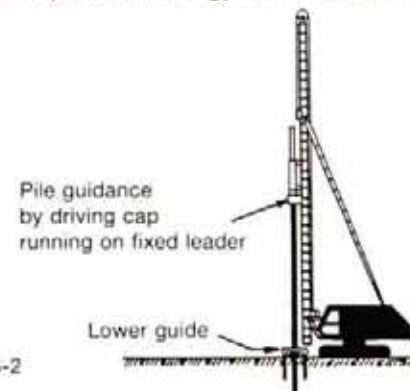


Figure 6-2

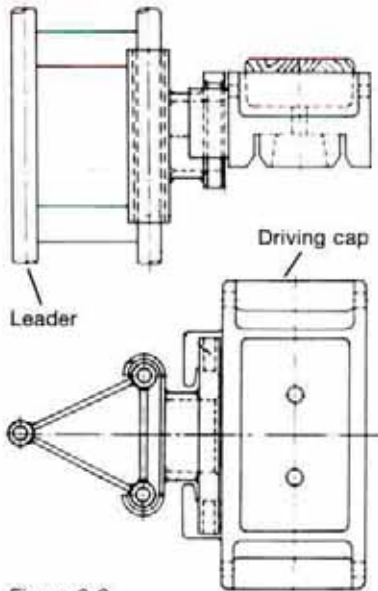


Figure 6-3



Figure 6-4



Figure 6-5

6.2.2 Driving with rope-suspended leader

This system employs a hammer which is supported and guided on the pile head by a rope-suspended leader, using a driving cap or leg guides. To ensure correct alignment of the hammer and firm seating on the pile head, the leg guides must be of adequate length and fit to ensure minimal movement.

A robust frame can be used to provide upper level guidance for the piles. To be effective it should be at least a third of the pile length above the lower guide and preferably located as close to the top of the pitched piles as possible.

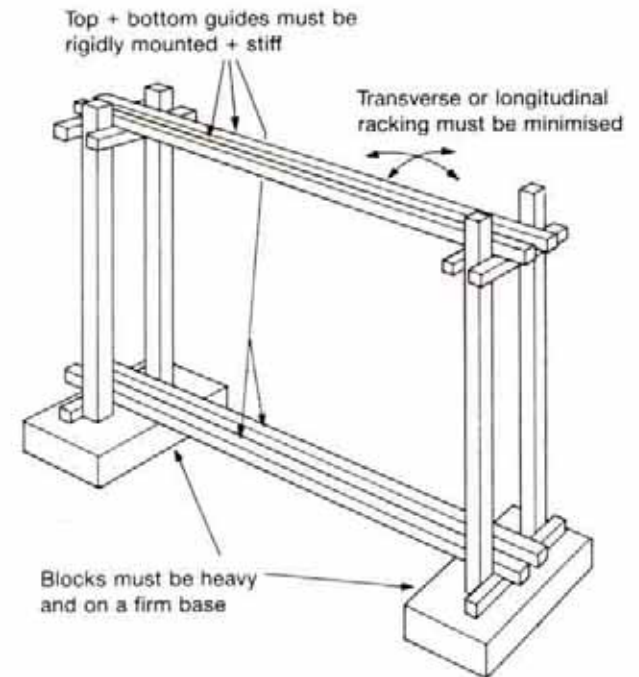


Figure 6-6

6.2.3 Driving with rope-suspended hammers

Hammers may be used rope suspended with leg guides fitted to suit the profile of the sheet pile. A robust frame can be used to provide upper level guidance for the piles. To be effective it should be at least a third of the pile length above the lower guide and preferably located as close to the top of the pitched piles as possible.



Figure 6-7



Figure 6-8

6.3 Lower guide

Irrespective of the driving method, a guide frame is always required at a low level to ensure correct alignment of the steel pile wall. It should consist of two sturdy beams and be mounted as low as possible, preferably on the ground. Lateral movement of this frame must be prevented. The guide length should cover at least 6 pile pairs, the existing wall (previously driven) being covered along some 1.5 m additional to the 6 pairs. The spacing of the beams must be maintained by spacers.

When pitching and driving, a guide element consisting of spreader and bracket should be located adjacent to the sheet piles being driven to prevent frame bulging.

To prevent pile twist within the frame, the free flange of a Z type sheet pile or free leg of the U type should be secured by a guide block during driving.

When driving piles in water the lower frame can be attached (above or below water) to temporary bearing piles.

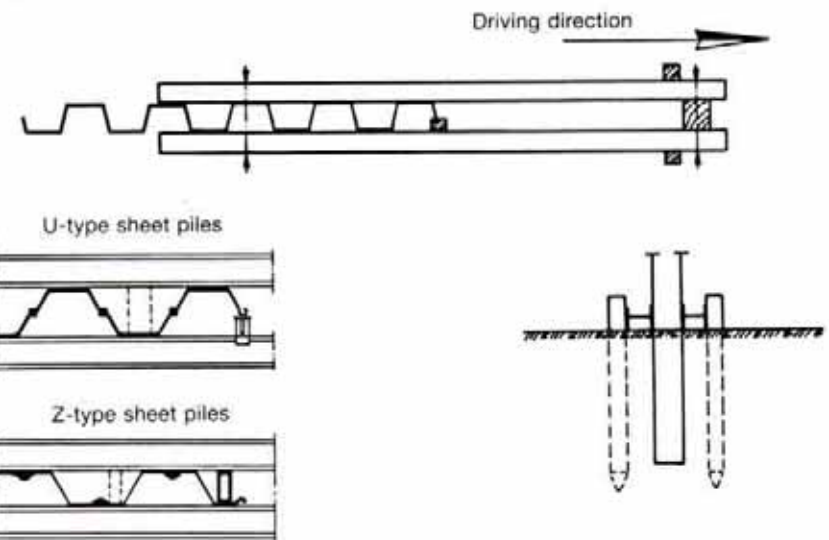


Figure 6-9



Figure 6-10

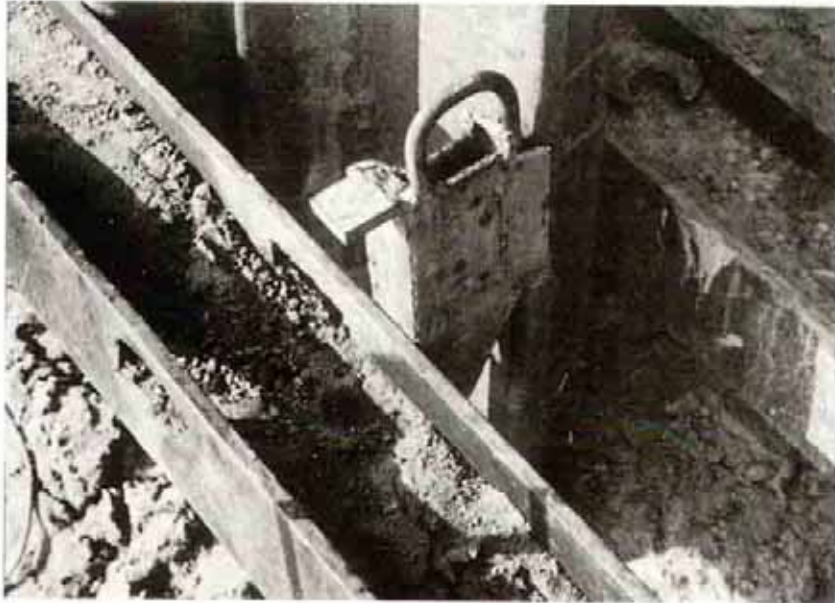


Figure 6-11



7. Ancillary Equipment

7.1 General

To facilitate the handling, pitching and driving of piling the following aids should be considered.

7.2 Prefabricated trestles and walkway walings (guides)

Trestles are quick to erect, strip and move, and can be dismantled and neatly stacked for transportation. Safety features are incorporated to provide safe access and working space when assembly is both complete or partially complete.

Walkway walings provide safe access and working space. They are stiff box-girder beams providing a rigid guide and straight edge for accurate pile alignment.



Figure 7-1:

Reprint from DAWSON catalogue

7.3 Shackles

Besides the standard shackles widely used, a variety of ground-release and ratchet-release shackles are available. These enable the crane connection to the pile top to be released, when required, from ground level or walkway waling level. This is fast, efficient and safe. The shackle uses a lifting hole in the head of the pile through which a shear pin passes. Friction grip methods of lifting should never be used as they can accidentally release in a number of different circumstances.

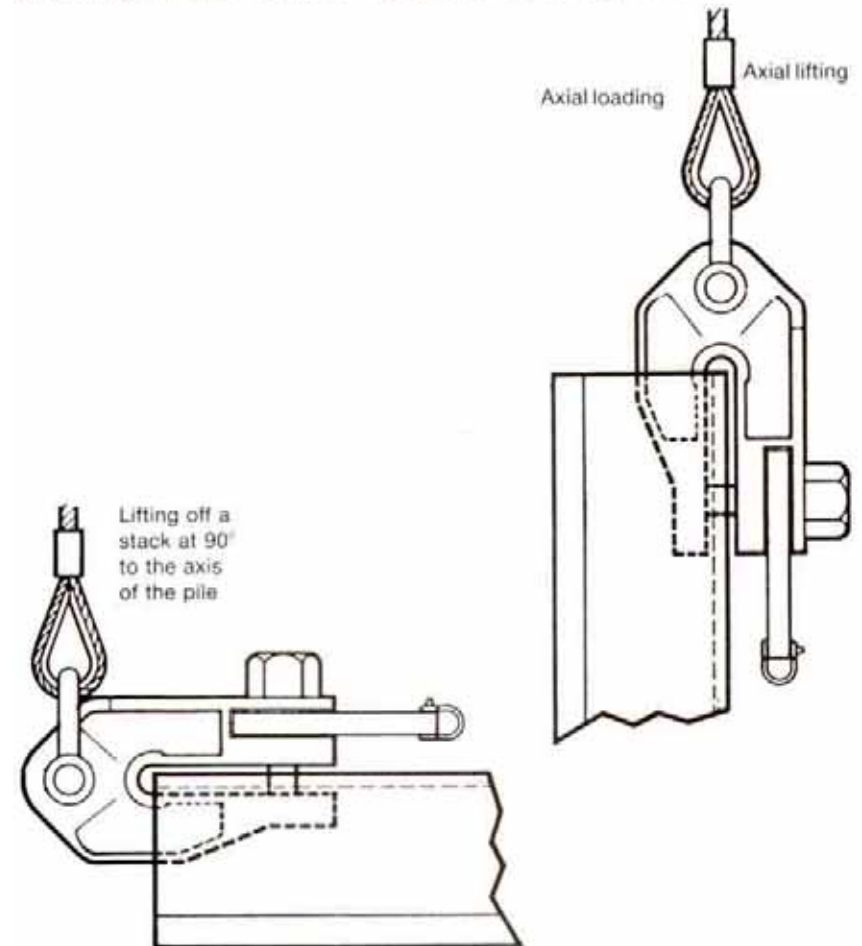


Figure 7-2

Method of operation for shackles when used in conjunction with pile threader (see Threaders, section 7.4)

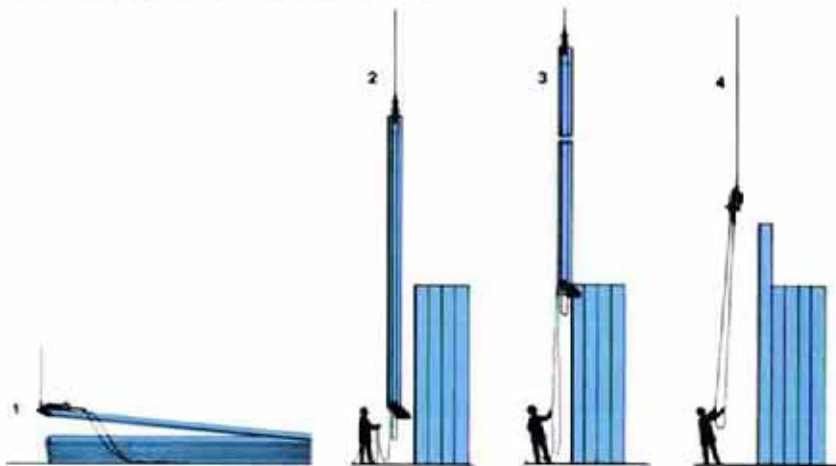


Figure 7-3

Reprint from DAWSON catalogue

1. Retract main pin on shackle until locked in open position. Slide shackle over pile head. Pull looped wire to release pin ensuring it is fully located through hole in pile and into shackle body. Attach a length of soft rope to pin-release wire.
2. Hoist pile into position and attach pile threader.
3. Locate pile threader and tie pin-release rope on shackle to threader (to prevent trapping or sagging). The sheet pile is then pulled up into threading position.
4. After threading has been completed, release shackle by pulling pin-release rope.

7.4 Threaders

As a consequence of panel driving, there is a need to interlock piles and release their crane connection, at a high level, with efficiency and safety. The sheet pile threader is designed to interlock any steel sheet pile accommodating the different profiles, handling and interlock types without the need for a man to be employed at the pile top. Work on pitching piles can also continue in windy conditions which would stop manual interlocking, making the work more efficient as well as safe.

PILE THREADER



Figure 7-4

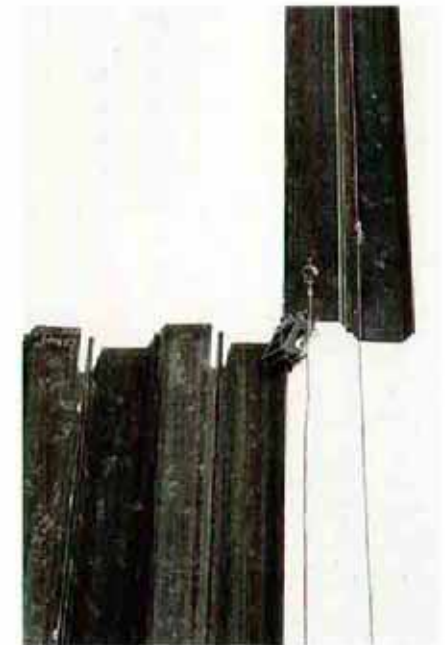


Figure 7-5

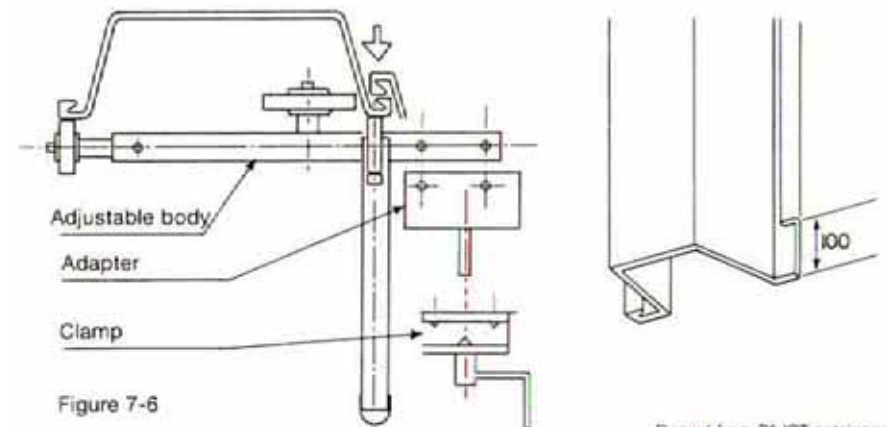


Figure 7-6

Reprint from PAJOT catalogue

With certain threaders it may be of benefit to cut approx. 10 cm off the lower end of the interlock of the pile.

7.5 Reinforcing shoes

Having taken all precautions to guide the piles accurately during installation, pile design efficiency may still make the pile vulnerable to damage from artificial or natural obstructions such as cobbles, boulders, concrete and old timber piles.

Reinforced shoes can be provided to give strength to the leading edge of the sheet pile and to help maintain its shape when passing through difficult ground.

7.6 Steel handling shoes

These are simple cast-steel shoes designed to slide between each pile in a stack to enable easy separation and handling.



Figure 7-7



Figure 7-8



Figure 7-9

Reprint from DAWSON catalogue

7.7 Driving caps

7.7.1 General

Driving caps with a dolly may be required when using impact hammers in order to transmit the blow directly to the pile and to protect the hammers and the pile heads.

Guiding grooves for the pile are formed on the lower surface of the driving cap.

A suitable connection between the leader and the driving cap can be obtained by a spacer insert to give the required clearance.

The insert must have a sliding connection on the cap and on the leader.

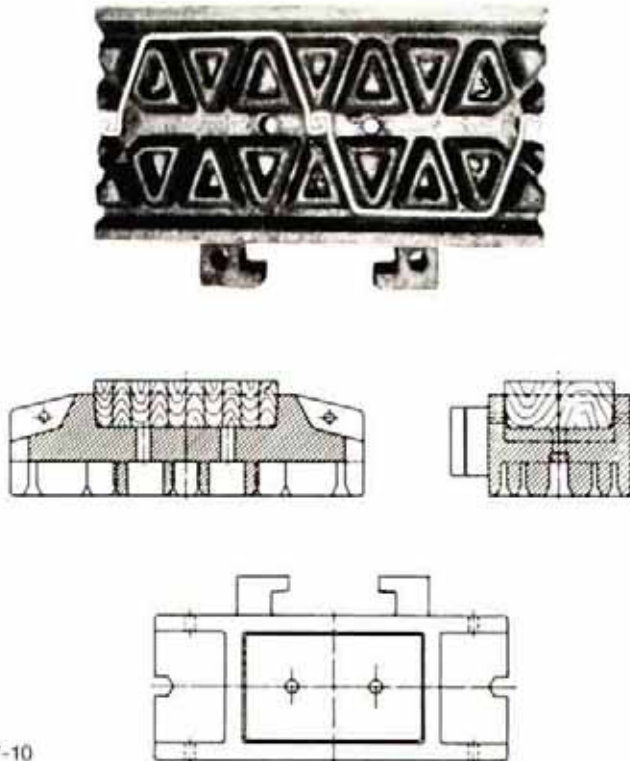


Figure 7-10



Figure 7-11

7.7.2 Dolly

The dolly is fitted into a recess on the upper surface of the driving cap. The dolly cushions the blow from the hammer and thus prevents damage to the hammer and the cap.

Dollies are normally built of plastic or wooden components, with a combination of steel cables and steel plates which give a reasonable life expectancy and also quickly dissipate the heat generated.

When hard driving is experienced the dolly has to be replaced more frequently than under normal requirements.



8. Driving Assistance

8.1 Jetting

8.1.1 General

Under certain conditions, driving, vibrating and pressing of piles can be achieved only with the help of jetting. This also prevents overloading of the installation machine, damage to the piles and reduces ground vibrations.

The objective of this procedure is to locate a pressurized water jet at the toe of the pile connected by a pipe to a supply pump on the ground surface.

The water pressure loosens the soil and removes loose material. The toe resistance of the pile is reduced and, depending on the soil conditions, the rising water reduces surface and interlock friction.

The effectiveness of the jetting is influenced by the density of the soil, the available water pressure and the number of jetting pipes. Care must be exercised to ensure that the ground treatment does not endanger adjacent structures.

Test driving to define the parameters is recommended.

8.1.2 Low pressure jetting

Low pressure jetting is mainly used in dense non-cohesive soils.

The jetting tubes have a diameter of up to 65 mm and the pressure produced by the pumps varies from 7 to 20 bar. A jet effect is created by reducing the diameter of the tube end or by special jet heads. The water volume required is 1000 litres/min maximum per jetting tube; these tubes are normally fixed to the piles and left in situ.

The large volume of water may cause settlements and a reduction in soil characteristics can be expected in the short term.

Low pressure jetting may also be used for ground pre-treatment prior to pitching and driving of the piles.

In combination with a vibratory pile driver, jetting can enable piles to penetrate very dense soils.



Figure 8-1



Figure 8-2

For this method two to four tubes of 20 mm diameter are fixed to a pair of sheet piles. Each tube is served by a pump, giving a pressure of 20 bar. Water volume per tube should be 120–240 litres/min. The toes of the tubes are at the same level as the toe of the pile and the jetting starts simultaneously with the driving to prevent intrusion of soil into the tube.

In general the soil characteristics are only slightly modified, although special care must be taken when piles have to carry vertical loads.

8.1.3 High pressure jetting

High pressure jetting may be used for driving in extremely dense soil layers.

If there is a risk of settlement, high pressure jetting is preferred to low pressure due to the reduced amount of water being used.

High-quality tubes are required, the pump pressure being 250 to 500 bar.

Special nozzles, sometimes flat jet nozzles, are used (30 mm diameter for the tubes, 1.5 or 3.0 mm diameter for the nozzles). Water consumption is 60–120 litres/min per tube. Soil mechanical characteristics are not modified by the system: this has been proved by test-driving in chalk, boulder clay and hard clay.

The tubes, fixed at the pile top, are guided in side brackets welded to the piles so that they can be re-used. The nozzles are located 5–10 mm above the pile tip.

Intensive monitoring is required during the work to adapt the system to the local conditions.

The diameter of the nozzles has to be adapted to the ground conditions, as have the number and the arrangement of the lances.

8.2 Blasting

8.2.1 General

This process is applicable to most types of soil which until now would have been classified as difficult or impossible for driving steel sheet piles, H-section, box and tubular piles.

8.2.2 Normal blasting

Explosives are lowered into drilled holes and covered with soil before detonation. This creates a V-shaped trench along the proposed line of the wall. The size of the fragments in the trench is dependent upon the amount of explosives used.

The driving conditions in the loosened area are still very tough and toe reinforcement of the piles is recommended.

8.2.3 Shock-blasting process

This blasting technique is a highly specialized form using very low-powered explosives, the principle being to reduce solid rock to a fine granular material without displacing it, rather than to blast a cavity in the rock.

The volume of rock affected is very small, being just sufficient to encompass the dimensions of steel piles.

The width of the granulated rock zone would be 500–700 mm and to the exact depth of the required pile penetration. The rock immediately adjacent to this zone remains totally intact.

The sheet piles should be driven into this granulated zone as soon as possible after blasting to obtain maximum benefit from the process.

The act of driving the sheet piles into this zone compacts the soil ensuring adequate support for the embedded piles.

8.3 Drilling

Easier impact driving, vibrating and pressing can be achieved by pre-drilling. Holes of about 30 cm diameter are drilled at centres of the system width of a pair of piles. This spacing is reduced for more difficult driving conditions.

The holes have the effect of reducing the resistance of the soil strata, by allowing redistribution during subsequent driving of the piles.

If greater diameters of holes are required, they must be filled with suitable material.

Even soils including hard rock layers can be made suitable for driving by this method.

Sometimes the loosening of the soil by an auger may be sufficient.

Another possibility is the creation of a trench by a powerful auger. This trench can be filled with suitable material or may just consist of loosened soil.



Figure 8-3



9. Driving Corrections

9.1 Correction of lean

In order to avoid the tendency of sheet piling to lean, the hammer should be positioned over the centre of gravity of the piles being driven and should be held vertically and firmly on the piles by means of efficient grips.

Transverse leaning of sheet piles is eliminated by the use of efficient guide walings. If the piles develop a transverse lean which needs to be corrected, the piles should be extracted and re-driven using more efficient methods.

Longitudinal leaning in the direction of driving, which can either be caused by friction between the last previously driven pile and the pile being driven, or by incorrect use of the hammer should be counteracted immediately it becomes apparent, otherwise the condition can become uncontrollable.

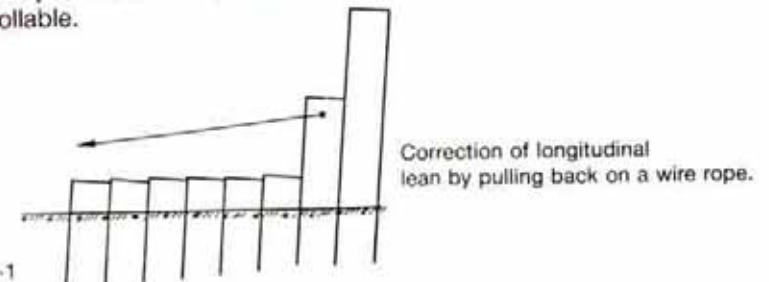


Figure 9-1

In conjunction with the above method, the hammer can be placed off centre of the pair of piles towards the last driven piles.



Figure 9-2

When, in spite of all precautions, a lean cannot be eliminated, taper piles must be employed to correct the error.

9.2 Drawing down

When piles are driven in soft ground, particularly when they are allowed to lean, the pile being driven may draw down the adjacent pile below its intended final level. If this occurs the affected pile should be extended by welding on a short length.

In order to prevent the drawing down of previously driven piles, several may be bolted together with a waling or alternatively the interlocks may be tack welded. As a further precaution against drawing down, a bolt may be inserted in the leading interlock of the pile prior to driving, thus preventing soil entering the interlocks, and reducing friction in the driving of the next pile.

Alternatively a clamping device for the sheet pile locks may be used thereby avoiding two or more sheet piles being drawn (or extracted) at the same time. If one is not sufficient a supplementary clamp can be used on the next lock.

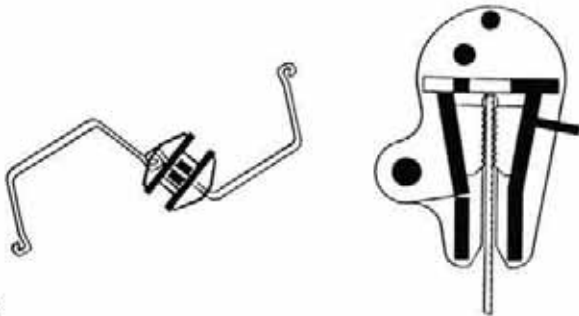


Figure 9-3

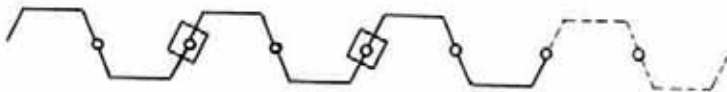


Figure 9-4

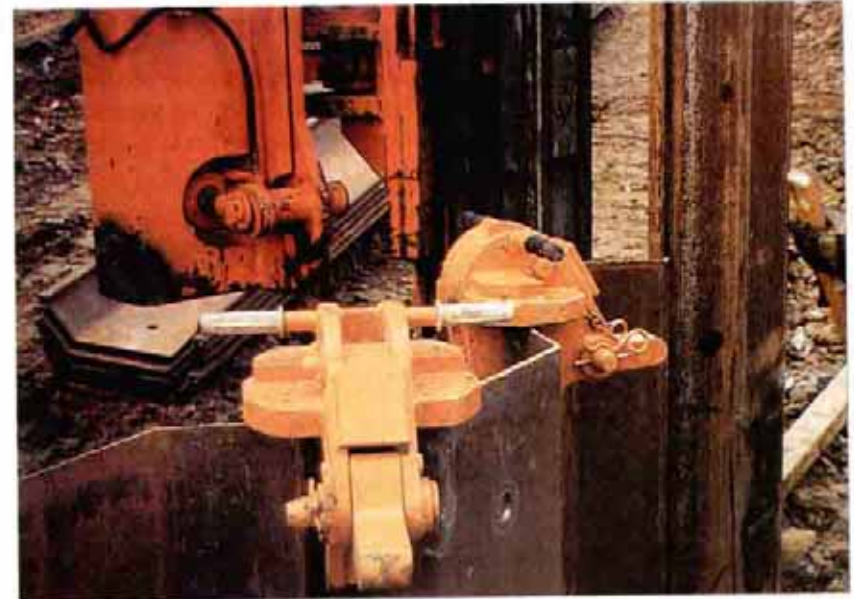


Figure 9-5

9.3 Control of wall length

Some control over the theoretical lock centres, which govern the length of the wall, can be established during pitching by varying the overall depth of the pile section.

U sections: if the wall is found to be gaining in length, this gain may be corrected by reducing the width between guide beams with timber blocks placed between the outside faces of the piles and the guide waling.

Conversely, a loss in length may be corrected by increasing this width by placing the timber blocks between the inside face and the opposite guide waling.

Z sections: if the wall is found to be gaining in length, this gain may be corrected by increasing the guide width with timber blocks placed between the inside faces of the piles and the opposite guide walings. Conversely, a loss in length can be corrected by decreasing this guide width.

If accurate theoretical wall dimensions have to be achieved, it may be necessary to introduce a fabricated pile.

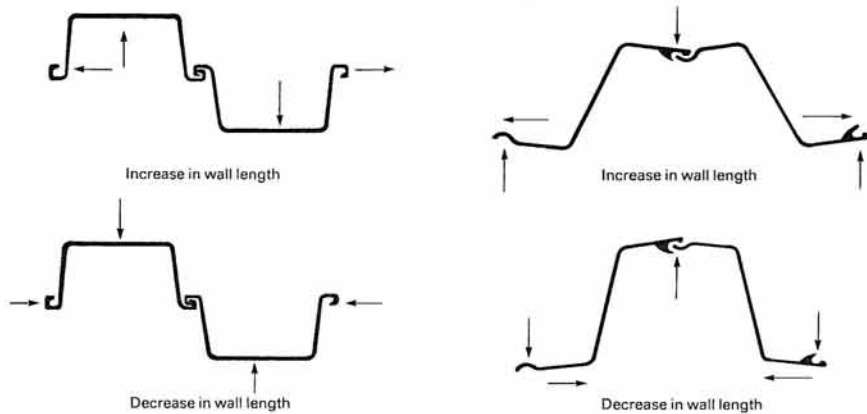


Figure 9-6

9.4 Driving tolerances

Position and orientation of the sheet piles are indicated in the driving plan. Deviations from this theoretical layout may occur due to rolling tolerances, soil conditions and driving procedure.

General tolerances for a straight and plumb sheet pile wall should be in accordance with the following figures:

- a) deviation normal to the wall line at the top of the pile ± 50 mm
- b) finished level deviation from nominal level of top of pile ± 20 mm
of toe of pile ± 120 mm
- c) deviation of verticality normal to line of piles as per cent of driving depth $\pm 1\%$

	for pitch and drive method	for panel drive method
	$\pm 1\%$	$\pm 1\%$
- d) deviation of verticality along line of piles as a per cent of driving depth $\pm 1\%$ $\pm 0,5\%$

In some cases and for certain constructions, tighter tolerances may be specified, as in the case for king piles of combined walls, where accuracy is especially important.



10. Special Aspects of Driving

10.1 Test-driving

Where an evaluation of the drivability of the soil is difficult to assess, test driving is recommended.

The reason for test-driving is to determine an adequate pile section which, when driven by a suitable hammer, will reach the required depth.

Test drives should be done in the line of the final wall, their number depending on the size of the project and on the variations of the subsoil strata.

Good control of the pile and the hammer is required and driving records must be taken.

Subsequent extraction of the piles may give supplementary information.

10.2 Driving in restricted headroom

Under bridges etc. the free height between soil level and the structure is often insufficient to allow normal pile threading/pitching.

One possibility is to drive the piles in short lengths, butt welded or fish-plated together as driving proceeds, the joints being to the full strength of the section; but, if possible, this should be avoided for reasons of economy.

A better way of overcoming the problem is to assemble a panel of piles horizontally on the ground, the length of the piles being less than the headroom. The panels should be bolted to temporary walings and moved into position.

In any case, the headroom may be increased by the excavation of a trench along the proposed line of the piling.

Driving is commenced using a double-acting hammer mounted in a cradle suspended at the side of the pile. As soon as sufficient headroom is available, the hammer should be moved to the normal driving position.

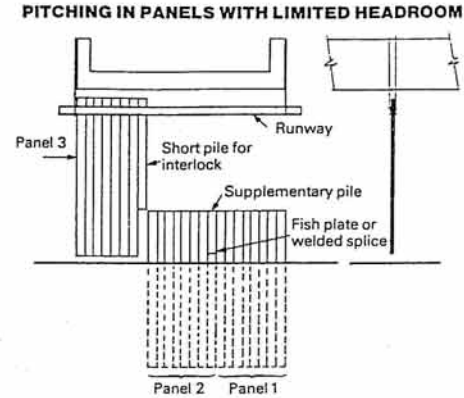


Figure 10-1

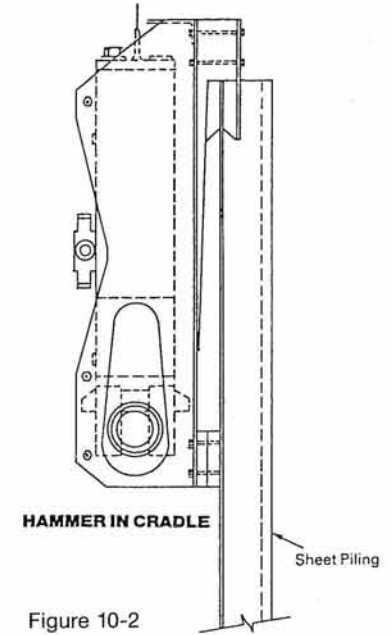


Figure 10-2

Alternatively, the initial penetration may be achieved by jacking the piles down from the overhead structure if permitted.

An alternative method is shown in figure 10-3. Over the required length at the upper end of the pile, part of the clutch is cut out so that the next pile can be interlocked.

In the soil the full interlock is maintained; in the upper part a welded flat avoids declutching.

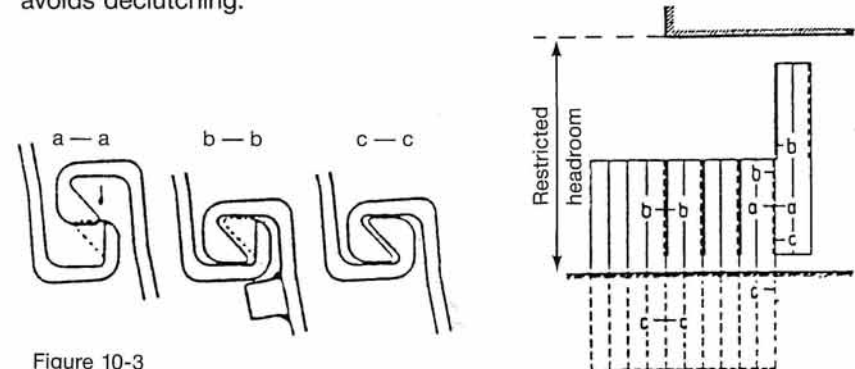


Figure 10-3



Figure 10-4: If the soil conditions allow the use of vibrators fixed directly to the boom of an excavator this may be a reasonable solution, as shown in the picture.

10.3 Driving under water

When piles have to be driven below water-level, a dolly pile should be inserted between the hammer and the pile head, the dolly pile being of such length that the hammer is always above water.

Double-acting hammers working with compressed air may work under water. Some vibrators and hydraulic hammers also work submerged.

Driving should be done in panels to allow clutching above water-level.

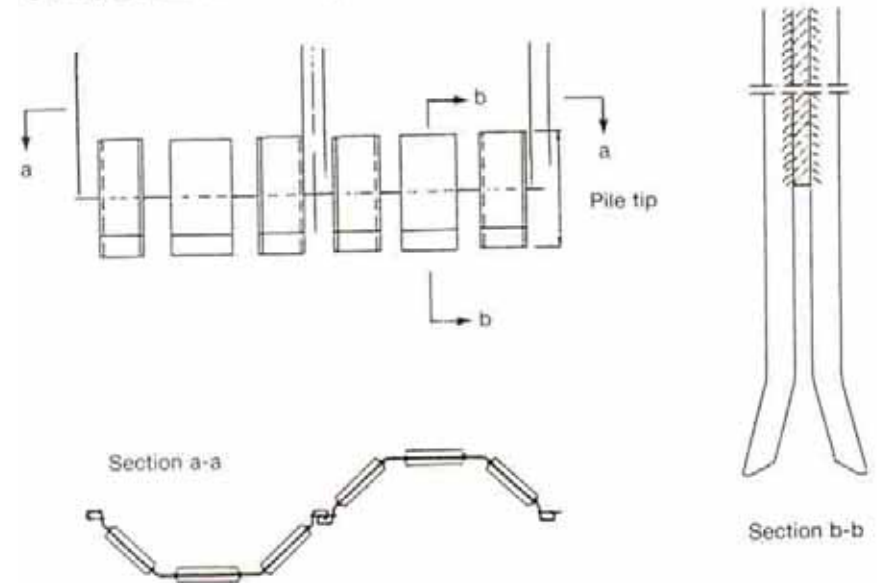


Figure 10-5

10.4 Vertical loads

The bearing capacity of sheet piles for vertical loads is often underestimated.

Indications of the possible bearing capacity can be given if, at the end of the driving, the required penetration resistance (set) is achieved and the hammers are in accord with the soil conditions and the pile section.

Test loadings may be carried out to prove the bearing capacity. Should the pile length prove to be insufficient sheet piles can be spliced and driven down further.

10.5 Noise level

The type of noise associated with piling works depends on the method of installation employed.

For example, pile driving using a drop hammer results in a well-defined, impulsive type of noise. Diesel, hydraulic and air hammers also produce impulsive noise, although their striking rates can be much higher than drop hammers. With vibratory driving the impulsive characteristic is virtually absent but an intermittent effect is still present. With jacked piling methods the resultant noise is steady.

Highly impulsive noise is generally less acceptable than steady noise. However, other characteristics of the noise source play an important part in determining the acceptability of noise, making other construction-site noises also very annoying (lorries, etc.). The duration of piling is usually short in relation to the length of construction work as a whole.

Also to be taken into consideration is the short-term effect of the driving cycles which has an influence on the definition of limit values.

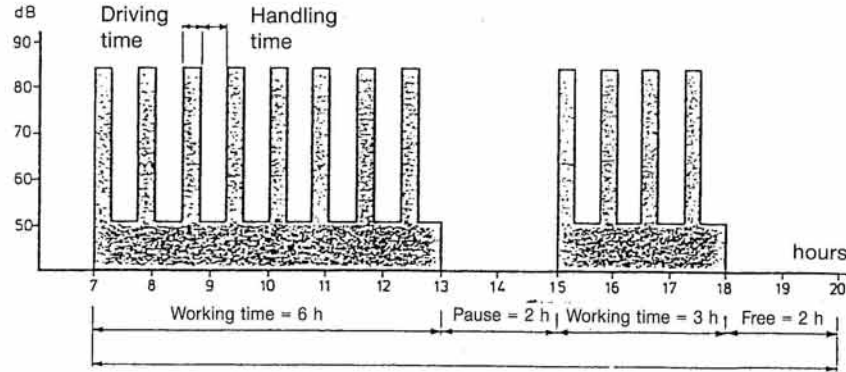


Figure 10-6: NOISES ON A PILE-DRIVING SITE VARIABLE WITH TIME

The following are characteristic noise levels for the different pile drivers:

Impact hammers	90–115 dB (A)
Rapid blow hammers	85–110 dB (A)
Vibrators	70– 90 dB (A)
Presses	60– 75 dB (A)
Measurements at 7 m from the machine.	

Noise can be reduced at source or, when this is not possible, the amount of noise reaching the neighbourhood can be reduced by screening.

Reductions usually achieved may be up to 10 dB (A).

Typical values for the intensity of sound in different areas are given in the following table:

Noisy factor/workshop	90 dB (A)
Busy street	85 dB (A)
Radio at full volume	70 dB (A)
Normal speech	55/63 dB (A)
Residential area	35 dB (A)

Typical noise levels of civil engineering plants are shown in the following table:

Piling hammer	110 dB (A)
Crawler crane	100 dB (A)
Unsilenced pneumatic breaker	90 dB (A)
Compressor	85 dB (A)
Measurements at 7 m from the machine.	

The arbitrary distance of 7 m between machine and measuring-point is another important factor. All sounds are attenuated with distance. The further sound travels through the air from the source, the less powerful it becomes. The attenuation factor is approximately a reduction of 6 dB (A) for each doubling of distance from source.

The following figure shows this as a graph:

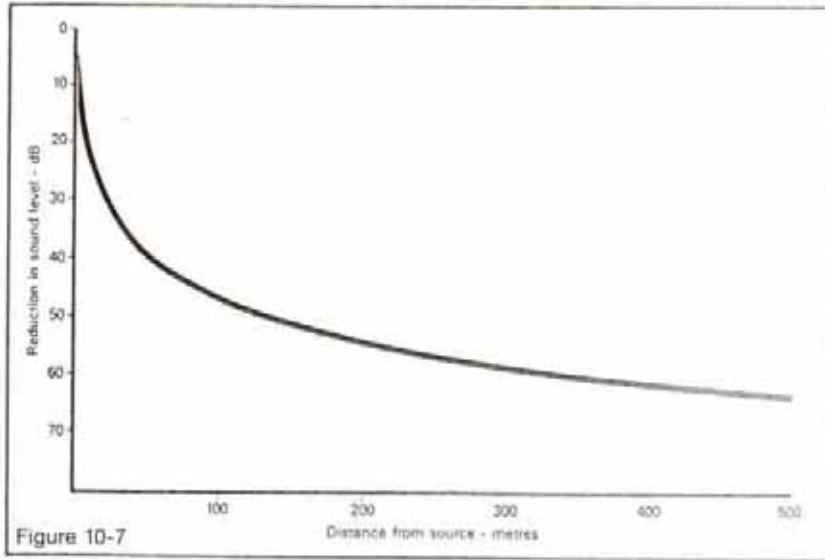


Figure 10-7

Driving assistance methods like jetting or ground pretreatment may ease penetration and thus reduce the noise-level and time of the driving work.



Figure 10-8



Figure 10-9



Figure 10-10

10.6 Ground vibrations caused by pile driving

10.6.1 General

When a pile is driven into the ground, some of the driving energy is transmitted into the adjacent soil and can be experienced on the surface as vibrations. The vibrations can cause discomfort to occupants of nearby buildings and may cause concern over the risk of damage to neighbouring property. A reasoned approach to damage limitation would comprise, firstly, measurement or an estimate of free ground vibrations based upon details of the type and length of pile, the type of hammer and its energy rating and the ground conditions; secondly, an assessment of the sensitivity of the structure to the ground vibrations and, thirdly, a decision on remedial action. Whilst publications are available to offer guidance on safe levels of vibration for various structural types, the conditions of the building and of the ground should be considered.

The building may already be stressed from differential settlement of uneven loading, so that a small dynamic strain may be sufficient to trigger damage.

Consider a mass falling on to the head of a pile, partly embedded in the ground: a comprehensive stress wave is initiated which travels down the pile.

Energy propagates outwards from the shaft of the pile with a near-cylindrical expanding wave-front.

When the compression waves reach the toe of the pile a large proportion of the remaining energy is absorbed, causing deeper penetration of the toe into the ground. It is probable that this action will induce compressional waves in the soil, which expand outwards from the toe in a spherical wave-front and with geometrical attenuation.

The compression wave travelling down the pile will cause lateral expansion due to Poisson's ratio effect, which in turn may generate compressional waves in the ground. The tendency of the pile to "whip" laterally may generate surface waves of the Rayleigh wave form, which may also contribute to the ground-wave composition.

Vibrations from these various sources of disturbance will arrive at a point on the ground surface nearby, in a complicated form, with the various components superimposed because the distances from the source are too short to allow waves of different propagation velocities to separate.

As the waves expand, the energy decreases because of geometric attenuation and material damping.

10.6.2 Measurement systems

Whether signals are transient, caused by an impact hammer, or continuous and periodic when excited by a vibratory driver, a measurement system will comprise transducers (eg geophones) which produce electrical signals proportional to vertical and horizontal vibrations and a system for display of the signals, perhaps with a processing facility. Estimations of vibrations may be made following various published recommendations, but site measurements are to be preferred.

10.6.3 Sensitivity of humans to vibration

There is no doubt that the human body is a highly sensitive transducer with respect to ground vibrations, and it is suggested that a common threshold of perception of vibration is about 0.1 to 0.5 mm/s. It is typical for people to overestimate perceived vibration.

A simple indication is offered by the widely used Rieher-Meister scale of human sensitivity to vertical vibration and in particular when equivalent particle velocities are superimposed.

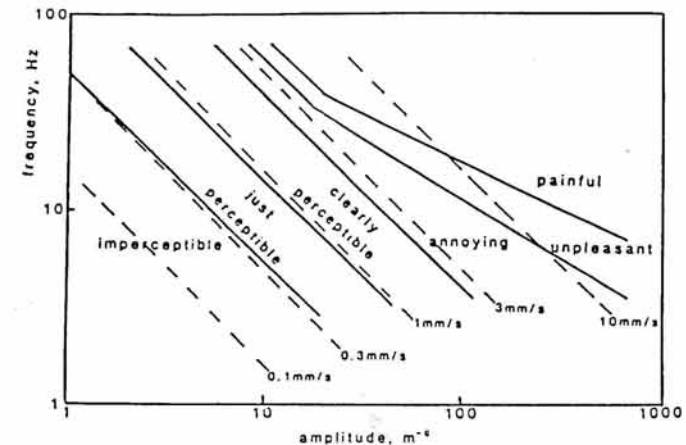


Figure 10-11: Rieher-Meister scale, with imposed velocities

10.6.4 Evaluation of the vibration effect

The response of a structure to a defined free-ground vibration signal can be evaluated either by a dynamic soil-structure interactive analysis, which is appropriate only to specialist structures, or by an empirical approach based upon limiting vibration levels. Further guidance is available from several European codes and from a number of publications. The possibility of vibration magnification by flexible floors in buildings should be noted.

10.6.5 Recommendations to reduce the effect of vibrations

The worries of householders and the probable number of complaints can be reduced, if neighbours to a piling site are visited, and are given a clear description of the extent and duration of the activity, and of the relatively low probability of structural damage despite their human perception of vibrations. On site, the major variable is the choice of hammer, and its mode of operation so as to control energy input.

Impact hammers may be controlled by the operator in terms of drop height or energy input and ground vibrations can be reduced if site measurements or observations dictate this, particularly at shallow toe penetrations.

Vibrators are very effective pile drivers essentially in granular soils and usually generate only modest vibrations; however, the vibrations are continuous and periodic and may cause problems if a nearby building element has a resonance at a similar frequency. Also these vibrations attenuate rapidly, which may be useful if a sensitive building is at a critical distance from the source. Pile jacking systems may be appropriate when soil conditions allow.

It may also be of benefit to use jetting or pre-drilling in conjunction with any of the above driving systems.

Whatever hammer type is used, good driving practice leading to axial impact on the pile, with suitable guidance to the pile to limit whip, will allow driving to continue with the minimum of disturbance or risk of damage to neighbours and their property.

The final recommendation is that when it seems a building may be at risk, or occupants worried, then before and after surveys be undertaken so that any induced damage can be evaluated, and repaired, whether it be caused solely by vibration, by vibration as a trigger when superimposed upon other strains, or as a result of piling induced differential settlement.



11. Flat Web Sheet Piles

11.1 General

Flat web sheet piles are intended essentially for the construction of cylindrical walls, generally closed, bounding an earth fill. They are used mainly for the construction of cofferdams, dock walls and dolphins.

Because of their low flexural rigidity, the straight web sections require careful storing, handling and lifting.

In order to compensate for this lack of bending resistance special attention must also be paid to the method of guiding during installation.

11.2 Storing

Incorrect storing may lead to permanent deformation which in turn may make it difficult, perhaps even impossible, to interlock the piles.

They can be stacked on top of each other provided they are offset sideways so that the clutches are situated alternately in the same vertical plane.

It is a good idea to insert wood packing between each pile, but it is also possible to stack several piles, providing the bottom piles are not overstressed (Figure 11-1).

Enough wood packing-pieces must be placed along the length of the piles to limit deformations (Figure 11-2).

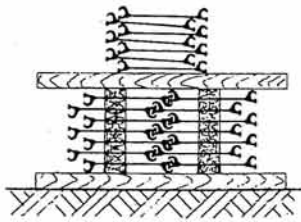


Fig. 11-1: SIDE ELEVATION

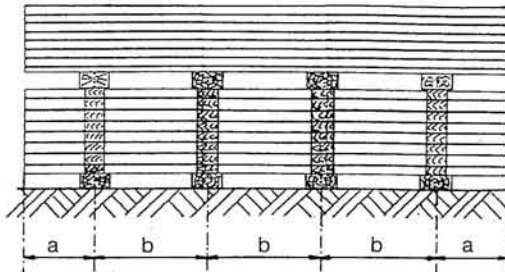


Fig. 11-2: ELEVATION

Packing for stacking flat web sheet piles (Applicable to site storage and transport)

- Overhang (a) preferably not over 1.5 m
- Spacing of packings (b) preferably not over 3 m

11.3 Handling

When sheet piles have to be moved from the horizontal storage position to another storage location, lifting beams (Figure 11-3) or brackets made from pile sections threaded in the interlocks prior to lifting should be used.

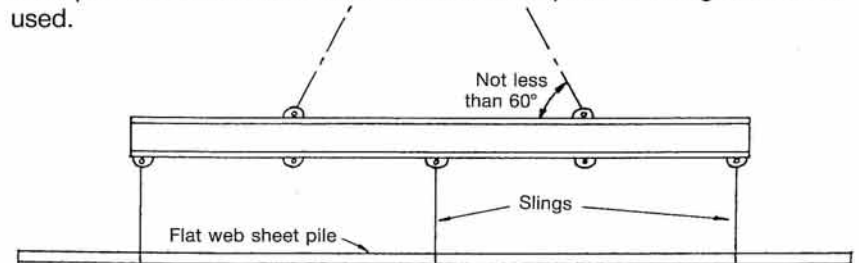


Fig. 11-3: LIFTING BEAM

11.4 Lifting

When pitching piles up to 15 m long, in the vertical position, only one point of support near the top is necessary.

Handling holes are normally provided on all piles, but if their use is not convenient, a cable choker biting on wood blocks can be used. The choker should be connected via a cable and hook to hold the lower end of the pile to prevent accidental release.

This method of pitching the pile makes it possible to reduce the height of the machine required for handling.

Flat web sheet piles in excess of 15 m should be lifted at two or even three points by a lifting beam especially equipped for this purpose, in order to avoid plastic distortions. The use of double piles is recommended as they are stiffer than single piles; they will also shorten the installation procedure.

11.5 Driving Operation

11.5.1 Template

The key to fast, economical construction of circular cell cofferdams is an efficient template to guide pitching and driving of sheet piling. It must be sturdy enough to withstand a large number of re-uses, and accurate enough to ensure closure of the circle of sheet piles without use of any special pile.

Design and shape of the template obviously depend on cofferdam size and site conditions. The selection of the material used in their fabrication (timber or steel) is dependent upon whether a floating or fixed guidance is appropriate to a particular situation.

Generally the template is positioned inside the cell, but of course alternative solutions are feasible, eg the guide placed outside the cell, or a combination outside-inside structure.

Double-level templates supported on temporary piles are more common.

The customary design is two horizontal circular template three-dimensionally connected by vertical bracing members.

With very long piles it might be advisable to provide additional circular templates to give better guidance.

A securely designed work platform will facilitate some of the placing operations of the piles.

Exact calculation of template diameter is very important to ensure correct pile positioning.

Furthermore, the rolling tolerances on the width of the piles should normally be taken into account in determining the dimensions of the template. As it is impossible to anticipate these values, it is generally advisable to adjust the dimensions of the template to the exact measurements of the delivered sheet piles.

11.5.2 Pitching flat web sections

When the template is securely anchored the sheet piles are positioned around its periphery and the whole cell is thus erected prior to driving.

Marks can be placed at the circumference of the working platform, in order to indicate whether the sheet piles are spaced properly.

Extreme care must be taken in pitching so that the piles remain plumb and do not lean.

Frequent checking of the verticality of the bars is very important and often saves time in the long run.

It is essential that junction piles are located accurately and positioned plumb. The piles should be pitched alternately from the two junctions using the centre pile or pair of piles to complete the arc.

When this method is adopted it should allow the free sliding of the closure pile, if necessary lifting of the adjacent piles will facilitate this.

Pitching piling in only one direction will magnify any errors. The first two piles of the interconnecting arcs have to be pitched prior to cell filling to facilitate the pitching of the remaining piles of the arc.

11.5.3 Driving

The driving of straight web sheet piles can be achieved by vibrators or impact hammers. In all cases the equipment should be light and easy to handle in order to facilitate repositioning and to make staggered driving easy.

Driving in double piles is recommended whenever possible in order to transfer the driving energy to the concentrated mass of the interlocks instead of the thin web.

Driving may be assisted by water-jetting whenever soil conditions make it necessary.

When the cell is completed, and before commencing the filling, ensure that all unsuitable soils are removed.

When the fill has reached a safe level, the template is lifted out and advanced to the next position.

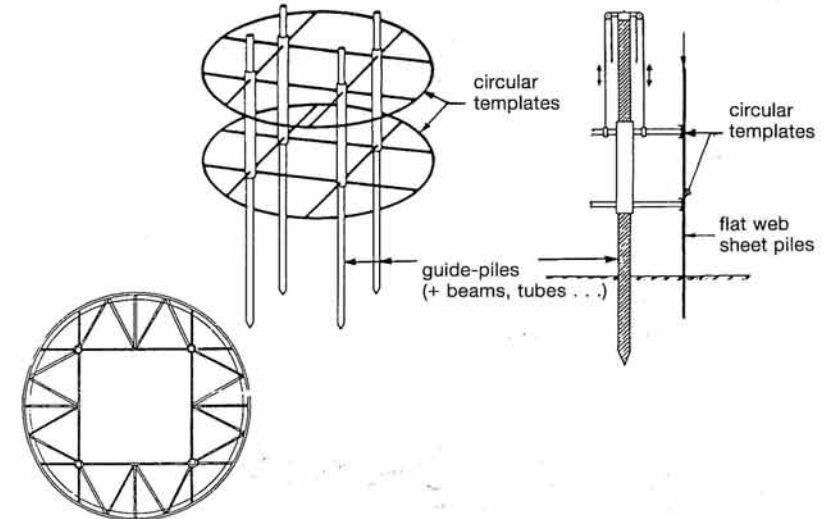


Figure 11-4: TEMPLATE – Typical layout of a template for flat web sheet piles.



Figure 11-5



Figure 11-6



12. Extracting

12.1 General

When piling is intended to serve only as temporary protection for permanent construction work, it can be extracted for re-use by means of suitable extractors either of the impact, vibratory or jacking type.

12.2 Measures to be taken before and during driving

When extraction of piles is foreseen, the following details must be taken into account: sheet pile section, sheet pile length, driving depth, subsoil data, embedded time and driving method. All these factors may create problems, as requiring very heavy extraction equipment or even making recovery impossible.

A slip coating on the inside of the interlocks reduces the friction.

In dense soils the use of sacrificial toe-protection shoes may be helpful. Immediately before driving, the shoe is put on the pile toe without welding. The protrusion of the shoe over the sheet pile creates a loosened soil zone along the surface of the pile.

For an evaluation of the required pulling force, the previous establishment of a driving record for each pile is very useful. This identifies the piles with the lowest resistance, thus defining the starting-point for the extraction work.

If driving records of the piles are not available, then the first pile to be extracted should be selected with care.

Piles near the centre of a wall should be tried until one pile begins to move.

If difficulty is experienced, then a few driving blows may be used to loosen a pile.

It may also be necessary to reinforce the head of the piles to aid the successful extraction of the initial pile.

Accurate driving of the piles in the soil makes extraction easier.

It may be necessary to increase the section to ensure good drivability and minimise damage to the piles.

12.3 Extraction

Vibrators and extractors of various sizes are available. They loosen the pile from its initial position, so that it moves with the help of the pulling force of the crane. The limit values of the extractors and crane loads given by the manufacturer must be respected.

The connection between pile and vibrator is made by hydraulic clamps, shackles and bolts.

Sometimes drilling or jetting is necessary to facilitate the extraction operation.



13. Conversion Table

Linear Measure

1 inch	= 25,400 millimetres	1 millimetre	= 0,03937 inch
1 foot	= 0,3048 metre	1 centimetre	= 0,3937 inch
1 yard	= 0,9144 metre	1 metre	= { 3,2808 feet 1,0936 yards
1 mile	= 1,6093 kilometres	1 kilometre	= 0,6214 mile

Square Measure

1 sq. inch	= 645,16 sq mm	1 sq. cm	= 0,1550 sq in.
1 sq. foot	= 0,0929 sq. m	1 sq. m	= { 10,7639 sq. ft. 1,1960 msq. yds.
1 sq. yard	= 0,8361 sq. m	1 hectare	= 2,4711 acres
1 acre	= 0,4047 hectare		
1 sq. mile	= 259,00 hectares		
	1 hectare = 10,000 m ²	1 km ²	= 247,105 acres

Cubic Measurement

1 cubic inch	= 16,387 cubic cm	1 cubic mm	= 0,000061 cubic in.
1 cubic foot	= 0,0283 cubic m	1 cubic m	= { 35,3147 cubic ft. 1,308 cubic yds.
1 cubic yard	= 0,7646 cubic m		

Measure of Capacity

1 pint	= 0,568 litre	1 litre	= { 1,7598 pints 0,22 gallon
1 gallon	= 4,546 litres		

Weight

1 oz.	= 28,350 grammes	1 gramme	= 0,0353 oz.
1 pound	= 0,4536 kilogram	1 kilogram	= 2,2046 lb.
1 ton	= { 1,016 tonnes 1016 kilograms	1 tonne	= 0,9842 ton

Section Modulus

1 inch ³	=	16,39 centimetres ³
1 inch ³ per foot of wall	=	53,7 centimetres ³ per metre of wall
1,86 inch ³ per foot of wall	=	100 centimetres ³ per metre of wall

Moment of Inertia

1 inch ⁴	=	41,62 centimetres ⁴
1 inch ⁴ per foot of wall	=	136,56 centimetres ⁴ per metre of wall

Miscellaneous Conversion Factors and Constants

1 lb (f) ⁴	=	4,449 Newtons
1 pound per linear foot	=	1,4881 kilogrammes per linear metre
1 pound per square foot	=	4,883 kilogrammes per square metre
0,205 pound per square foot	=	1 kilogramme per square metre
1 ton (f) per linear foot	=	32,69 kilonewtons per linear metre
1000 pound (f) per square foot	=	47,882 kilonewtons per square metre
1 ton (f) per square inch	=	15,444 Newtons per square millimetre
ton (f) per square foot	=	107,25 kilonewtons per square metre
100 pound per cubic foot	=	1602 kilogrammes per cubic metre
100 pound (f) per cubic foot	=	15,7 kilonewtons per cubic metre
1 ton (f) foot Bending Moment per foot of wall	=	10 kilonewton metres Bending Moment per metre of wall
1 metre head of fresh water	=	1 kilogramme per square centimetre
1 metre head of sea water	=	1,025 kilogramme per square centimetre
1 cubic metre of fresh water	=	1000 kilogrammes
1 cubic metre of sea water	=	1025 kilogrammes
1 radian	=	57,3 degrees
Young's Modulus, steel	=	210 kN/mm ²
100 microns	=	0,1 mm = 0,004 inch
10 bar	=	1 MN per square meter

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