Shoring
Technology
Interest Group
STIG

Safety in Shoring

The Proprietary Shoring and Piling Equipment Manual

National Construction College

Safety in Shoring: The Proprietary Shoring and Piling Equipment Manual

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CONTENTS

Foreword

The Construction Plant-hire Association (CPA) represents the needs of a diverse range of special interest groups within the plant-hire sector. The Shoring Technology Interest Group (STIG) is one such group. Formed in 2000 it has been actively involved in promoting guidance, best practise and training to those involved in shoring and piling operations on construction sites.

The use, range and scope of proprietary shoring and piling equipment have all increased dramatically within recent years. Whilst shoring and piling operations are often among the first tasks on a new construction site, they are often treated as separate entities with little consideration to the natural link between them. This book attempts to bring these two operations together and illustrates the latest equipment, considerations surrounding the selection of equipment types, methods of use, safety issues and legislation surrounding these operations.

The book will give the reader an insight into current techniques and practical aspects involved with these operations. Its scope focuses on proprietary shoring equipment and small to medium piling operations.

STIG would like to acknowledge and thank the primary authors and editorial team for their time and effort in producing this book.

David Coley
Aldridge Piling Equipment (Hire) Co Limited

Tony Gould
Vp plc (Groundforce Shorco)

John Harris
Technical Consultant

Haydn Steele
Manager: Safety, Training & Technical

A list of STIG member companies is listed below:

Aldridge Piling Equipment Co Ltd
www.miniape.com

Dawson Construction Plant Ltd
www.dcpuk.com

Groundforce Shorco
www.groundforce.uk.com

Mabey Hire Ltd
www.mabeyhire.co.uk

MGF (Trench Construction Systems) Ltd
www.mgf.ltd.uk

Piletec Dudley Vale
www.piletec.co.uk

Site Equipment Ltd
www.site-equipment.co.uk

CHAPTER 1

SHORING DESIGN CONSIDERATIONS

Forward

Proprietary equipment for temporary works of any type should not be used on site until its suitability has been assessed for the application in mind.

In the case of temporary works support for an excavation, this requires the user to adopt the following approach:

i. specify what is required for the temporary works - the type of excavation, plan size, depth etc.

ii. establish the ground and groundwater conditions, surcharges and topographical conditions in the vicinity of the proposed excavation.

iii. define a proposed method of working

iv. pass the above data on to a competent designer who will rely on it to prepare a design scheme for the temporary works.

All personnel involved in steps i – iv above should be suitably qualified and competent to carry out the tasks required

Scope

This chapter lists information that a potential user of proprietary shoring will need to collate and provide to the chosen designer, bearing in mind that the designer will probably not visit site, who may be one of the members of STIG. This is not a design manual but should enable the reader to gain an understanding of the engineering design process involved in specifying a safe, economic and workable shoring solution.

Introduction

Proprietary ground support equipment can be broadly divided into two categories.

a. Trench lining systems such as trench or manhole boxes and drag shields.
b. Shoring systems such as trench sheeting and supporting frames and struts.

Category a- Comprises systems with predetermined strength characteristics and it normally only remains for a competent person to check that the earth pressure expected to be encountered on site does not exceed that prescribed for the supplier's system.

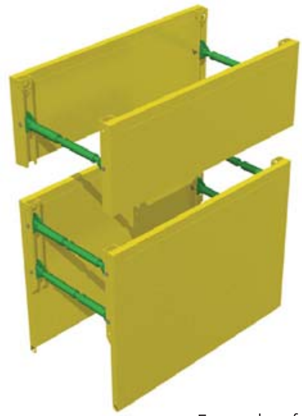


Figure 1.1
Example of a trench box and top

Category b - Includes a range of components in the form of sheets supporting frames and cross struts that can be combined in many different configurations. For these systems, a site-specific design will be required for each application together with supporting drawings indicating the exact configuration of equipment to be used. Temporary works designs should only be undertaken by a competent and qualified Engineer who has obligations under the Construction Design and Management Regulations (CDM) to provide a safe and workable solution.

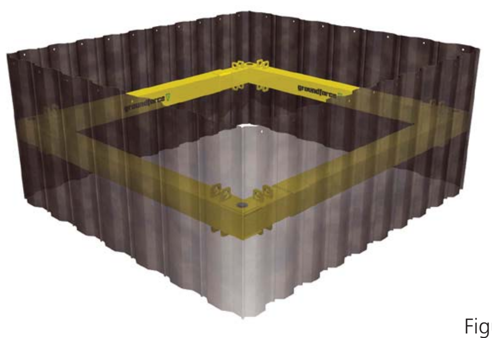


Figure 1.2
Example of a hydraulic bracing frame and trench sheeting

All STIG member companies supplying shoring equipment offer a design service. However it is important to remember that these designs are based wholly on information provided by their customer (the Contractor). The accuracy and validity of this information is wholly the contractor's responsibility and one can see therefore that a design so produced will be totally reliant on the quality of the design brief.

To assist contractors in providing a good design brief a pro-forma design request form is available and reproduced in Appendix 1. The information required to complete the form will be examined in the remainder of this chapter. A glossary of common engineering terms is included in Appendix 2 to assist the user in understanding some of the terminology used.

Note on CDM: Under the Construction Design and Management (CDM) regulations 1994, for the majority of projects, the client is required to appoint a Planning Supervisor . This may be the principal contractor, lead designer or a third party specialist. The planning supervisor's main responsibility is to ensure that all those who carry out design work on a project, particularly during the design phase, collaborate and pay adequate attention to the need to reduce risk wherever possible.

Although not mandatory, it is common practice for the main contractor to appoint a temporary works coordinator to ensure that the permanent and temporary works designs and safety issues are fully considered and co-ordinated on site.

To meet their design responsibilities under CDM, a shoring designer would normally expect their brief to include:

a) Names and contact details for the:
i. Planning supervisor
ii. Principal contractor
iii. Temporary works coordinator (if one has been appointed)

b) All relevant information from the Health & Safety plan which needs to be taken into consideration when preparing the design

Figure 1.3
A 22m long prefabricated tank installed in a braced excavation

Excavation Dimensions

The starting point of the design brief is the excavation size and footprint. If rectangular, a statement of the excavation size will be sufficient. If more complex, a sketch or drawing is essential.

Dimensions can be specified either as sheet to sheet or in terms of clearance dimensions required inside supporting framework. The latter is probably the preferred method particularly in the case of say an excavation for a prefabricated tank, where the essential requirement is for the tank to be able to fit between the supporting framing at installation stage. If the designer is aware of the clearance requirements they will be able to specify an overall excavation size to take into account the size of the supporting members plus of course an allowance for deflection.

In the case of concrete structures it is usual to allow a working space for formwork etc. and the amount required must be specified unambiguously to avoid unnecessary re-designs.

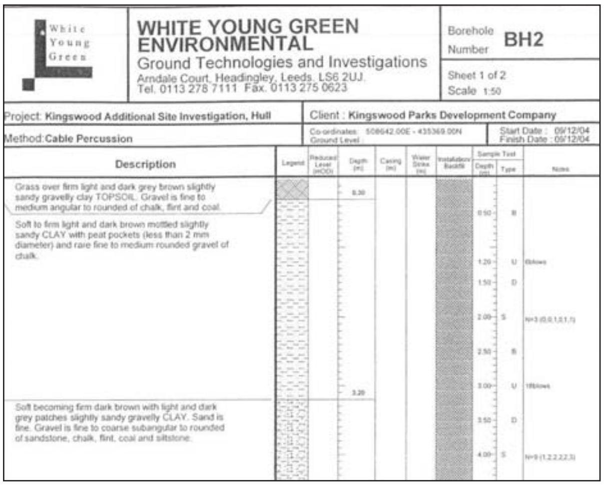
Any other restrictions to the excavation must be stated such as pipe lengths and other limitations on strutting etc to enable the designer to provide a workable solution.

Certain design guides require the designer to allow for an element of over-dig when determining the design depth of the excavation; this can be as much a 10% of the excavation depth. If the contractor wishes to have an allowance for over-dig included in the design this should be specified within the design brief.

Finally, for complex strutting schemes such as basement propping it is very beneficial for the designer to work straight from construction drawings. Most construction drawings are produced in AutoCAD ® format. These can be emailed directly to the design office and will enable the designer to superimpose the shoring layout directly onto the permanent works. This will readily identify any potential clashes with the permanent works such as columns or lift shafts for example.

Ground Information

The loads generated on any shoring system are entirely dependent on the ground conditions likely to be encountered. Engineering skill and judgement is crucial in interpreting ground conditions and groundwater regimes and translating these into a safe design.



White Young Green

WHITE YOUNG GREEN ENVIRONMENTAL
Ground Technologies and Investigations
Arndale Court, Headingley, Leeds. LS6 2UJ.
Tel. 0113 278 7111 Fax. 0113 275 0623

Borehole Number BH2
Sheet 1 of 2
Scale 1:50

Project: Kingswood Additional Site Investigation, Hull
Client : Kingswood Parks Development Company
Method: Cable Percussion
Co-ordinates: 508642.00E - 435369.00N
Ground Level:
Start Date: 09/12/04
Finish Date: 09/12/04

Description	Depth (m)	Sample Depth (m)	Type	Notes
Grass over firm light and dark grey brown slightly sandy gravelly clay TOPSOIL. Gravel is fine to medium angular to rounded of chalk, flint and coal.	0.30			
Soft to firm light and dark brown mottled slightly sandy CLAY with peat pockets (less than 2 mm diameter) and rare fine to medium rounded gravel of chalk.		0.50	B	
		1.20	U	6blows
		1.50	D	
		2.00	S	N=3 (0,0,1,0,1,1)
		2.50	B	
	3.20	3.00	U	18blows
Soft becoming firm dark brown with light and dark grey patches slightly sandy gravelly CLAY. Sand is fine. Gravel is fine to coarse subangular to rounded of sandstone, chalk, flint, coal and siltstone.		3.50	D	
		4.00	S	N=9 (1,2,2,2,2,3)

Figure 1.4 A typical borehole log

High quality soil information is essential for the designer to be able to produce a meaningful design. There is little point in calculating loading to several decimal places if the soils information is poor or non-existent. Furthermore the designer will likely err on the cautious side resulting in a less efficient design.

Soil information can be supplied to the designer in a number of ways.

Site Investigation document (SI)
Borehole extracts
Trial pits
Verbal description

Most large sites will have had a site investigation undertaken by a specialist company. This document will cover topics such as geological conditions, borehole records, detailed soil analysis, bearing capacities and contamination plus recommendations for foundation construction and temporary works support. As far as the temporary works designer is concerned only a relatively small part of the SI document will be relevant but is nevertheless the most comprehensive source of ground information. S.I.'s can be bulky documents and it is not always practical and economic to send these to designers.

Boreholes provide the most useful and relevant source of soil information to temporary works designers providing they are located somewhere near the proposed excavation. Information on soil strata is recorded in a consistent manner as specified in B.S. 5930:1981 Code of practice for site investigations, that can be readily interpreted and translated into engineering properties by a competent engineer. Information on boreholes include: general description of strata and make up of constituents, levels of strata change, indication of compaction or density, groundwater details and possibly other structural properties. A borehole should be regarded as the minimum level of soil information that should be presented to the designer for any significant excavation.

Trial pits provide limited information on ground conditions. Due to the fact the pits are usually dug by a mechanical excavator, little if any soil testing takes place and therefore the information is usually limited to a general description rather than quantitive data. The other major limitation is that trial pits are relatively shallow, depth being limited by the reach of the excavator and stability of the unsupported excavation sides. Care should be taken in extrapolating soil conditions beyond the depth of the trial pit.

Verbal soil descriptions outside of a site investigation should be treated with a good deal of caution as these will generally be based on previous experience of excavations elsewhere on site and will usually be provided by unqualified people. A layman's verbal description of firm clay may differ wildly from the engineering description of firm clay, whilst a verbal description of "running sand" will provide the TW designer with little scope to provide a good solution. Verbal soil descriptions should only be used for shallow excavations in non-critical areas.

As a rule of thumb, where the soil is required to provide support to the retaining structure i.e. in the case of propped cantilever piled walls, a borehole should be provided with the design brief. In the case of a cantilever design, which is totally reliant on the ground for support, a borehole is essential.

Groundwater

The presence or absence of groundwater is probably the most important factor in the preparation of a shoring scheme. Groundwater can make its presence felt in a number of ways and poses the designer a number of problems to address before a satisfactory support system can be proposed.

Figure 1.5 A flooded excavation

As mentioned earlier, a verbal description of "running sand" is not very helpful apart from indicating the presence of groundwater.

Groundwater can exist either as:

1. Perched
2. Artesian conditions
3. Natural level

Perched conditions occur when surface water is prevented from draining through to its natural level by an underlying impermeable cohesive strata such as made ground over clay.

Artesian conditions are exactly the opposite of perched, that is when groundwater is confined, under pressure, below a cohesive strata. If the cohesive stratum is punctured, the groundwater will rise sometimes very rapidly to its natural level. If the base level of an excavation is some distance above the confined aquifer, special measures may not be required. As the formation level approaches the aquifer the base will tend to heave upwards and possibly "blow" with total loss of passive pressure. Natural groundwater level is the level at which water level occurs without the effects of either perched or artesian effects. Non-cohesive soils such as sand and gravels usually allow natural levels to prevail.

Likely rate of inflow is also important and is dictated by the three conditions above and the permeability of the ground strata present.

Design Considerations

When faced with a groundwater problem, the designer has three basic choices in how to deal with it:

1. Exclusion
2. De-watering (removal)
3. Free draining

Exclusion is the term used when water is kept out of the excavation by a fully enclosed cofferdam using interlocking sheets or piles including corners, with piles being toed in sufficiently below formation to minimise water flow underneath. Sump pumping will probably be required to deal with residual water entering the excavation. The designer needs to consider external water pressures in additional to soil pressure on the support system and possibly the effects of seepage forces on the piles and piping conditions beneath the piles, usually indicated by "boiling" effects at the formation. Consequently a robust design will be required with possible long pile penetrations into cohesive ground to act as a cut-off to groundwater flow.

Dewatering processes pump water from the surrounding ground before it reaches the excavation. This reduces the wall loading and avoids water flow into the formation of the excavation. There are several methods of dewatering, all having limitations. The most popular is well pointing where water is literally drawn out of the ground through a series of suction tubes surrounding the excavation. Dewatering is a complex subject and is outside the scope of this book. Further information on dewatering can be obtained by reading CIRIA Report 113 – Control of groundwater for temporary works. Note: sump pumping is not a true method of dewatering.

Free draining conditions allow groundwater to flow through non-interlocked or lapped sheets or piles into the excavation to be removed by sump pumping. This is only really an acceptable solution where groundwater flow is likely to be very low such as through cohesive material or when perched conditions exist where flow is likely to diminish over time. The risk of such a scheme is the potential migration of fines into the excavation, which could lead to voids in the surrounding ground and consequent settlement problems.

To summarise this section:

- Good quality ground information is essential in order to produce a good quality design.
- Borehole data should ideally be interpreted by a competent engineer.
- It is essential that groundwater profiles are interpreted accurately.
- Verbal descriptions should be avoided for all but the shallowest of excavations and must not be used for cantilever designs.

Surcharges

Surcharge is the generic name given to any external factor that can affect the load on an excavation support system. Examples of surcharges are:

- Adjacent structures.
- Spoil heaps.
- Adjacent roads, railways etc.
- Slopes and batters.
- Adjacent traffic, site plant, cranes, excavators etc.

Figure 1.6 Examples of excavation surcharges and lack of support

As a general rule, the closer a surcharge is to the side of an excavation, the greater its effect, different soil types will also exhibit differing susceptibilities to surcharge loading.

A surcharge must be within the zone of influence to have a significant effect on the excavation. As a rule of thumb, if a line is drawn at 45° up from the toe of the sheets to the ground level, anything between the line and the side of the excavation will be within the zone of influence and therefore needs to be accounted for in the design. Anything lying outside the line will have little effect and can usually be ignored by the designer.

Most standards and codes specify that a general surcharge of 10kN/m2, irrespective of other surcharges present, is applied to design calculations. This is to take into account general site traffic including excavators up to 30 tonnes. Crane outriggers can apply very significant local surcharges and consequently should be sited away from critical areas if possible. The designer must be made aware of any crane operating within the zone of influence.

The effects of adjacent structures must be assessed very carefully as excessive deflection of the supporting structure can lead to movement of foundations with catastrophic effects. The depth and magnitude of foundations need to be accurately specified to the designer. Buildings on piled foundations however are likely to have little effect providing that the piles extend well below the depth of the excavation.

Topographical effects

In addition to the factors already mentioned within the surcharge section, it is important to communicate to the designer details of the general area surrounding the excavation. A couple of examples:

Excavations within or at the base of slopes or embankments are worthy of particular mention. Transferring loads across from the high side to the low side of an excavation within a slope can cause problems without building up the ground on the low side. Removing soil from the base of slopes can lead to loss of global stability e.g. slips.

Three sided excavations such as for river outfall structures need careful consideration to prevent the support system moving. Tidal effects, if applicable, will also need to be allowed for.

A good diagram or photographs will aid a designer immensely.

Methods of working

A competent designer will check the adequacy of the support system components at all stages of its construction and not just the final stage. It is quite common for frame loads and sheet bending moments to be more onerous during the transient installation stages as opposed to the final installed condition.

To be able to carry out this check effectively it is necessary to know the method of installation of the sheets and frames. The most common methods of installation are:

1. Pre-driven sheets / piles
2. Dig and push / drive
3. Slit trench
4. A combination of the above

Figure 1.7 Driving trench sheeting with an excavator mounted vibratory hammer

Pre-driven method

This is the simplest, safest and most accurate method of getting sheets or piles into the ground. It has the added advantage of generally ensuring that shoring installation can be carried out with little risk of the sheets kicking in during excavation.

Consideration does need to be given to the hammer / sheet combination to achieve success in any particular ground conditions bearing that more than one type of hammer may be required to achieve full sheet penetration. Furthermore, the impact stresses imposed on a sheet during installation usually dictate its specification rather than those produced by lateral earth pressure alone. This subject is dealt with at length elsewhere in this manual.

The dig and push method

This is where the sheets are driven to refusal ahead of the excavation usually by the digger bucket! This method of installation is much preferred by contractors as being cheap, however significant sheet penetration can only be achieved in relatively soft ground conditions. Other disadvantages are a greater risk of damage to sheets and a high probability of the sheets not going in very straight. Dig and push is really not a practical method where either interlocking sheets are specified or for cantilever support where large sheet pile penetrations are required. From a designer's perspective, dig and push poses more problems in providing a safe solution during intermediate construction stages. Generally a minimum toe-in ahead of the excavation is specified. There is always doubt as to whether this will happen on site which needs to be dealt with in the contactor's risk assessment.

The slit trench method

This is where the sheets are placed in a pre-excavated narrow trench and backfilled to hold them in place prior to bulk excavation. It relies on short-term stability of the ground to prevent the "slit" trench collapsing and is consequently generally limited to good ground. Clay ground conditions are ideal. If the designer has specified a toe-in on the sheets, this should be into undisturbed ground, i.e. the sheets must be driven below the slit trench to achieve the specified toe. An alternative to a driven toe is to overdig the slit trench and concrete in the sheet toes.

Although this method provides an effective anchorage, subsequent removal of the sheets may be difficult. Slit trenching is only recommended in excavation depths up to 4m. From a designer's perspective this method can be treated in a similar manner to pre-driven sheeting although one could argue that the ground, having been disturbed by the trenching operation, will exert different lateral pressures than normally assumed.

Effect of deflections

The consequences of unplanned or excessive deflections on a support structure can be dramatic. The designer must be made aware of anything within the zone of influence that may be so affected (in a similar manner to surcharges) e.g. roads, structures, underground services.

Figure 1.8 Deflection of excavation support

Unless adequately braced, proprietary hydraulic shoring frames are generally more flexible than a welded framework. Furthermore, the structural capacity of these frames is often used to the full, hence a fully loaded frame can show large deflections. This may be perfectly acceptable when the excavation is in an open field but will cause a problem when located next to a high-pressure gas main!

Another consideration is where a prefabricated tank, for example, is to be lowered through a supporting frame. The contractor wants to minimise the excavation size for obvious cost saving reasons. However, if adequate clearance has not been allowed, beam deflection can result in the tank not passing through the framework.

Cantilever designs, although being very popular due to absence of any supporting framework, can result in very severe deflection at the top of the pile and are not recommended for temporary works where there are adjacent structures.

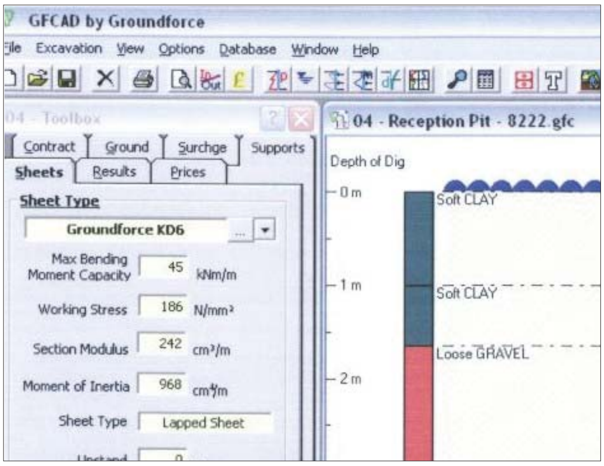
Use of computer software in shoring design

There are several software packages on the market varying in complexity. They also require differing degrees of skill to be used effectively and to produce safe designs. Software, available for earthwork support, can be broadly divided into two types:

1. Limit equilibrium (L.E.) calculation methods.
2. Soil interaction methods including: -

a. Beam-spring interaction (subgrade reaction) methods.
b. Finite element and finite difference packages.

Soil interaction software packages require relatively complex input data and designers using this type of software require a good level of training and skill to produce realistic results. The design time involved is significantly greater than that required for the much simpler L.E. software. Consequently, their use is limited to more complex situations.



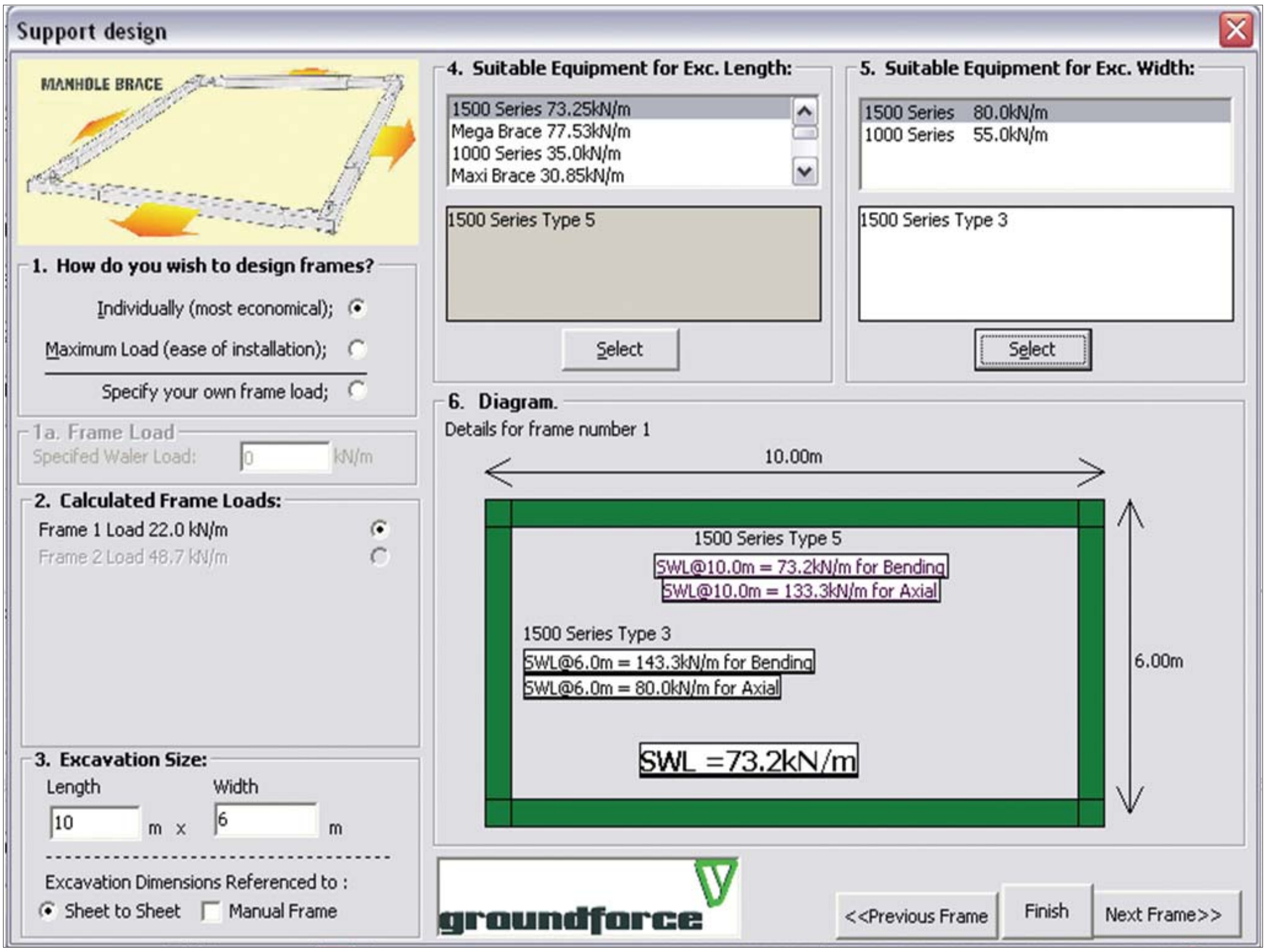


Figure 1.9 Proprietary excavation support design software

L.E. software is simple and straightforward to use and will allow the designer to deliver results very quickly. Deflections predicted by L.E. methods should be treated with caution.

However, much experience has been obtained over many years with these methods and the use of conservative soil parameters will generally lead to safe, if sometimes uneconomic, designs.

The complexity of the software is generally reflected in the purchase price. Some STIG member companies supplying shoring equipment offer bespoke integrated software packages using L.E. calculation methods linked to equipment design modules.

Editable databases for soil parameters simplify input and provide a degree of safety, being based on conservative values. The software can determine if sufficient sheet/pile toe-in depths are achieved, both during installation stages and at full depth.

Design software is intended as an aid for experienced engineers. It is not a substitute for sound engineering experience and judgement. The user must have a basic understanding of soil mechanics and should refer to recognised textbooks for in-depth explanation of any theories.

Summary

The design of excavations is an inexact process relying very heavily on engineering interpretation and judgement of many factors. The better the quality of design brief and accompanying soils information supplied will enable the designer to produce a better and more economic and appropriate shoring design.

Appendix 1

TEMPORARY WORKS DESIGN REQUEST

GENERAL INFORMATION

Customer:	Main Contractor:	
Site:	Scheme Title:	
Site Contact:	Site Tel:	Site Fax:
Date Requested:	Date Required:	

NOTES

- *Complete all sections giving as much detail as possible. Where _ appears, tick the appropriate choice.*

DIMENSIONS

Dig Depth:	Plan Dimensions:
Clearance required below bottom frame:	Clearance required between frames:

- *Specify dimensions as 'sheet to sheet' or 'inside of frame'. Provide a sketch if required.*
- *Give size of proposed or existing structure where applicable.*

GROUND CONDITIONS

Soil detail provided by: Position:		Borehole Log No(s):
Nearest/most relevant BH:	Distance from excavation:	Borehole location plan available? YES _ NO _

Verbal Soil Description:		Thickness (m):
Layer 1		
Layer 2		
Layer 3		
Layer 4		

Existing Ground Level:	Groundwater Level:	De-watering: YES _ NO _ Method: Reduced GWL:

- *State the person who provided the soil information.*
- *Where possible, provide a borehole location plan with the proposed excavation marked clearly on it.*
- *If there is no borehole or trial pit information available, provide an accurate and detailed description of the soil conditions in the space provided.*
- *Specify method of dewatering; if well pointing, specify the reduced water level.*

ADDITIONAL INFORMATION

External Loading (Plant / Site Traffic):	At distance:
Adjacent Structures / Cranes / Roads / Railways:	At distance:
Adjacent Services:	At distance / level:
Anticipated Duration of Excavation:	
Does the Health & Safety Plan identify any hazards?: YES _ NO _	

- *State the maximum laden weight of plant to be used near the excavation.*
- *Describe adjacent structures in detail. Include dimensions and foundations for buildings, dimensions and loadings for cranes and similar for roads and railways.*
- *State estimated TOTAL time of excavation in weeks.*
- *Please provide a copy of the Health & Safety Plan*

Appendix 1

TEMPORARY WORKS DESIGN REQUEST

METHOD OF WORKING

Preferred solution:		• *i.e. 'propped cantilever / two frames & no toe / three frames & toe / cantilever sheets etc.*
Installation of sheets: *PRE-DRIVE* _ *DIG & PUSH* _ *SLIT TRENCH* _		• *Indicate preferred method of installation.*
Maximum (anticipated) achievable toe:	2-stage construction? *YES* _ *NO* _ Concrete Base Thickness:	• *2-stage = cast concrete base against the sheets and remove bottom frame(s).*
Ground reduction:		• *Give detail on any ground reduction or batter including angles & distances.*

NOTES

• *Provide any other relevant information in the space provided, or attach to this sheet.*

SKETCH

• *Provide a sketch for any unusually shaped or complicated excavations.*

I confirm that the above information comprises the design brief that should be used to prepare a temporary works shoring scheme.

Signed:…………………..Name:……………………………Position:……………………………….Date:………

Appendix 2

COMMON ENGINEERING TERMS

TERMINOLOGY	DEFINITION
Active pressure	Minimum soil pressure generated by the active side of the excavation. (see below)
Active side	Retained earth side of the excavation (of an excavation)
Allowable load	(see Safe Working Load)
Bench mark	Permanent 'mark' (often chiselled into a building or wall) of precise known height above ordinance datum (sea level) for the purpose of setting out levels
Berm	Level area separating two slopes.
Bill of Quantities	Forms part of the contract documentation; schedule details descriptions, quantities and unit rates for all items of construction work.
Blinding (concrete)	Lean-mix concrete protection to the formation, normally 75mm thick
Boiling (see Piping)	Occurs when the upward pressure on the soil grains is so large due to seepage flow of water at F.L, that soil effective weight is reduced and a 'quick sand' condition results.
Box-out	Method to avoid obstructions, or allow later access in newly constructed concrete walls
Brothers	Two, four or multi-leg lifting chains
Bulk density	The natural insitu density of a material (partially saturated). Also called bulk unit weight
Bund	(Protective) barrier often constructed in soil or bank of soil left in the excavation to provide additional support to the sheets
C.H.S	Circular hollow section (steel tube)
C.L	(see Cover level)
Caisson	Hollow open bottom structure sunk into ground by removal of soil within
Cantilever wall	Wall or structure entirely dependant upon its embedment into the ground for stability.
Cantilever, propped	Singly braced, propped or tied wall, achieving stability by sharing the load between brace and soil.
Characteristic	The value of resistance / strength that has a specific probability (usually 95%) of being resistance/achieved strength
Characteristic load	The value of load that has a specific probability (usually 5%) of not being exceeded
Closure piles	Special fabricated pile to close a cofferdam wall.
Clutches/Interlocks	Hook shape at the end of a sheet pile which grips a corresponding hook on an adjacent pile allowing the piles to link together.
Cofferdam	Generic name for a sheet piled, usually water retaining, excavation.
Cohesion	A measure of the shear strength of a (cohesive) soils. Its ability to 'remain' or 'stick' together.
Cohesive soils	Soils that exhibit cohesion. Typically having a significant proportion of clayey materials. Bonding between the very small particles results from their lamellar shape and being densely packed restricting the movement of air and water. Cohesive soils tend to lose their internal strength following excavation.
Competent Person	A person having the knowledge, ability, training and experience of the type of work to recognise the risks and the means to minimise them
Compressive (load)	An inward load applied to the ends of a member
Contiguous piles	A line of bored cast in-situ piles whose outer edges just touch
Corner piles	Used to close a piled cofferdam - Three main types: Bent. Cut longitudinally and intermittently welded. Cut longitudinally and intermittently welded to a plate or spacer. Both 'open' and 'closed' piles are available.
Cover level	Level, usually that of a manhole or chamber cover, above a datum
Datum	Any level taken as a reference point for levelling
Deadman anchor	A buried plate, wall or block some distance from a sheet pile or other retaining wall which serves to anchor back the wall through a tie between the two.

Appendix 2

COMMON ENGINEERING TERMS

Design/ resistance/ strength	The characteristic resistance /strength divided by the partial safety factor relating to the parameter
Design load	Is the characteristic load multiplied by a partial load factor
Driveability	The measure by which a pile can be forced into the ground by a hammer. Note the SPT value of the soil is a good indication of driveability
Duckbill anchor	Proprietary soil anchor
Dywidag bar	Proprietary threaded tie-bar system.
Earth pressure at rest	Lateral pressure exerted by a mass of soil where no movement has taken place.
E.G.L	Existing Ground Level. Level before any reduction or deposition of material
Effective stress	Soil Condition: Represents the stress transmitted through the soil skeleton only. (effective stress is total stress minus pore water pressure). Applies predominantly to saturated granular soils in both short and long term timescales.
Embedment length	(see penetration)
End bearing piles	A bearing pile which carries its full load down to hard ground at its point
F.F.L	Finished Floor Level
F.L	Formation Level
Falsework	Temporary structure, used to support formwork
Finished slab level	Level of finished concrete
Fixity (of a pile)	The natural support given to a pile driven to sufficient depth below formation that it is able to act in cantilever to partially or wholly to support the retained soil - see cantilever and propped cantilever walls"
Formation (level)	The surface of the ground in its final shape before concreting but after earthworks
Formwork	Temporary structure/mould to contain wet concrete
G.M.S	Galvanised Mild steel
G.R.P	Glass Reinforced Plastic
Granular soils/	Soils predominantly with relatively large angular grains Or cohesionless soils such as sands and gravels whose strength is determined by the matrix being held together under its own weight (or applied load)"
Haunching	A filling of mortar to smooth the junction between two or more objects
Heave	An uplift in the formation surface following excavation, which can occur in very compressed underlying soils
Hydrostatic head	A measure of pressure equivalent to a height of water
I.L	Invert Level (see invert)
Impervious	Not able to be penetrated by water
Invert	The lowest visible surface of a pipe, culvert, drain, channel or tunnel
Junction piles	Consists of a half pile welded longitudinally to a full pile to form a ‘T’ junction.
Kelly block	Dead weights, normally concrete often associated with piling frames
Kentledge bearing piles	Dead weights, normally concrete or steel often used as dead weight when testing
Kicker	A concrete plinth formed in a slab pour to start a wall or column
Lean mix (concrete)	Concrete with low cement content
Limit state requirements	A particular state at which the member or structure no longer satisfies the design
m.A O.D	A level in metres above Ordinance Datum

Appendix 2

COMMON ENGINEERING TERMS

Mixed soils	Combination of granular and cohesive soils such as sandy clay
Multi-propped	Multiply braced or tied wall, achieving stability by sharing support between braces and soil (if embedment available)
Net pressure	The resultant sum of active and passive pressures acting against both faces of a piled wall
No-toe	Zero sheet embedment. Only possible with multi-propped walls.
Over burden	a) Loose, poor quality material overlying rock in a quarry
	b) Term for weight of soil when calculating pressure
Passive Pressure	Soil pressure generated by a wall moving towards a soil mass i.e. at the front face of a sheet wall toe
Passive softening	Softening of unprotected cohesive formation, usually limited to the first metre below formation. Consequent reduction in resistance offered to the pile toe by soil.
Penetration	The length of sheet or pile embedded into the ground
Permeability	A measure of the rate of flow of fluid (groundwater) through a soil under the influence of a hydraulic head
PFA	Pulverised Fuel Ash, power station waste, often used as fill material
Phi	Ø – symbol used for a soil’s internal angle of resistance
Piezometer	Insitu device for measuring ground water depth and pressure
Piping	(see boiling)
Prop	Support to prevent something failing, sagging or falling
Quarry waste	Ungraded stone often used as fill material (usually fines)
RHS	Rectangular hollow section (includes SHS)
R.L	(see reduced level)
Rebar	(See reinforcement)
Reduced level	Level relating to an agreed datum
Reinforcement	Ribbed steel bars cast within concrete to cater for tensile loads
Retained height	Height of material retained by a wall or structure
S.H.S	Square Hollow Section
Safe Working Load (SWL)	See Working Load Limit
Secant piles	A line of bored cast in-situ piles whose outer edges interlock
Serviceability	A condition at which the member or structure is in the verge of ceasing to satisfy the limit state imposed functional requirements. E.g. maximum permitted deflection. Note: serviceability is usually assessed with a load factor of 1
Skin friction piles	Piles, which rely on the frictional force of the surrounding soil against their sides to bear load
Soffit (level)	The highest part of an arch shape (inside of drain or sewer)
Soil parameters	The numerical measurements of a soils engineering properties
Stability	The resistance of a structure to sliding, overturning or collapsing
Standard	An in-situ test to measure the resistance offered by a cohesionless soil when a specific Penetration apparatus is driven into the bottom of a borehole over a set depth under a set load. This Test (S.P.T)‘resistance’ can be correlated to phi value.
Starter bars	Reinforcement protruding from a concrete pour to provide continuity to an adjacent pour
Steel grade	Classification based on strength and material content
Strata	Layer
Stress	The force on a member divided by the area, which carries the force

Appendix 2

COMMON ENGINEERING TERMS

Strut	Member in compression
Sub base	Graded, crushed stone usually beneath a road
Submerged density	The apparent density of a submerged material
Sump	Recess at lowest part of the formation in which water is collected for removal.
Superimposed loads	Linear/area/strip/point to model more specific loading.
Surcharge	A load above the earth, which is level with the top of a retaining wall
T.B.M	Temporary Bench Mark. A level mark for the purpose of setting out. Could be an assumed value or transferred from a true benchmark.
Tapered piles	Special fabricated pile to correct a wall that has moved out of vertical
Tensile (load)	'Stretching' force in a member
Tension crack	In cohesive soil. Release of lateral loading (e.g. from drying out) to form vertical cracks or fissures which can fill with surface water.
Tie	Member in tension
Total stress	Soil Condition: Total stress = effective stress plus pore water pressure. Associated with cohesive soils. Initial soil parameters taken to be cohesive before pore water drains away whereby cohesion reduces with time (see effective stress).
U.B	(see Universal Beam)
U.C	(see Universal Column)
Ultimate limit state	A condition at which a member or structure is in a state of incipient collapse
Ultimate stress	The stress at which a material will fail
Universal beam	A standard shape of rolled steel joist
Universal column	A standard shape of rolled steel joist
Working load/stress	An allowable load/stress which incorporates a factor of safety
Working Load	Is the maximum weight or load that a piece of equipment is designed to withstand in Limit (WLL) service (or unfactored) conditions. Note this has replaced the term "Safe Working Load" or "SWL"
Yield stress	The stress beyond which a material deforms in a non-elastic (plastic) manner

CHAPTER 2

GROUND SUPPORT EQUIPMENT

Support Systems Historical Overview

Ground support systems for both temporary and permanent works, were historically site-fabricated systems, consisting of basic structural elements made of wood or structural steel. The fabrication was performed by highly skilled workers, often having to operate in unsupported excavations.

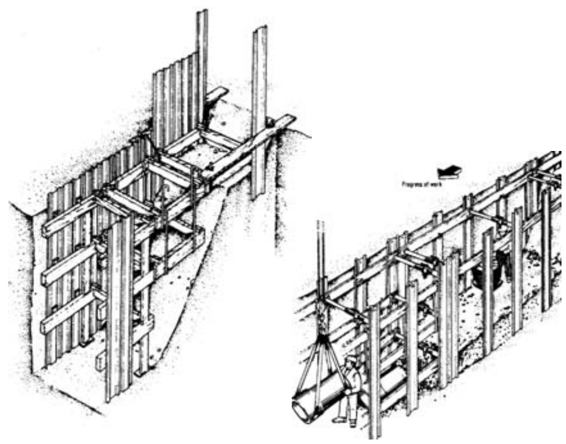


Figure 2.01 Traditional Shoring Practices

However, safety levels during fabrication were often very low and required a great deal of skill and experience to minimise the risks involved.

In the earliest systems, the entire support structure would be made from timber polling boards, walings and struts. Steel sheet piles and structural steel fabrications were used in deeper 'piling' applications. Gradually, the use of timber struts was replaced by the use of adjustable re-usable mechanical struts and trench sheeting quickly replaced the use of timber polling boards.

The economics involved in comparing proprietary systems over fabricated systems can vary depending on the duration of use, especially when there is no requirement for the material to be re-used.

Steel or concrete fabricated systems are still very much in use in very large temporary applications but outside the scope of this report.

Figure 2.02 Fabricated trench shoring- wooden struts and walers in combination with trench sheeting

With specially fabricated shoring, two factors not often considered are:

- Safety issues related to working in an unsupported excavation and
- Costs associated with fabricating the framing and the use of materials, which have limited scope for reuse

Safety legislation and the decline in skilled labour resources meant that new methods were needed that offered higher levels of safety, lower labour costs through improved mechanisation and lower overall costs, through higher re-usability materials.

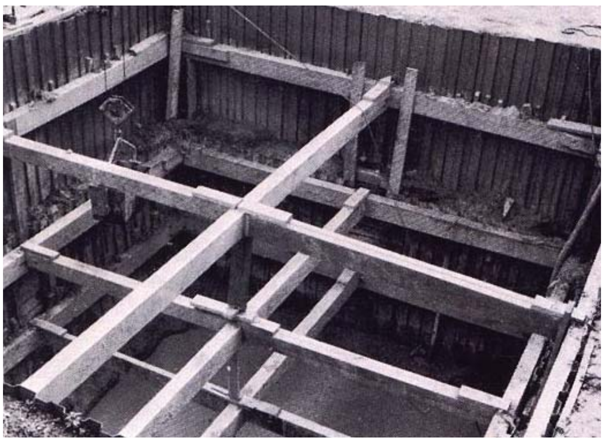


Figure 2.03 Fabricated excavation shoring - wooden struts and walers in combination with Trench sheets

Modern Proprietary Ground Support

Modern proprietary shoring products are most accurately considered as systems, rather than structural components. The concept behind all modern day systems is the replacement of one-off fabricated shoring or bracing with multi-use systems. The majority of modern day proprietary shoring equipment originated in America and Germany. In the UK however, a more comprehensive range of products have been progressively developed and adopted throughout the market. The key to the success of proprietary equipment is the ease of use and re-usability.

These two attributes also serve to make the equipment a realistic hire item. Whilst the boundaries are constantly expanding, it is clear that there is a size limitation for proprietary equipment being produced in modular form. This is currently based around site restrictions and transportation problems, not necessarily a limitation of the equipment itself. The requirement for ground support depends on many factors as outlined in Chapter 1 Paragraph 1.4.3.

A wide variety of proprietary equipment is available. Whilst other classification systems have been considered, it is most appropriate to classify them as follows:

- Sheeting and mechanical shoring products
- Hydraulic shoring products
- Trench lining systems

It must be made clear that these three classifications can be used in isolation, or more usually together as part of a proprietary shoring system. There are discrete products within all three classifications that can be used for single side support (retaining walls); two sided support (trench support) and multi sided support (cofferdams, shafts, manhole pits currently etc.).

This classification breakdown is in-line with new European Standards being implemented. The details of the proposed standards will be discussed in later chapters. For a general guide to proprietary shoring equipment please refer to CPA Safety Guidance - Selection of Proprietary Shoring Equipment STIG 0201.

Sheeting and mechanical shoring products

These include:

- Plastic, vinyl & composite FRP sheet piling
- Aluminium sheets
- Trench sheets (Cold Formed)
- Steel sheet piles (Hot rolled)
- Mechanical trench struts
- Mechanical bracing struts
- Waling frames
- Load bearing piling guide frames

Trench Sheeting and Steel Sheet Piles

This type of equipment can be used in combination with both hydraulic and mechanically operated products, the combination of which creates a system, which can be adjusted and controlled from outside the excavation. In general, this type of equipment is used in situations where trench-lining systems are not suitable.

Trench sheets and sheet piles are distinct products respectively serving the lighter and heavier ends of the market with considerable overlap in the medium sector. Sheet piles are used much more extensively in permanent works the range of sheeting products has grown substantially over the last 20 years.

By examination of the manufacturers' / suppliers' sheet specifications, it can be seen that today there is a virtually seamless transition from the lightest trench sheets to the strongest sheet piles.

There are predominantly two primary types of sheeting, interlocking and overlapping.

Modern trends in trench sheets have been:

- In line with steel sheet piling, wider sections are now more common
- The use of low friction surface coatings, high slip PTFE paint, galvanising for applications requiring greater protection, and improved driving rates.
- The use of high yield steels to offer superior load bearing capacity, at reduced weight and better durability.
- Novel corrugated or ribbed sections for improved load bearing capacity and improved driving characteristics.
- The inclusion of additional pitching hole to enable safer handling when used in combination with clamping based piling hammers.
- An increase in the range of heavy duty interlocking sheets.
- The introduction of plastic, composite or aluminium piles.

Plastic Piling, Vinyl, Composite FRP and Aluminium Sheeting

Vinyl sheet piling and composite FRP sheet piling, have both extensively been used for soil retention in North America and Continental Europe, particularly for waterway and marine applications. The term Plastic Piling in the UK, whilst generically related to Vinyl Sheet Piling, is used to describe domestically produced light duty sheet piling made from recycled PVC.

At present there are few instances where such products are used in the UK for temporary works. However, with the growing availability of domestic and imported products, it is likely that during the life of this document the true potential of these products will be realised. The advantages over steel piling can be substantial - low weight, lower cost, and no deterioration over time by oxidation or biodegradation. It is unaffected by UV light, which combined with the other features illustrate its quick acceptance for low load permanent applications. The recent reintroduction of Vinyl sheet piling from the US, will greatly increase market penetration, with a product range in PVC, reinforced Polyester and Polyurethane which matches and surpasses cold form steel sheet properties.

Some composite products under development should even match hot rolled steel section properties at a fraction of the weight.

The longevity of product life has yet to be applied to temporary applications requiring reuse. This is mainly due to the extraction and driving problems encountered to date. Even when driven, substantial damage can be produced on the sheet, at the toe in cases of obstructions, and at the head in the instance of hammer damage.

With modern advances in driving equipment it is clear that head damage can be minimised and when matched correctly to the application, toe damage can be avoided. Both Vinyl and Composite sheet piling can be driven to more difficult ground conditions by using a steel mandrel, with or without water jetting enhancements. On the whole plastic, vinyl and composites are more normally driven using piling vibrators.

Due to the novelty of plastics within construction, much of the initial specifications are based on the research of the general plastic industry. It has been suggested that vinyl sheet piling will have a future for applications such as earth retaining structures; temporary works; slope stabilisation; noise barriers; channel linings; anti scour around bridge foundations; balancing pond walls; flood control walls and cut-off slurry walls. Aluminium sheet piling, has found an application within emergency shoring for bomb disposal work. This trench sheeting offers higher strength characteristics at low weight but at higher costs than equivalent steel trench sheets.

Figure 2.04 Plastic piling retaining structures

Figure 2.05 Plastic piling cut-off wall

Mechanical Bracing Struts

Mechanical struts are not strictly proprietary equipment, since despite being prefabricated and being reusable, this type of equipment will still require personnel to enter the trench to install and adjust. There are two common types, "acrow" type trench struts & heavy duty bracing struts

There are a huge variety of different sizes, based on weight or load capacity, typically available in 30 – 800kN capacities. Mechanical bracing struts are sometimes preferred to hydraulic struts as they are not reliant on hydraulic sealing practices. The larger capacity struts can also be used in corner or "knee" brace applications.

Figure 2.06 300kN Bracing Struts used in singles and pairs

Figure 2.07 300kN Bracing Strut with Knee Brace

Raking Shores

Some of the larger bracing struts can be adapted to be used as raking struts as illustrated below:

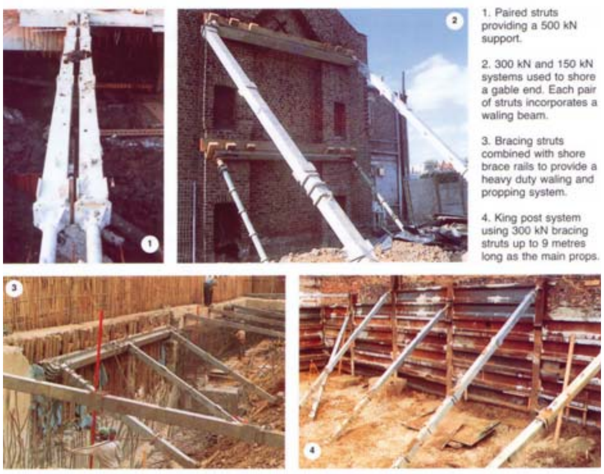


Figure 2.08 Bracing Struts used in raking design

Load Bearing Piling Guide Frames

This type of product is used with trench sheeting to provide both a support frame, for accurate pitching of sheets prior to driving and also to act as a guide for trench sheeting. (See figure 2.09) When services cross the trench, sheeting can be safety omitted from these locations. Note this product remains in the ground as part of the shoring system.

Hydraulic ground support products

It is the development of hydraulic ground support products that has shaped the ground support industry of today. The ability to install hydraulic equipment remotely from above ground provided an immediate increase in speed and safety leading to their rapid adoption in the UK market in the 1970's. Early hydraulic shoring products originated in the United States, with the introduction of the vertical shore and hydraulic waler frame, which incorporated hydraulic cylinders as the strut members.

Following the introduction of hydraulics into the mainstream shoring industry, it soon became apparent that larger systems could be produced to replace the use of structural steel within fabricated shoring.

Single acting expansion only systems were followed by double acting expansion/retraction systems as size and strength increased. Aluminium systems were soon joined by stronger steel equivalents.

This has resulted in larger trench work and excavations falling within the daily workload of the specialist shoring suppliers.

Figure 2.09 Piling Frame

The main limiting factors inhibiting further growth in size of proprietary products is the ease of use and ultimate weight, associated transport and handling problems and the cost associated with longer term hire periods.

It is now possible to support multi-sided excavations by novel arrangements of modular systems. See figs. 2.20 and 2.21

Figure 2.10 Piling Trestle used forTrench Sheeting

Figure 2.11a
Piling Trestle using a Leader rig

Figure 2.11b
Leader rig as described in the following chapter.

Hydraulic Waler Frames

There are two main types of waler frame, aluminium and steel. The latter provide higher loading characteristics at the expense of greater weight. A wide range of sizes and load characteristics are available according to specific requirements and the frames can be strengthened in the ground by installing additional struts. Waler frames are always used in conjunction with trench sheeting and they are relatively light compared to most other shoring systems. Restraining chains must be fitted to prevent accidental dislodgement of the frames.

The maximum width of trench that can be accommodated is approximately 4m. This will of course depend on the ground conditions and the loading on the shoring system. Waler frames are clearly only suitable for two sided support, although adapted versions for end closing are available.

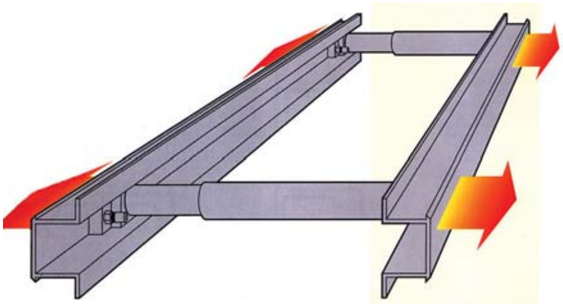


Figure 2.13 Hydraulic waler frame diagramatic representation

Figure 2.14 Hydraulic waler frame in situ

Vertical Shores

These were the first hydraulic products to be introduced in to the UK in the mid 1970's. These are used in applications where the ground is self-supporting and free from water. Each unit comprises two aluminium rails, which are expanded against the trench wall by a number of interconnected hydraulic cylinders as shown Fig 2.12.

Vertical shores are generally recommended for short-term usage in the ground (typically 48 hrs). They are only suitable for relatively shallow and narrow trench applications (0.3m - 2 m depths, 0.5m - 2 m widths).

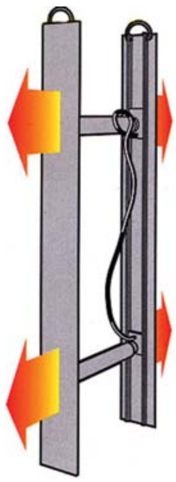


Figure 2.12 Hydraulic Vertical Shore in situ and diagramatic representation

Hydraulic Shoring Shield

This is a hybrid of a box and integrated hydraulic shoring. This device, being fabricated predominantly from aluminium, is very light and lends itself to emergency shoring and manual installation applications.

At present its use is limited to fairly small applications. The technique can be applied to both two sided or four side support, by addition or removal of side plates/trench sheets.

There is full protection for all cylinder and valve manifolds, as these are fully enclosed. The ram unit incorporates a spring return ensuring that the equipment is easy to remove.

Figure 2.15 Hydraulic Shoring Shield

Hydraulic Bracing Frames

These are four-sided assemblies that are designed to resist applied load in all directions. All sides contain hydraulic rams to facilitate on-site adjustment.

The bracing leg is a telescopic assembly, whose length is adjusted by a hydraulic ram. Each end of the leg has a pin connection to the adjacent leg. Some leg types also have a telescopic mechanical adjustment often known as a rough adjustment facility. There are many different sizes and strengths of leg for differing applications. The legs can be made in either a one piece or a modular format.

The braces are predominantly used for perimeter bracing around the internal walls of the excavation. They are always used in combination with trench sheeting or sheet piles. By this means the excavation maintains a clear opening for easier access, but can be cross-strutted after installation for additional strength.

The hydraulic system prevents ground movement adjacent to the excavation. The majority of systems use double acting hydraulics, whilst some of the smaller brace systems are single acting. The smaller brace systems are commonly referred to as a manhole braces. These braces are capable of many other applications apart from supporting excavations for manholes. Examples are tank installations, reinforced concrete chamber construction and working shafts for tunnelling.

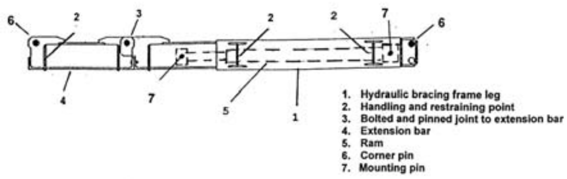


Figure 2.16 Hydraulic Bracing Frame leg section

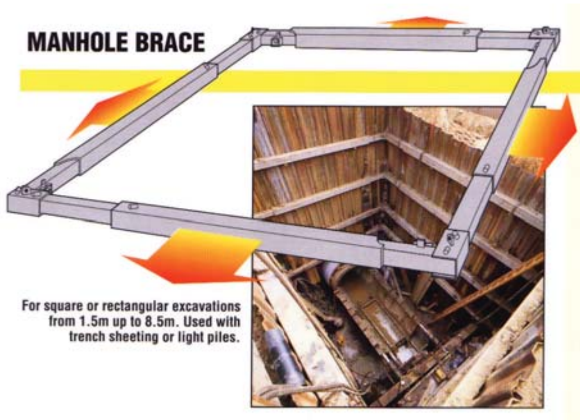


Figure 2.17 Hydraulic Bracing Frame - The Manhole brace

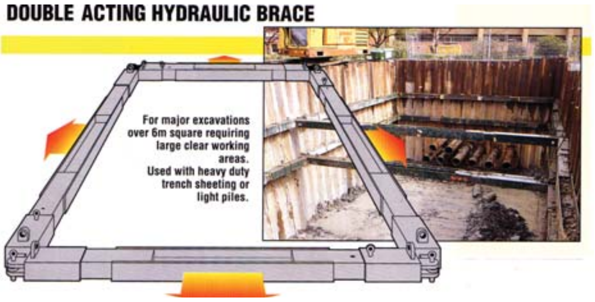


Figure 2.18 Hydraulic Bracing Frame - Double acting brace

Figure 2.19 Hydraulic Bracing Frame - Double acting brace.

Bracing frame legs are always used with restraining chains to prevent accidental dislodgement of the frame especially during installation and removal.

The first hydraulic braces back in the 70's were designed to support pits less than 3m square but progressive development has enable excavations over 15m square to be supported without cross bracing. Modular systems can be extended indefinitely with appropriate cross strutting.

To enable larger sizes of brace to be produced whilst minimising production costs, and maximising the utilisation of components, larger braces are constructed in a modular format. Modular units consisting of a hydraulic unit and a variety of extension pieces connect together to form a leg of the overall excavation size. This permits a wider variety of sizes to be produced, whilst minimising duplication of hydraulic components, increasing the utilisation of the more complex modules.

The modular nature of these bracing legs permit a range of multi-sided formats to be assembled, maximising the internal working space, whilst minimising the overall size of the excavation.

Figure 2.20 Hydraulic modular double acting brace in an octangonal arrangement

Figure 2.21 Hydraulic modular double acting brace in in an octangonal arrangement

Hydraulic Telescopic Struts

As mentioned in the previous section on braces, whilst it is often desirable and possible to maintain a clear excavation by the use of high load braces, some designs will require the use of cross-struts to meet loading requirements. These can be the mechanical variety mentioned earlier, individual brace legs used as a bracing strut or purpose designed telescopic hydraulic struts.

Telescopic hydraulic struts were introduced to offer higher strutting force at longer lengths than is possible when using brace legs as struts. Struts are of square or tubular construction, which offers an efficient section for unsupported spans. These can range up to 30m with strutting capacities from 300 to 2500 kN

Modular struts can be used in a variety of configurations as illustrated in figures 2.22 to 2.26.

Additional Benefits

The potential for this type of equipment is considerable. Hydraulic struts are frequently used in larger scale operations particularly in conjunction with bored and sheet piled walls where progressive support is required during the excavation process. They can be used directly against capping beams and conventional steel framing where they can be readily relocated, as the construction process requires.

The integral hydraulic ram can be used for load monitoring, and can pre-stress or pre-load a support system to minimise the risk of wall deflection and consequent ground settlement around the excavation.

Figure 2.22 Hydraulic telescopic strut

Figure 2.23 Hydraulic telescopic strut

Figure 2.25 Hydraulic telescopic strut

Figure 2.26 Hydraulic telescopic strut used with in situ concrete piling .

Figure 2.27 Pressure/load monitoring of a proprietary hydraulic strut

Trench Lining Systems

Trench linings cover a major section of the shoring market and are typified by their simplicity, robustness and ability to be installed by an excavator with the minimum of personnel input.

There are four sub-categories as follows:

- Trench Boxes
- Drag Boxes or Shields
- Manhole Boxes
- Slide Rail Systems

Trench Boxes

As the name suggests these boxes are for use in applications requiring two-sided support. Trench boxes do not apply a preload to the trench walls since they are mechanically extended i.e. not hydraulic. The exception to this is the relatively small Shoring Shield detailed in the hydraulic section of this report. The trench box is the most common form of trench support, being easy to use with minimal disturbance to neighbouring environments. Whilst the design principle has not changed to any great extent, development has provided a broad range of this type of equipment for excavations up to 6m deep and five metres wide. Boxes can vary in weight from 500 kg to 5000 kg.

Current development is focussing mainly on the smaller lighter products such as the backhoe box. This box fulfils a niche requirement for sites where the primary source of certified lifting power is a backhoe loader and as a result, these boxes weigh under one tonne.

Generally a trench box will be the first choice of shoring equipment. Boxes cannot be used when there are extensive services or in ground made up of very soft clays. In these fairly unstable soils, installation and removal can be quite difficult. Where significant ground water is present, such as in some granular soils, a means of lowering or controlling the water flows must be found if boxes are to be used.

There are a few specialist trench boxes on the market that provide larger than standard clearance under the bottom strut. One such type is the rolling strut box. This type of box is particularly useful where large pipes are being installed as the clearance under the strut can be varied to optimise load capacity. However installation requires a large excavator and careful control of alignment to be effective.

Figure 2.28 Trench box, trench lining

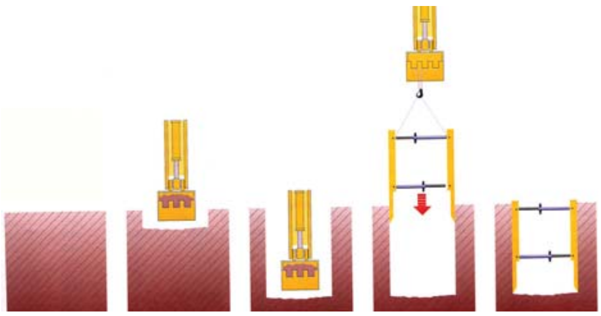


Figure 2.29 Pre-dig method of trench box installation

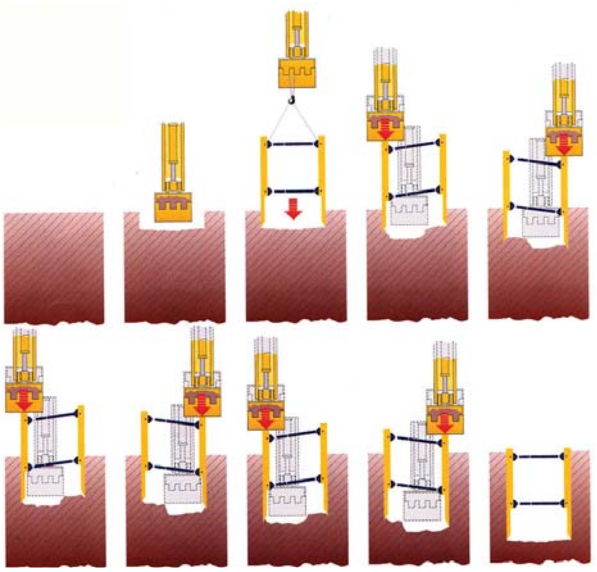


Figure 2.30 Dig and push Method of trench box installation.

Figure 2.31 Heavy DutyTrench box

Figure 2.32 Backhoe Box Trench box

Figure 2.33 The Rolling Strut trench box - shown with high clearance positioning of rolling strut.

Figure 2.33 Proprietary edge protection to a trench box.

Drag Boxes or Drag Shields

These are a modified form of a trench box, being typically longer and used individually. They are used to protect personnel necessarily working in the short section of trench where the pipes are being laid.

The box is pulled forward when each pipe has been jointed and surrounded by its gravel haunch and backfill. The box forms a shield to prevent possible collapse of the sides during the installation process. It is possible to achieve very high production if ground conditions are suitable for its use.

This is normally in open areas without obstructions or changes in direction. The box needs to be dragged by the excavator from the start of the trench to the end. Movement of the box could be difficult if side loading exists due to friction on the plates.

General guidelines on the use of drag boxes or shields

1. They should only be used in ground that will stand to the excavated depth.
2. They are not suitable for use in urban conditions
3. They are not suitable if compaction in layers is required, unless a robot compactor is used which do not require personnel to work in the trench.
4. They are not suitable for use in soils with a high water table.
5. They are not suitable for trenches, which are crossed by frequent services
6. They are designed to be placed into a fully excavated section of the trench.
7. They must only be moved when personnel are clear of the working area
8. Personnel must enter and leave the working area by means of a suitable ladder, and must never use an unsupported section of the trench for access.

A standard trench box must not be used as a drag box unless it has been designed for dual purpose use. Trench box struts are generally unsuitable for pulling by an excavator. Drag boxes are available up to seven metres in length and can weigh in excess of 6 tonnes.

Figure 2.34 Drag Box

Inspection Shields

Unlike drag shields the inspection shield is static, being inserted into a pre-dug excavation and left in place until work has been completed.

The Inspection shield shown is circular, incorporating an internal ladder for access. There are adjustable feet at its base to allow for uneven ground. To assist service access at the base of the excavation there are a number of cut out options to straddle pipes or cable ducts in the base of the excavation.

Inspection shields are available in a number of diameters, and have optional top sections, enabling them to be used in excavations up to 4 metres deep.

Figure 2.35 Inspection Shield

Manhole Boxes

These boxes are analogous to the standard trench box except that support is provided for four sided support. Due to the strut location there are openings on two faces which, if required, like the Shore Shield, can be closed off using trench sheeting.

Figure 2.36 Manhole Box

Slide Rail Systems

These consist of vertical posts separated by struts. The post can have one, two or three slots in each side for panels to slide up and down.

- Single slide rails has one sliding slot and has a maximum operating depth of 4.0m
- Double slide rails has two sliding slots either side and has a maximum operating depth of 6 - 7m
- Triple slide rails have three slots either side and has a maximum operating depth of 10.0m.

Slide rail systems are primarily trench support systems but corner posts have been developed enabling rectangular excavations to be carried out.

Slide rail systems have an advantage over trench boxes in that the bottom panel can always be removed before the upper panels enabling the compaction of the fill material to be made across the full trench width.

A disadvantage of slide rail systems is that they require quite large machinery to install and remove the systems and the installation requires a set procedure of accuracy when installing the system. Badly installed systems or those installed in unsuitable ground can be very difficult to extract.

Figure 2.37 Slide rail Option 2 Rolling Strut

The strut systems have three options

1 Individual struts that have specific locations on the post
2 A large single strut with rolls at each end that can slide up and down the post slots
3 A fixed frame that has rolls mounted on each end that can also slide up and down.

Most modern systems use options 2 and 3.

Figure 2.38 Slide rail option 3

King Post Systems

These methods utilise a combination of shoring components in single sided applications by anchoring long posts deep in the ground below formation level. It has the advantage of leaving the construction area relatively free of temporary works.

The post can be installed into a pre-drilled hole or driven into the ground using a piling hammer. The shoring between the posts can be any of the following: -

- Horizontally installed trench sheets that are welded into place so that the construction can proceed from the top down.
- A steel plate such as a trench box panel can be placed to the full depth. This can be dug into position or driven with a vibrating piling hammer. The steel plates can usually be removed.
- In situ concrete panels cast as the excavation proceeds
- Plastic reinforced panels - typically cast with steel reinforcement.

Figure 2.39 King post system (In US)

For excavations exceeding 4.0m deep, the posts usually require additional support.

Figure 2.40 King post system

Speciality Products - The Press box

This hybrid system is a specialised type of linear shoring, which incorporates a driving mechanism. The drive mechanism uses a pressing in force of approximately 12 tons. This system is ideal for use in applications requiring low noise and minimal vibration.

The system differs from linear shoring in that when assembled, it forms a complete unit that has limits to the size at which it can be used. The trench is dug a segment at a time, determined by the length of the Pressbox. Once the pile elements are driven, the trench is dug, lateral supports installed as necessary, work completed and the elements extracted. The whole device is then dragged along to permit working on the next section of the job.

Figure 2.41 King Post using reinforced PVC panels

Figure 2.42 SBH Press Box

Figure 2.43 Kring Press Box

CHAPTER 3

PILING EQUIPMENT

Scope

This chapter details a range of piling equipment suitable for driving steel, plastic and composite sheet sections, as used within a temporary works application.

Introduction

The previous chapter, showed that modern shoring systems have developed, eroding into temporary applications previously serviced by fabricated systems using Larssen type sheet piles.

The use of piling equipment for installing trench sheeting is displacing other more basic installation techniques e.g. dig and push techniques or bucket ramming by use of a driving cap positioned on top of the sheet. The increasing use of piling equipment within temporary works enables applications to benefit from improved accuracy and also faster speeds of installation. Savings on labour costs normally exceed the cost of the piling hammer.

The selection of piling equipment for shoring applications is based on the following considerations:

- Required force and size of hammer. This is determined by the pile section properties and the ground conditions.
- Size limitations and suitability to site e.g. environmental conditions, access etc.
- Range of technologies available, relating the equipment to be used to the skills available on site, or those of a specialist sub-contractor.

Figure 3.1Plastic piling retaining wall installed using an EMV70 excavator mounted vibrator

Required force and size of hammer

There is a finite amount of force that can be applied to any specific pile before damage will occur; likewise there is a minimal amount of force required to drive through a specific ground type, to a specific depth. In addition, it is also clear that lighter piles are rarely driven to any great depth, the reduced penetration required for these applications lending themselves to the use of less forceful equipment.

Soil information is essential to determine the correct type of piling equipment.

Size limitations and suitability to site

Often sites performing small temporary works cannot utilise the most appropriate selection of piling equipment available, because of physical or economic restrictions.

It must be appreciated that to use piling equipment, there is often a requirement to scale up associated equipment, such as the crane or excavator required to handle the device. For some sites this is either not considered or not physically possible.

Figure 3.2 BSP 500N driving steel sheet piling

The range of technologies and suitable adaptation of piling equipment

The UK and European temporary works markets are very different, and whilst commonality in proprietary equipment exists, specialised proprietary products available are better suited to the UK market applications and ground conditions.

In terms of piling equipment, the vast majority is imported from Europe creating a heavy reliance on vibratory technology, due to few impact hammers being produced that are suitable for this application.

Modern developments within piling equipment, have created an environment of extremes, where equipment can be simplistic, or be of substantial sophistication. This in turn has created two supply chains, depending on the requirement for the provision of a skill operator. Equipment is available in the UK through two main outlets:

- Non-operated plant hire companies
- Specialised piling subcontractors

The former requires fairly simplistic equipment, or equipment for which trained operators are freely available from outside the hire company. This then permits 'supply only' equipment.

As new equipment is introduced, the immediate supply of the products through the non-operated plant hire companies is not always appropriate. In cases when the new product involves either a method change, or its use requires a degree of skill for safe operations, it will be more typical for this product to be supplied via specialist piling companies with trained operators.

Common forms of piledriving equipment

There are four main types of piling equipment in use in the UK:

1. Air hammers - IMPACT
2. Hydraulic Drop hammers -IMPACT
3. Vibratory hammers - VIBRO
4. Pile presses - STATIC

All are suitable for the installation of heavy-duty steel sheet piling, with fewer suitable for driving trench sheets and plastic piling. Non-operated plant is normally limited to air hammers, excavator mounted vibratory hammers and the smaller suspended vibratory hammers.

Figure 3.3 EMV300 excavator mounted vibrator pitching trench sheeting

Impact Hammers

These represent one of the oldest techniques employed to drive piles. Modern day impact hammers can either be considered as single acting (gravity based - mass raised and them allowed to free fall) or double acting where the mass is accelerated downward by an additional force to gravity.

Types of Impact hammer:

- Drop hammer
- Air Hammer
- Hydraulic Drop Hammer

Advancements in technology are based around improvements in efficiency, noise reduction and durability with the increasing reliance on hydraulic systems. As impact hammers are less affected by ground conditions than vibrators, the combination of the two equipment types can improve final drive depth. This is especially important when restrictions on site limit the size of vibrator that can be used. Despite this advantage, the major reason why impact hammers are not the first choice relates to the high noise levels produced and to a lesser degree a lack in development of smaller impact units suitable for trench sheeting and plastic piling.

Impact hammers also require support frames that can vary in complexity from ground level support, through to gate systems with several waler frames.

Figure 3.4 APE No.2 air hammer driving plastic piling

Figure 3.5 Two common forms of Hydraulic Drop Hammer

Vibratory Hammers

These are by far the most common type of piling equipment used for both installing and extracting trench sheeting and sheet piling.

When driving an element into the ground, resistance is met at the tip, and also by friction along the sides of the element. By applying vibration to the element being driven, the friction between it and the ground is greatly reduced. The vibrator vibrates both the pile and the ground. A temporary fluidity in the soil results and the pile slides into the ground virtually under its own weight

There are a variety of vibratory hammers available on the market, mostly differing by the range of working specifications. There are other variants, which offer innovative methods of handling and manipulating the pile.

Common to all are the hydraulic clamps, which enable a vast array of piles to be gripped and driven without any physical modification e.g. sheet piles and king posts. These clamps, in combination with the available bidirectional force, also enable very efficient extraction. The ability to both drive and extract sheets provides an optimised use of one specific piece of piling plant. Special clamp configurations exist, for example to drive concrete or timber sections.

There are three principal variations of vibrator types:

- Standard Frequency
- High Frequency
- Resonant Free/Variable moment

Standard frequency vibrators operate at the lowest frequency, but offer the greatest amplitude. They are the chosen plant when driving heavier piles such as pile casings.

Figure 3.6 ICE 328M excavator mounted vibrator driving steel sheet piling

The higher frequency of operation of the High Frequency vibrators, combined with their lower amplitude reduces the overall levels of ground vibration as resonant frequencies are avoided during operation. The vibration produced dissipates faster. Improved penetration into cohesive soils has also been noted at high frequency. Resonant Free vibrators operate at similar frequency and maximum amplitude as that of the High Frequency vibrators. However, a further reduction in ground vibration is observed with Resonant Free units, through the elimination of low frequency vibration at start up and shut down, whilst providing a wide range of permissible amplitudes. Resonant Free units are the preferred vibrator when used in conjunction with mobile cranes.

These vibrators are available in a range of design formats, including suspended, leader and excavator mounted.

Figure 3.7 EMV70 driving interlocking trench sheeting

Static Load Equipment

This type of pile driver takes full advantage of the high force available through the use of hydraulic systems. Rather than vibration or percussion, a constant force is exerted onto the pile forcing it into the ground. The main advantages of this technique are clearly illustrated by trade names - silent and still, referring to the low noise and low ground vibration

There are four primary designs of pile press

- The European panel presses e.g. the SERF Pilemaster, the ABI Hydropress and the Dawson Powerpress (DPP),
- The Japanese single pitch and drive presses, e.g. the Giken Silent Piler and the Tosa Still Worker.
- The ground reacting extraction press
- The Press Box - See Chapter 2

Commercially, the main limitation of these techniques is the availability of the equipment and skilled operators, with the net result being the supply of equipment through subcontract or contract hire.

Technically, the main limitation is based on creating and maintain substantial reaction force to press against. It is common practice to assist the drive by pre-augering or water jetting. Pile clutches are sometimes welded together to prevent sheets being pulled out when reaction is insufficient. In the UK, no press models are currently available that can operate with trench sheeting or plastic piles.

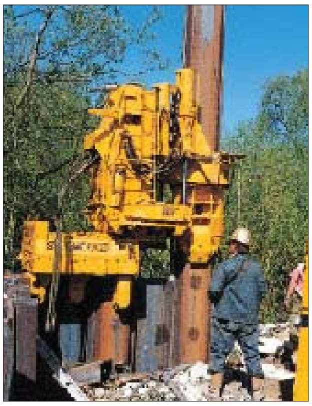


Figure 3.8 Common forms of pile presses or press systems

Ground Conditions

Cohesive soils	Cu	Soft	Firm	Stiff	Very Stiff
Hammer Type	kN /sq.m	0-45	46-80	81-150	150 +
Air hammer		A	B	C	D
Small Hyd Drop		A	B	B	C
Large Hyd Drop		C	A	A	A
Diesel Hammer		A	A	A	B
Small Vibro		C	D	D	D
Large Vibro		B	C	D	D
Excavator mounted Vibrator/push		A	C	D	D
Vertical Stack Vibro/Push		B	B	C	D
Pile Press		A	A	A	B

Granular Soils	SPT	Loose	Medium Dense	Dense	Very Dense
Hammer Type	N Value	0-10	11-30	31-50	50 +
Air hammer		A	A	C	D
Small Hyd Drop		A	A	B	C
Large Hyd Drop		C	B	A	A
Diesel Hammer		C	B	A	A
Small Vibro		A	B	C	D
Large Vibro		B	A	B	C
Excavator mounted Vibrator/push		A	A	C	D
Vertical Stack Vibro Push		A	B	B	C
Pile Press		B	B	C	D

Most suited	A
Suitable	B
Not Ideal	C
Not Suited	D

Limit conditions

The two main limiting conditions for successful pile driving are refusal and rebound.

Refusal is the point at which the pile cannot effectively be driven further, without damage to the hammer and the pile. In the case of vibratory equipment operating at refusal, there have been instances where the pile has become friction welded to the clamping jaws.

Clearly, it is neither economic nor practical to operate the hammer until the pile has completely stopped moving, therefore certain refusal rates have been specified for the different types of equipment available.

Once refusal has been reached, site must upgrade to more powerful equipment, and possibly stronger piles capable of handling the increase force of the hammer or penetrating harder material. .

Rebound occurs when a large portion of the hammer's energy is "bounced" back up into the pile as a result of force reflection at the pile tip due to the pile hitting an impenetrable layer or obstruction.

For vibrators, the rebound forces will be transferred back into the suppresser head. As a result, the head will start "jumping" relative to the vibratory case. For percussion hammers, this increases the chances of anvil breakage, as the hammer may be "off pile" head during the impact phase of its cycle, following rebound.

Refusal Rates

Air Hammers

There is no recognised refusal rate for Air hammers, since their mechanism lends itself to hard driving, their action often described as chiselling. However a logical refusal rate of 1 mm / blow has occasionally been used based on economic restriction.

Figure 3.9 BSP 500N Air hammer

Hydraulic Drop hammers

The stated refusal rate depends on the make of hammer, with some designs featuring an automatic cut-off to prevent the overworking of the hammer. Refusal rates vary from 1 mm / minute to 25 mm/10 blows. Due to the widespread use of hydraulic hammers for the installation of bearing piles, it is often the bearing capacity of the driven pile, which determines the termination of driving.

Figure 3.10 Hydraulic impact hammers

Static press hammers

There is no information available for refusal with these units, since in difficult driving conditions the hammers are often used in combination with water jetting equipment. In the applications that lend themselves to this type of device, there is little that can be done once the full power of the machine and jetting have not worked.

Figure 3.11 Leader mounted press

Vibratory hammers

Refusal rates for vibratory hammers tend to vary considerably. For suspended vibrators, a rate of 500 mm/minute has been specified, below which it has been found that friction in the pile interlocks can generate heat resulting in distortion of the piles.

Manufacturers of excavator-mounted units have stated that refusal is defined when the penetration rate does not exceed 250mm/5 minutes. The penetration distance of 250mm is absolute, i.e. No conversion is allowed to, for instance, 60 minutes per 1 metre penetration.

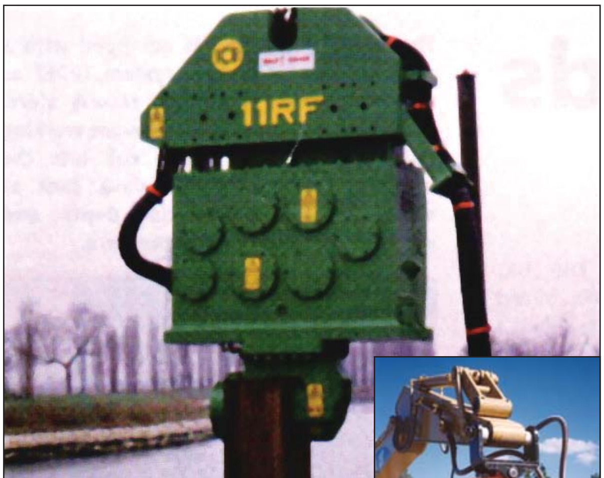


Figure 3.12
11 RF and the EMV300
vibratory hammers

Noise and Vibration Noise

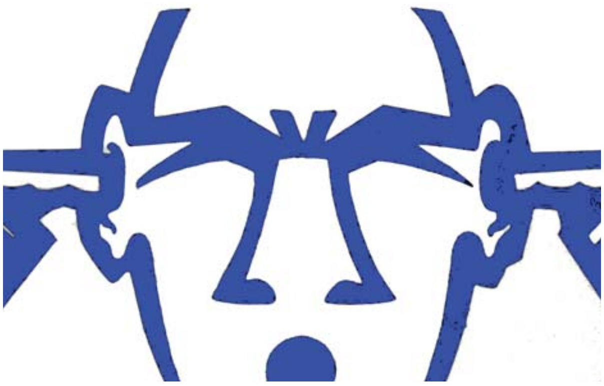
Piling hammers when operating can produce high levels of noise. Noise levels for vibratory hammers are lower than for impact hammers, but nonetheless of a substantial magnitude. Vibration between adjacent piles, particularly between overlapping trench sheets also generates noise.

Noise and vibration are the most common cause of complaints arising from piling operations. Few sites are sufficiently remote from occupied property to be out of earshot and heavy vibration can transmit several hundred metres

Whilst impact hammers are currently one of the noisiest piling equipment available, they may be the fastest option. Noise exposure duration does have an influence, especially in cases of annoyance. Impact hammers, despite producing high noise levels, are often perceived by neighbouring locations as producing lower ground vibrations. When considering the best type of hammer for an application, consider the broader picture – "what equipment will cause the minimum site and environmental disruption?".

Useful Conversions and equations

Where R= Distance from source
LAeq =LWA •20 log R •8
L A01 = L Aeq + 5



Units of Noise

Noise is a form of energy, existing as pressure waves. It may be either described in terms of the intensity, measured in decibels – dB, (a logarithmic, reference scale), Pascals – Pa, (units of pressure); or in terms of the frequency of the waves -kHz.

These expressions of noise are invaluable when selecting the most appropriate hearing protection.

Noise at higher frequencies sounds louder, and is more damaging than at lower frequencies. The numerical manipulation of the noise energy, expressed as 'A 'weighting, provides a more appropriate measure of the actual effects on the human ear. The unit of measurement is dB(A).

There are also many ways that noise can be expressed taking into account exposure duration, for example LAEQ, which is typically stated over an eight-hour period. This is the equivalent continuous noise level for variable noise, as associated with impact hammers rather than continuous noise such as that produced by a cars' engine.

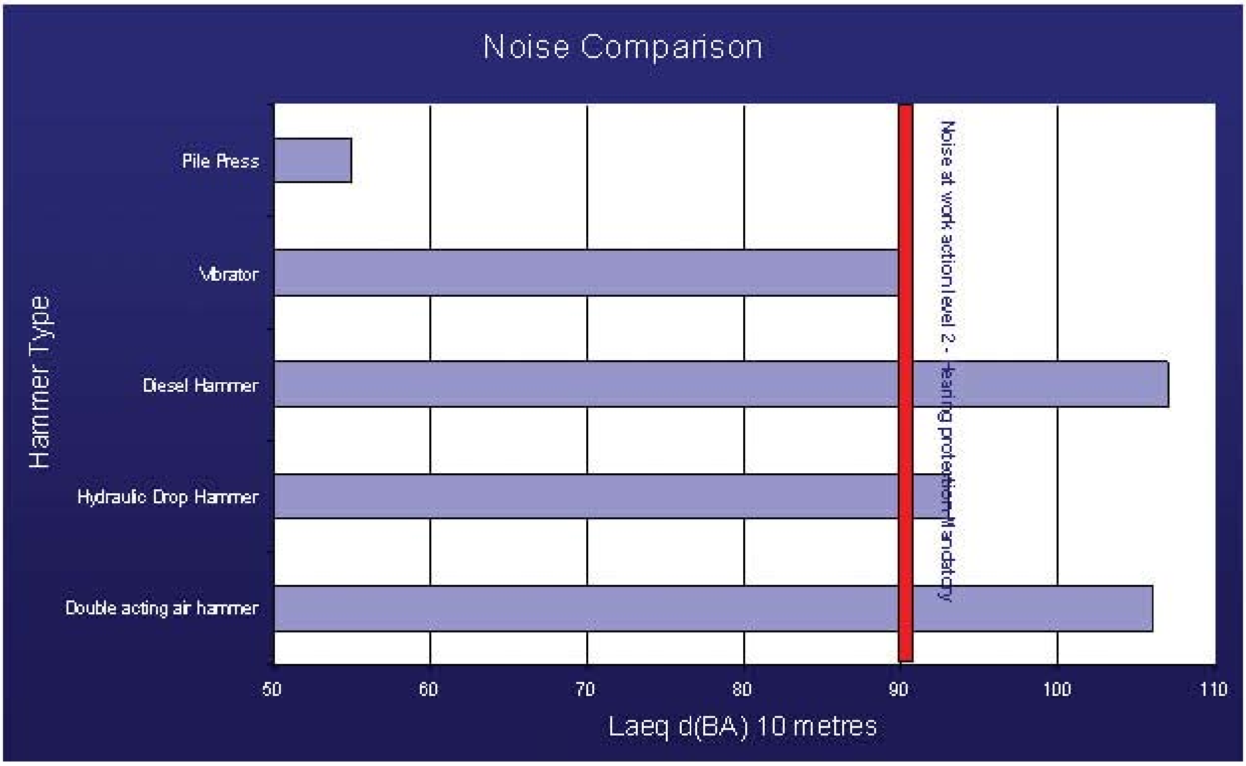
In some instances, the LAEQ also needs adjustment to provide for the effect of impact noise, especially isolated impacts, with 'quiet' periods in between - see BS 5228.

Double-acting diesel hammer on sheet piling, where Lw = 135dB. Calculate L_{aeq} values at 2m, 10m, 20m and 50m.

From L_{aeq} = Lw - 20 log(R) - 8. dB(A)

L_{aeq} = 135 - 20 log(R) - 8.

For R = 2m, L_{aeq} = 135 - 6 -8 = 121 dB(A)
For R = 10m, L_{aeq} = 107dB(A)
For R = 20m L_{aeq} = 101dB(A) (Note, for doubled distance, a 6dB reduction occurs)
For R = 50m L_{aeq} = 93dB(A)


Noise Comparison
Hammer Type
Pile Press
Vibrator
Diesel Hammer
Hydraulic Drop Hammer
Double acting air hammer
Noise at work action level 2 - hearing protection mandatory
50
60
70
80
90
100
110
Laeq d(BA) 10 metres

Vibration

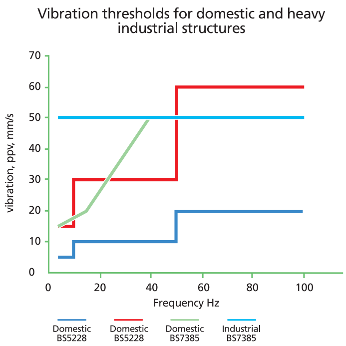
Piling using an impact or vibrator will generate ground vibrations, the magnitude of the vibration being greatest close to the pile. The frequency, duration and magnitude of vibration vary depending on distinct hammer types and ground conditions, and human perception will interpret them differently.

It is possible to estimate likely levels of ground vibration using empirical methods; these are relatively conservative and will assist with arranging a Prior Consent Agreement for the works. Frequency of the input vibration is important to avoid resonance, a phenomenon at which vibration introduced has the greatest effect on soil and neighbouring buildings.

Environmental problems caused by ground vibrations can be alleviated or eliminated by:

- Pre-contract planning, to obtain a Consent to Work Agreement.
- Selecting the most appropriate piling equipment and working method,
- Forewarning residents of the forthcoming work and its duration and assuring them of the very low risk of damage to property,
- Carrying out property surveys, before and after work.

Applicable British Standards



Building Type	No Cosmetic Damage
Max PPV below 50 Hz	
Ruins and buildings of architectural merit	2mm/sec
Residential	5mm/sec
Light Commercial	10mm/sec
Heavy Industrial	15mm/sec

Minor damage is possible at vibration magnitudes greater than twice the above limits and major damage may occur at four times these tabulated values.

Type of Building	Peak component particle velocity infrequency range of predominant pulse	
	4Hz to 15Hz	15Hz and above
Reinforced or framed structures. Industrial and heavy commercial buildings	50mm/a at 4Hz and above	
Unreinforced or light framed structures Residential or light commercial type buildings	15mm/a at 4Hz increasing to 20mm/a at 15Hz	20mm/a at 15Mz increasing to 50mm/a at 40Hz and above

BS5228 part 4 relates to vibration caused by piling processes, and details threshold levels for distinct building types below known levels for cosmetic damage.

Hammer and pile	distance from pile (metres)	radial ppv, mm/s	transverse ppv, mm/s	vertical ppv, mm/s	resultant ppv, mm/s
Air, 600N u-pile	2	8.6	7.2	17.0	18.0
	8	5.6	2.9	8.2	8.4
	22	3.8	2.7	5.1	6.1
BSP 357, (3^T) z-pile	2	10.6	7.7	22	25
	5	4.5	5.0	4.8	6.1
	18	0.5	0.6	0.9	0.9
BSP 357, (5^T) H section	4	10	4.5	25.9	26.9
	17	13.8	2.3	11.0	15.0
	37	3.3	1.0	1.2	3.5
Vibro MS25H z-pile	2	22	28	6.8	34
	5	2.8	2.6	8.2	9.0
	16	1.5	1.7	2.3	2.5

BS6472 relates to the human response to vibration, and possibilities of adverse comment - quite stringent since based at the level of complaint, rather than threshold for illness or property damage.

BS7385 provides threshold values in excess of the previous two standards, relating to levels likely to cause structural damage in buildings

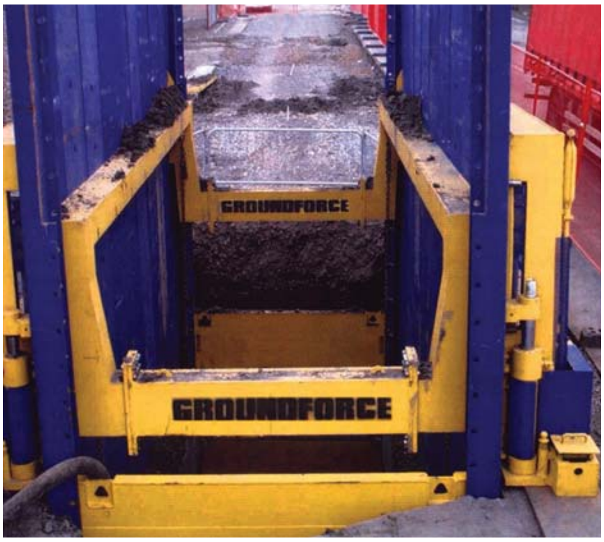


Figure 3.13 The Press Box

Equipment

Equipment Considerations

Potential vibration problems must be assessed in advance and the appropriate standards addressed all piling equipment, that produces impact or vibration will have some effect on the environment

Equipment must be selected that suits the location of piling. Theoretically, there is often little difference observed between impact and vibratory hammers. Practical experience has shown a perception of lower levels of ground vibration using impact hammers in comparison to vibrators.

The vibration produced by impact hammers is less likely to result in compaction or settlement of ground, which could undermine a nearby structure.

In highly sensitive locations, very close to existing structures or historic buildings, pile press systems are recommended, as they produce no ground vibration. However, attention must be paid to the use of water jetting equipment with the pile press because this can cause erosion and variation in the ground water level and have an equally damaging effect.

There is a wide range of available vibrators, used most effectively in granular soils, and to a lesser extent in clays and silts. Selection of a high frequency or resonant frequency vibrator will lead to faster attenuation of ground vibrations produced, minimising disruption and avoiding potential resonance.
Recent developments have brought advances in the automatic control of vibration output to ensure that ground vibrations -as measured by suitable sensors - do not exceed predetermined levels.

For driving into stiff, cohesive soils, an impact hammer is likely to be needed. Vibration can be minimised through using a controllable hydraulic hammer. In instances where nuisance is the main concern an impact hammer will serve to reduce the duration of exposure.

Double acting air hammers

Double acting air hammers

Overview

- Very basic hammer design, impact based with a rapid blow action.
- Wide size range available in the UK, ranging from 90kg for the APE No.1 through to 3000kg for the BSP 700N. Relatively small hammers are ideally suited to small scale temporary works applications.
- Less affected by ground type, typically used to finish drive to depth, if not for the full drive.

Advantages

- Cheap to Hire
- Well established basic design
- Wide size range available
- Can be handled by an excavator
- Will drive sheets into virtually all soil conditions

Disadvantages

- Less locally available than vibrators
- High Noise levels
- Low energy efficiency -30 - 40% efficient
- Open lubrication system can cause a pollution problem
- Does not permit sheet handling
- Air hammers are not suitable for extraction. Whilst historically modifications were available, extraction was very inefficient.

In some cases the use of such hammers is completely ruled out under the Control of Pollution Act 1974. Often listed as a requirement of the Notice of Prior Consent supplied by local authorities.

Figure 3.14 The APE No.2 driving plastic piling

Figure 3.15 BSP No.300 driving trench sheeting

Environmental

- Noisy, 134dB LwA, 106dB LA eq at 10 metres (BS5228) hearing protection mandatory
- Ground vibrations considered to be of a continuous form, in common with vibratory technology.
- Open lubrication system can cause a pollution problem

Figure 3.16 BSP 500N driving trench sheeting

Hydraulic Drop Hammers

Overview

- Most modern form of impact hammer, hydraulically powered drop hammers.
- Available as single acting (gravity based) or double acting (power assisted).
- Cross over between driving steel and concrete permissible, with high impact velocity double acting variants better suited to driving steel.
- Precise control over output energy available with latest models.
- Utilise high pressure hydraulics to maximise the forces available relative to hammer size.
- Typically too large for temporary works applications, size range 3000 kgs for the HPH1200 to 300000 kgs for the MHU 3000T.
- Less affected by ground type, typically used to finish drive to depth, if not for the full drive.

Environmental

- Substantially lower noise production than air hammers. 90 dB LA eq at 10 metres
- High efficiencies with high forces within smaller equipment
- Transient form of ground vibration produced

Advantages

- Modern with high efficiency and lower noise production.
- No open lubrication system, envionmentally more sensitive than air hammers
- Very powerful, will drive sheets into virtually all soil conditions

Figure 3.17 The HPH series of Hydraulic Drop Hammers

Disadvantages

- Typically too large for temporary works, unless using substantial steel piling
- Smaller machines were designed to drive primarily single sheets, with the decreasing availability of Larssen (U) piles, larger hammers sizes will be required to drive the z profiles in pairs.
- Does not permit sheet handling
- Will not extract sheets.
- Need to be crane suspended or leader mounted as hammer length too great for excavator suspension

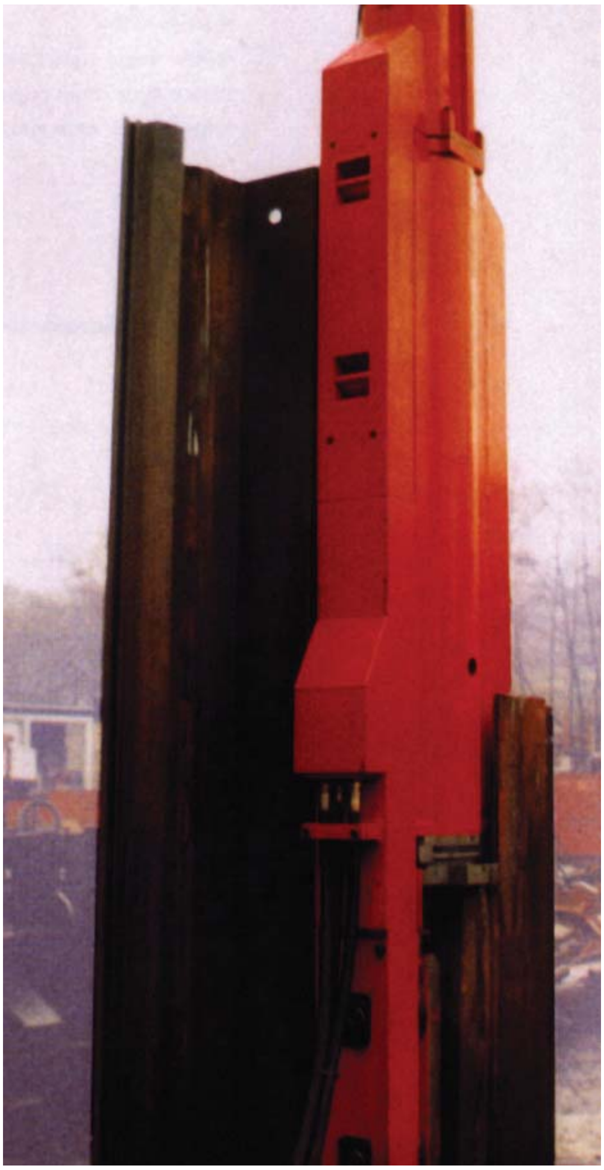


Figure 3.18 BSP HH 1.5 Double Acting Hydraulic drop hammer

Standard Frequency Vibrators

Overview

- Typically available only in a freely suspended format, with separate powerpack, these represent the first format of vibrator adopted.
- All units within this category have a frequency range of between 22Hz and 30Hz, the frequency decreasing with increasing vibrator size.
- The centrifugal forces available being spread between 140 through to 2300 kN.
- Extremely high amplitudes are available, which in combination with the low frequency provides optimum driving characteristics.
- Very likely to cause resonance in the surrounding soil and neighbouring buildings.
- Ideal for loose granular soils, effectiveness greatly reduced in dense or cohesive soils
- Same unit capable of driving and extracting sheets
- Typically too large for temporary works applications. These units tend to be relatively heavy, total weights varying between 1 to 17 tonnes.

Environmental

- Substantially lower noise production than air hammers. 94dB LAeq at 10 metres
- High efficiencies with high forces within smaller equipment
- Resonance of soil and neighbouring buildings highly plausible especially at start up and run down.

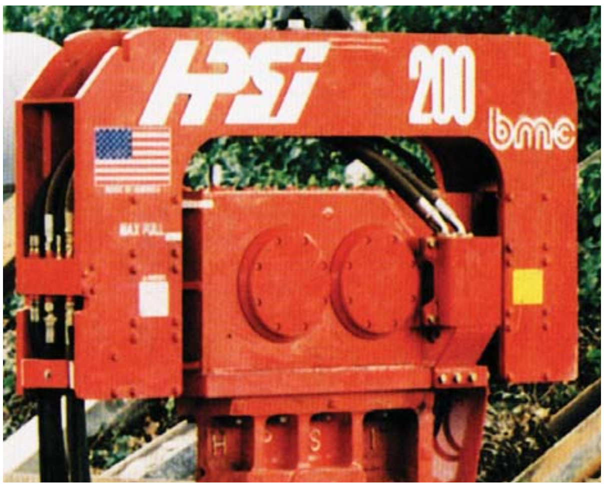


Figure 3.19 HPSI Model 200 Driving Sheet Piling

Advantages

- Modern with high efficiency and lower noise production.
- No open lubrication system, environmentally more sensitive than air hammers
- One tool drives and extracts
- Rigid connection to pile via clamp
- Cheapest form of vibrator

Disadvantages

- Whilst smaller units are available, this variant is typically too large for temporary works, unless using substantial steel piling
- High amplitudes are too severe for thinner sections and plastic piling.
- High levels of ground vibration and vibration transmitted to lifting equipment especially during start up and shut down.
- Poor at driving piles into dense or cohesive soils.

Figure 3.20 ICE 815 driving Steel Casings

High Frequency Vibrators

Overview

- This is the most common form of vibrator in use with trench sheets and smaller piles, particularly excavator mounted versions.
- All units within this category have a frequency range of between 35Hz and 60Hz, the frequency decreasing with increasing vibrator size.
- The centrifugal forces available being spread between 22 through to 1400kN.
- High power to weight ratio, due to high frequency of operation, typically substantially lower amplitudes than standard frequency units.
- Less likely to cause resonance in the surrounding soil and neighbouring buildings, due to high frequency of operations.
- Ideal for loose granular soils, effectiveness greatly reduced in dense or cohesive soils
- Same unit capable of driving and extracting sheets
- Extremely wide range of units available, although smaller units are typically excavator mounted, total weights varying between 1/4 to 7 tonnes.

Environmental

- Substantially lower noise production than air hammers. 94 dB LA eq at 10 metres
- High efficiencies with high forces within smaller equipment
- Disturbance through sympathetic vibration of soil and neighbouring buildings. Resonance can occur during start up and run down.

Figure 3.21 ICE 328B extracting tubes

Advantages

- High efficiency and lower noise production.
- No open lubrication system, environmentally more sensitive than air hammers
- One tool drives and extracts
- Extremely fast driving and extraction rates
- General availability

Disadvantages

- Noise levels still relatively high and no real data available to distinguish between different vibro types.
- Moderate levels of ground vibration - resonance still possible at start up and shut down.
- Poor at driving piles into dense or cohesive soils. Although an improvement is shown in comparison to Standard Frequency

Figure 3.22 Muller MS4 extracting trench sheets

Figure 3.23 EMV300 vibratory hammer

Resonant Free Vibrators

Overview

- This is the most advanced form of vibrator in use, available as freely suspended, leader and excavator mounted.
- These units employ a mechanism, which enables complete control over the output vibration, through control of the degree of eccentricity of the spinning weights. This advanced level of control enables zero vibration during start up and run down eliminating resonance
- Units within this category have a very narrow frequency range typically operating between 33Hz and 38Hz.
- The centrifugal forces available being spread between 0 through to 2680kN.
- The amplitude also is full controllable.
- Whilst still affected by soil condition the variation in output vibration enables a more precise match to site and environmental requirements.
- As for all vibrators the same unit capable of driving and extracting sheets
- Designed with sheet piling in inner city areas there is a relatively smaller weight range with units weighing between 1.5 - 9.5 tonnes. Typically heavier than equivalent high frequency equipment due to the double set of eccentric weights employed

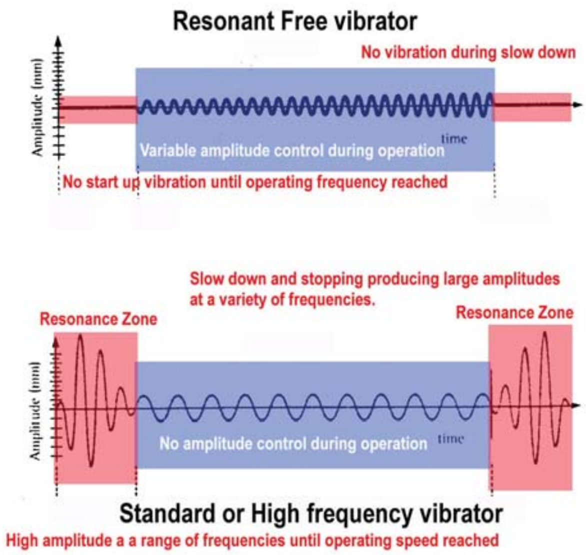


Figure 3.20 Comparison on vibration waveform curves

Environmental

- Substantially lower noise production than air hammers. 94 dB LA eq at 10 metres
- High efficiencies with high forces within smaller equipment
- Provides the greatest control over the levels of piling vibrations produced and employed. However, some disturbance possible through sympathetic vibration is still possible. Resonance can be avoided during start up and run down.

Advantages

- Full controllability over the vibrational output
- Control can be automatic or via an operator. Automatic control using real time monitoring equipment.
- Modern with high efficiency and lower noise production.
- No open lubrication system, environmentally more sensitive than air hammers
- One tool drives and extracts
- Can be used with mobile cranes
- Increasing availability.

Figure 3.24 ICE 7RF resonant free vibrator

Disadvantages

- Noise levels still relatively high and no real data available to distinguish between different vibro types.
- Cost premium - these units are more expensive to buy and hire.
- Optimised but still less effective than impact hammers at driving piles into dense or cohesive soils.

Panel Presses

Overview

- The original SERF Pilemaster design predates all other press designs. The generic designs consists of multiple hydraulic cylinders arranged within a panel acting to apply a high static load onto the top of a panel of piles. The required reaction originating from hammer and pile mass, crowding from attached base machine, and reaction from previously driven piles.
- The piles are driven either sequentially or several sets at a time, using an alternating cycle of press and react between driven sets.
- With no reliance on dynamic forces these units produce very low noise and vibration.
- The available forces are considerable ranging from 75 to 200 tonnes.
- At present these units are leader mounted, to enable the technique to take advantage of additional crowding to provide the initial reactive force required.
- These devices are often of a modular construction, with each individual cylinder construction weighing up to 4 tonnes. Although the smallest units currently available consist of a 3 cylinder configurations with the total assembly weighing 3.9 tonnes.

Environmental

- Substantially lower noise production than air hammers or vibrators. 65 dB LA eq at 10 metres
- High efficiencies with high forces.
- Vibrational disturbance is negligible, with no chance of resonance.

Advantages

- Low Vibration
- Low Noise
- Modern with high efficiency
- No open lubrication system, environmentally more sensitive than air hammers
- One tool drives and extracts
- Panel presses are easily adaptable to a wide range of steel piling both Z and U profiles.
- Available with experienced operators.

Disadvantages

- Current models available are not suitable for trench sheeting and plastic piling
- Cost premium - these units are relatively expensive to buy and hire.
- Top acting and so relatively rigid piles required
- Typically leader mounted and so access to certain locations can be problematic
- Few units available
- Very few trained or experienced operators

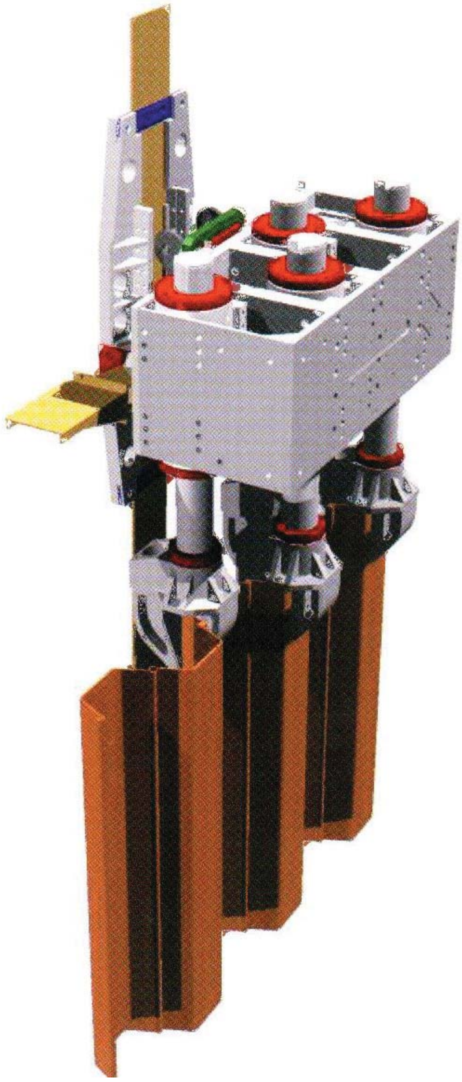


Figure 3.25 DCP Panel Powerpress

Pitch & Drive Presses

Overview
- This equipment utilises the reaction force of pre-driven piles and as a result relies less on physical mass (5 - 10 tonnes). The press is capable of self-travel "walking" along a length of piles and so obtains greater access to restricted sites than panel presses.
- Piles are driven one at a time, the unit moving forward after each pile is driven ready to accept the next. The devices are capable of driving and extracting, often offering a high extraction force.
- With no reliance on dynamic forces these units produce very low noise and vibration.
- The available forces are considerable ranging from 600 to 1600kN.
- Unlike panel presses the design of the chuck and spacing of the reaction clamps limit the piles that can be driven.

Environmental
- Substantially lower noise production than air hammers or vibrators. 65dB LAeq at 10 metres
- High efficiencies with high forces.
- Vibrational disturbance is negligible, with no chance of resonance.
- The self travel features enables greater access to restricted sites. Reduces site disruption

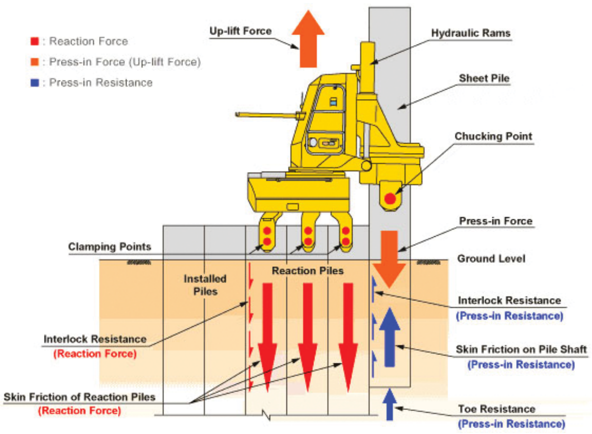


Figure 3.26 Pitch & Drive press concept

Advantages
- Low Noise
- Low Vibration
- Modern with high efficiency
- The self travel features enables greater access to restricted sites
- One tool drives and extracts
- Available with experienced operators.

Disadvantages
- Current models available are not suitable for trench sheeting and plastic piling
- Cost premium - these units are relatively expensive to buy and hire.
- Few units available - but this is less of an issue with the available of Contract hire or subcontract services.
- Very few trained or experienced operators
- Pile types that can be used are limited to chuck sizes and availability.
- Requires additional 'supportive' plant, for example these presses cannot handle piles until placed in jaws

Figure 3.27 TOSA Still worker

Press extraction systems

Overview

- Quiet vibration-less pile extraction system available with either a 4080 or 10,190kN force. Uses the ground as a reaction based and so no crane line or neighbouring piles required for use.
- Can extract "H", "U" and "Z" profiles and straight profile sheets.
- Safer than extracting piles using a vibrator or pulling with a crane as the system can be operated remotely.
- Equipment size 12 - 24 tonnes and therefore unlikely to be used with trench sheeting applications.

Environmental

- Substantially lower noise production than air hammers or vibrators. 65 dB LA eq at 10 metres
- High efficiencies with high forces.
- Vibrational disturbance is negligible, with no chance of resonance.
- Remote control usage possible, negates the requirement for crane pull reducing site disturbance.

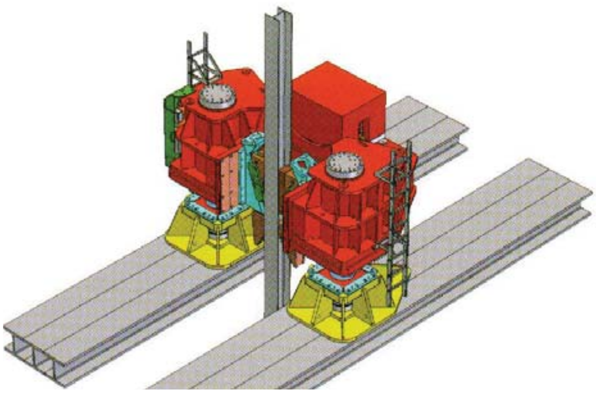


Figure 3.28 DCP Extraction Press

Advantages

- Low Noise
- Low Vibration
- Modern with high efficiency
- No crane line or neighbouring piles required and so isolated piles can be extracted.
- Capable of extracting all pile types, including tubes after some modifications.
- Available with experienced operators.

Disadvantages

- Current models available are not suitable for trench sheeting and plastic piling
- Cost premium - these units are relatively expensive to buy and hire.
- Few units available - but this is less of an issue with the available of Contract hire or subcontract services.
- Very few trained or experienced operators

Figure 3.29 DCP Extraction Press

Variation within piling equipment types based on suspension or mounting

With the hammer types discussed, it is important to consider on how the hammer will be mounted, and the ancillary plant that may be required such as compressors, generators, craneage, leaders and piling frames:

- Suspended from a crane or excavator,
- Mounted as an excavator attachment or
- Part of a leader rig piling system.

Figure 3.30 ABI Leader mounted Vibrator

Figure 3.31 ICE 7RF suspended vibrator

Figure 3.32 EMV300 excavator mounted via a Powertilt

Figure 3.28 The Movax side driving excavator mounted vibrator

Excavator Mounted

Top acting Vs. Side Acting Vibrators

The four main problems with top acting devices are:

- Handling long sheets without damage
- Pitching the sheets into position
- Driving vertically
- Driving thin sheets without damage

Figure 3.33 ICE SH Top Acting mounted vibrator

Figure 3.34 ICE SH pitching sheets

Figure 3.35 EMV 300 driving trench sheets

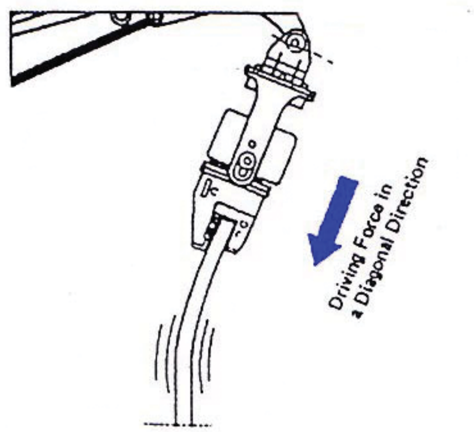


Figure 3.36 Top acting representation of possible driving damage

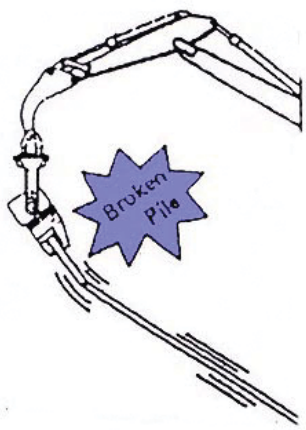


Figure 3.37 Top acting representation of possible pitching damage

Excavator Mounted

Side Acting vibrators

The main problems with side acting devices are:

- Availability of plant and trained operators
- Abuse is possible with overloading of the clamp

Although side-acting devices can potentially handle longer piles than top acting devices, it is important to take note of the weight of the pile and position of the clamp.

Figure 3.40 Movax pitching method

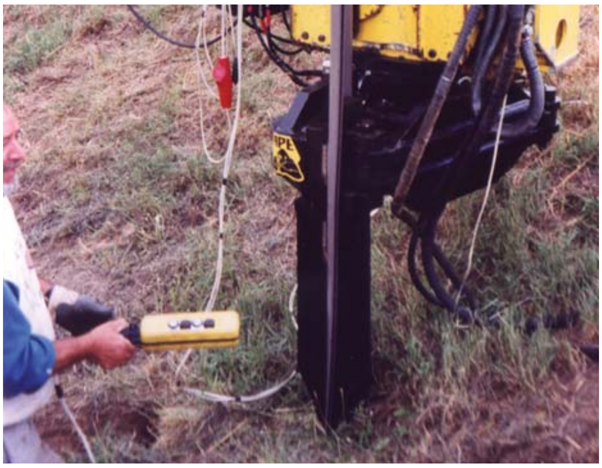


Figure3.38 Converted EMV300 driving plastic piles

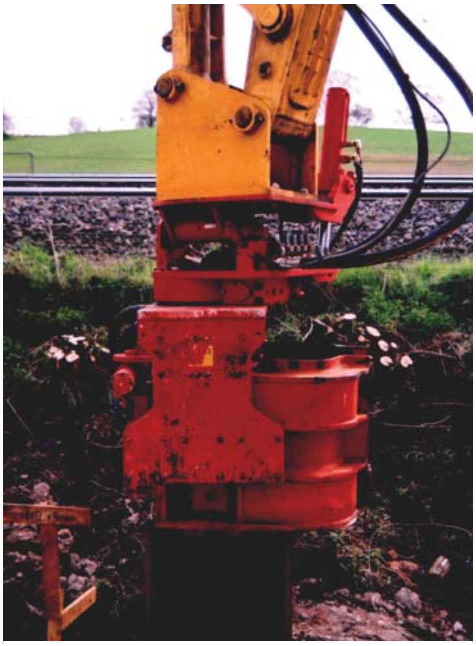


Figure 3.39 Movax capable of top driving

Figure 3.41 Multipiler side driving

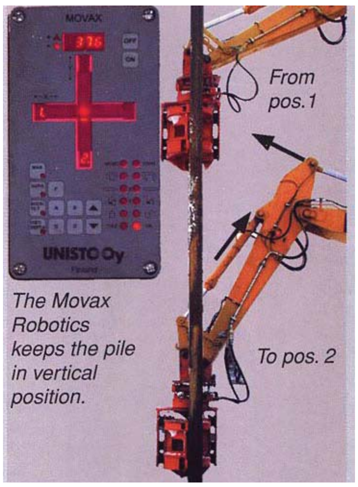


Figure 3.42 Movax computer controls

Leader Rigs and leader mounted hammers

A type of leader rig has emerged which has been designed for driven steel sheet piles, these feature telescopic leaders with high static downward forces and high adjustability. Other features include the ability to change attachments quickly on site.

The most popular leader rig in the UK from the Mobilram range is the TM 13/16, which will handle up to 16 metre sheets. This is more than adequate for most piling activities and virtually all temporary works activities.

The advantages of such a system are clear; the complete system can be delivered to site and be put to work straight away. Leader rig systems are competitive against suspended hammers particularly those that require craneage.

Whilst impact hammers and press systems can be leader mounted the most popular leader attachment is the vibrator, most typically one with a 900kN centrifugal force, and variable moment.

With the use of wider sheets much larger based leader rigs such as those produced by Lieberr are likely to increase in popularity. As piles become wider the range of possible attachments also extends, permitting vibrators with 1200kN forces to be used.

Despite these large piling forces, the variable moment systems can adjust to drive even plastic and composite piling. From a cost perspective and also transportation, it is unlikely that leader rigs will have much impact on the smaller excavator mounted vibrators and smaller scale temporary works.

Figure 3.43 Dawson Leader mounted panel press

Summary

There is clearly a wide range of hammers now available for temporary works applications, however the majority are still designed for steel sheet piling rather than trench sheeting.

With several new product development soon to enter the market, the next five years will prove to be exceptionally dynamic, with more attention paid to the environmental requirements of lower noise and vibration.

CHAPTER 4

HEALTH & SAFETY

Introduction

This chapter covers aspects of Health and Safety that are applicable to the use of ground support systems and pile driving equipment.

Health and safety is of importance to every employer, employee and the self-employed. Legislation on health and safety is intended to be both preventative punitive and compensatory. It is constantly evolving, especially through implementation of European Directives.

In the UK, the application of health and safety still relies on the provisions set out in The Health and Safety at Work Act 1974 (HSWA). The Act introduced the concept of duties of care for employers and employees and imposed certain legal requirements on those that manufacture, import, design or supply articles and substances to be used at work. The Act further required all employers to take into account the health and safety of persons not in their employment but who may be affected by their work activities.

Prior to the HSWA, there were a number of Construction regulations based around the Factories Act 1961. As modern legislation has been introduced, many of these have been revoked and this document will primarily consider the modern, construction related, regulations.

Additional UK based legislation has been introduced under the HSWA, most of which is still applicable, however other regulations have been revoked as a consequence of the implementation of European Directives. Their implementation into the UK has served to clarify, modernise and consolidate the means of applying the duty of care created in the HSWA.

Those regulations that are still applicable include:

- Construction (Head Protection) Regulations 1989
- The Control of Noise at Work Regulations 2005
- Electricity at Work Regulation 1989
- The Control of Substances Hazardous to Health (COSHH) 2002
- The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995
- Confined Spaces Regulation 1997
- Lifting Operations and Lifting Equipment Regulations (LOLER) 1998
- The Work at Height Regulations 2005

These regulations are typically procedural, introducing assessment, minimum requirements, maximum exposure limits, and means of documentation and monitoring.

The implementation of the Framework Directive led to the introduction of a six-pack of regulations:

- The Management of Health & Safety at Work Regulations 1992 (now 1999)
- The Provision and Use of Work Equipment Regulations 1992 (now 1998)
- The Manual Handling Operations 1992
- The Health and Safety (Display Screens Equipment) Regulations 1992
- The Personal Protective Equipment at Work Regulation 1992
- The Workplace (Health, Safety and Welfare) Regulations 1992

Central to all these is the introduction of the concept of Risk Assessment as a means of evaluating the hazards involved through their identification, cause and effect with to associate them to the likelihood their occurrence. Documentation is important, especially with regards to the ultimate evaluation into how the hazards can be avoided or the risk minimised. Information provided by the shoring or pile driving equipment suppliers may well include a risk assessment in the case of structural elements or a hazard narrative in the case of machinery. The latter details all associated hazards without assessing risk, since risk is site specific and will often vary depending on how the equipment is used.

Risk assessment is the starting point of all health and safety management systems.

> Guidance on risk assessment and a generic hazard list specifically for shoring and piling operations is available from the CPA titled **'Risk Assessment for Shoring and Piling Operations'**, which covers this in more detail.
> (Ref STIG 0403)

All these requirements, acts and regulations are valid within construction and so are applicable to the use of ground support equipment and pile driving equipment. However, due to the high injury and fatality rates in the construction industry, the European Union issued a Directive (92/57/EEC) on construction safety, which through the Temporary or Mobile Construction Sites Directive required the implementation of minimum health and safety standards on construction sites. Primarily, two sets of regulations have been produced from this directive:

- The Construction (Design and Management) Regulations 1994
- The Construction (Health, Safety & Welfare) Regulations 1996.

Most recent changes have been the consolidation of the lifting equipment regulations, creating the Lifting Operations and Lifting Equipment Regulations 1998. (LOLER)

Health & Safety at Work Act 1974 (HSWA)

The main aims of the Act are to:

- Secure the health, safety and welfare of all people at work
- Protect others e.g. general public, contractors etc. from the risks associated with the activities of people at work
- Control the emissions into the atmosphere of noxious or offensive substances.

Within the HSWA, the main two sections applicable to ground support, or those most often cited, are sections 2 & 3. The prime duty of the HSWA is the general duties of the employer to the employee, the "duty of care". It shall be the duty of the employer to ensure as far as is reasonably practicable, the health, safety and welfare of all his employees. However, it is important to be aware of Section 7, which covers the responsibilities of the employee.

Section 2 - The duty, as laid out in section 2, extends to a safe place of work, with safe means of access and exit, safe plant and systems of work, safe use, handling, storage and transport of articles and substances, provision of necessary information, instruction, training and supervision and a safe working environment.

Section 3 - This states that every employer is under duty so far as is reasonably practicable to ensure other persons not in their employment who may be affected are not exposed to risks to their health and safety.

Section 7 - This places a duty on all employees to take reasonable care of their own and others' safety. Employees must also cooperate with their employer to enable the latter's duty to be performed. For example, the wearing of supplied personal protective equipment or by performing tasks in the prescribed safe manner.
personal protective equipment.

The Management of Health and Safety at Work Regulations 1999

The principle feature of this legislation is the requirement of a risk assessment (Regulation 3) to identify hazards and the nature and level of risk associated with the task.

In addition, Regulation 5 ('Health and Safety arrangements') requires an employer with five or more employees to record the arrangements made for Health and Safety. The main elements of management practice, as given, are planning, organisation, control, monitoring and review of the preventative and protective measures.

In addition to the duty imposed on employees under the HSWA, this regulation imposes a duty on them to inform their employer of any dangerous situations or shortcomings in the employer's safety procedures.

The Provision and Use of Work Equipment Regulations (PUWER) 1998

PUWER places duties on employees, the self-employed and people who have control of work equipment and aims to ensure that the use of work equipment does not result in health and safety risks, regardless of age, condition or origin. It applies to all work equipment including mobile and lifting equipment. Lifting requirements are implemented through the Lifting Operations and Lifting Equipment Regulations (LOLER) 1998.

PUWER is of particular importance when one considers the use of piling equipment. A list of hazards related to piling equipment is stated in BS EN 996:1996. As a result, when equipment is supplied, operating instructions should include relevant guidance of remaining hazards to enable site to develop their own risk assessment.

This can be included within the operating instructions or provided as a Hazard narrative.

Inspection requirements are incorporated in both PUWER and LOLER. The inspection requirements in LOLER are more stringent and so it is important to clarify what is lifting equipment and what is work equipment.

For example, consider the range of Excavator mounted vibratory hammers, which use pitching chains. The pitching process whilst not lifting as such would require the chain used to be inspected via LOLER. The point at which the chain is connected to the hammers, being part of the hammers and as such non-removable for other lifting operations is covered by the inspection regime of PUWER. This is primarily because the principle purpose of the piling hammer is to drive and/or extract piles or trench sheeting and not to be used as a lifting device. However, the attachment of a chain involves LOLER since the principle purpose of the chain is to lift, and it is possible that the chain may be removed and used for other lifting operations.

Since PUWER's introduction in to the UK, there have been amendments made to the duty holders to include a duty on people who have control of the equipment, and therefore addresses the responsibilities of the Plant supplier. The supplier's main responsibility is the establishment of a maintenance schedule and the inspection and maintenance of equipment according to the schedule.

The supplier in general has the following duties:

- To provide equipment, which is suited to the task (Regulation 4)
- To provide operating instructions on the products (Regulation 8) and notification of residual hazards (Regulation 7)
- To record the inspection (Regulation 5) and the maintenance (Regulation 6) of the equipment. This will take place before and during the hire, as the schedule requires.

Because of the general risk assessment requirements in the Management regulations, there is no specific regulation requiring a risk assessment in PUWER.

Regulation 11 of PUWER details the measures taken to prevent access to dangerous parts of the machine, such as guarding, and has implications for vibratory equipment, in that certain dangerous components, such as the clamp, cannot be guarded since this would prevent their function.

The levels of acceptable protection in Regulation 11 are stated as:

- Fixed enclosing guards
- Other guards or protection devices such as interlocking guards and pressure mats
- Protection appliances such as jigs, holders and push sticks etc;
- The provision of information, instruction, training and supervision.

Clearly, the latter is the only means of protection from the hydraulic clamp. It is important that the suppliers operating instructions are adhered to in full and that information on residual hazards is understood and assessed.

All excavation and piling equipment must be continually monitored when in use, to ensure that any deterioration is noted and reported to the relevant responsible person. If in doubt always, stop using and seek advice.

The Manual Handling Operations Regulations 1992

These regulations apply to manual handling of loads by human effort. The effort may be applied directly to the load or indirectly by hauling on a rope or pulling on a lever. Mechanical assistance such as sack trucks may reduce but do not eliminate manual handling. The regulation has to be considered with the Management Regulations, which require a risk assessment.

The duty is on the employer to avoid unreasonable manual handling and reduce the risk of injury. The risk assessment should be performed with regards to the factors specified in schedule 1 of the regulation and the questions of that schedule. The factors considered are: the task, the load and the working environment. There are a number of guidance notes available from the HSE, including a new guidance on safe manual handling in construction.

The Construction (Design & Management) Regulations (CDM) 1994

The main objectives of these regulations are to identify the main duty holders (client, principle contractor, principle engineer, planning supervisor and contractor) and their roles. The impact these Regulations have on ground support systems lies primarily with the duties of the Temporary Works Designer, who must ensure that the effects of any proposed ground support system are made clear to the other duty holders and do not negatively impact on the overall project.

The Construction (Heath, Safety and Welfare) Regulations 1996

These are of particular relevance since regulations 12 & 13 are devoted to excavations, cofferdams and caissons. The Regulations are aimed at protecting the health, safety and welfare of everyone who carries out construction work. They also give protection to other people who may be affected by the work. They also cover inspection periods and the use of suitably qualified personnel to assess changes in conditions and safety during the course of the works.

Regulations 12 & 13 - Excavations, Cofferdams and Caissons

PLEASE NOTE THE "FOUR FOOT" RULE HISTORICALLY ASSOCIATED WITH A TRENCH OR EXCAVATION HAS BEEN REVOKED

These regulations are intended to ensure that cofferdams and caissons are properly designed, constructed and maintained. From the outset and as work progresses, an excavation that has the potential to collapse unless supported should have suitable equipment immediately available to provide such support.

Underground cables and services can also be a source of danger. These should be identified before work starts and positive action taken to prevent injury. This is clearly important when considering piling and surface driven systems, where such underground services are not visible.

Also relevant is regulation 9, which relates to prevention of collapse of new or existing structures or those under construction due to any excavation work. This will have implications with regard to supports and props used near an excavation and also to the selection of piling equipment when the effect of vibration on structures is considered.

Confined Spaces Regulations 1997

This regulation requires the employer to avoid entry of employees into confined spaces If entry to such a confined space is unavoidable then a safe system of work should be followed. Adequate emergency procedures should also be put into place before work starts. From the outset, any excavation should be considered as a confined space and assessed accordingly.

Lifting Operations and Lifting Equipment Regulations 1998

LOLER applies over and above the general requirements of PUWER 1998 in dealing with specific health and safety issues associated with lifting equipment and lifting operations.

When considering shoring products, it is current practice throughout the UK shoring Industry to use chain assemblies to support shoring equipment when installed within an excavation. There is often considerable confusion as to whether or not these chains should be covered by LOLER. LOLER defines lifting equipment as 'work equipment for lifting or lowering loads and includes attachments used for anchoring, fixing and supporting it'. Hanging or restraining chains are not intended for lifting or lowering a load and therefore fall outside the scope of LOLER.

Safety guidance is available from the CPA titled **'The Use of Chains to Support Shoring Equipment'**, which covers this in more detail. (Ref STIG 0202)

The Control of Noise at Work Regulations 2005

The Physical Agents Directive, has now been implemented in the UK partially in ter form of the Control of Noise at Work Regulations 2005. This imposes a duty on the employer to take steps where an employee is likely to be exposed to noise at or above three action levels.

The Lower Exposure level - a daily personal noise exposure (LEPd) of 80 dB(A), or a peak of 135 dB(C)When this is exceeded, a Noise Risk Assessment must be conducted and an action plan developed. Hearing protection MUST also be made available. .

The Upper Exposure level - a daily personal noise exposure (LEPd) of 85dB(A), or a peak of 137dB(C). When this is exceeded a Noise Risk Assessment must be Condutced and an action plan developed. At this level, wearing hearing protection is compulsory for all employees and a health surveillance programme must be implemented.

The exposure limit value provides an absolute limit of exposure and is measured at the ear. Therefore hearing protection can be considered as part of your control measures.

There are also levels of noise exposure, which must not be exceeded: exposure limit values: Daily or weekly exposure of 87 dB and peak sound pressure of 140 dB. These exposure limit values take account of any reduction in exposure provided by hearing protection.

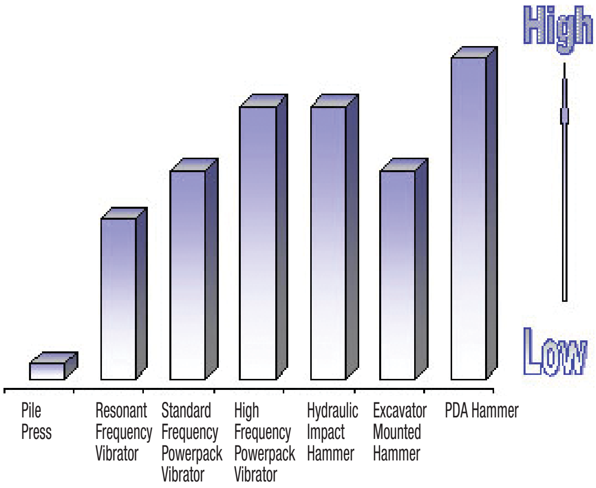
The definition of LEPd can be regarded as the total exposure to noise throughout the day, taking account of the average noise levels in the working area and the time spent in them.

The use of piling equipment presents significant noise hazard. Vibratory hammers are often substantially quieter and therefore are typically selected first and only upon failure of the vibratory technique to drive the piles, will an impact hammer be considered. Enforcement of the Noise at Work Regulations, is seldom policed due primarily to the rapid action of environmental health controls by local authorities.

In some cases the use of such hammers is completely ruled out by the Local Authority, under the Control of Pollution Act 1974, often listed as a requirement of the Notice of Prior Consent supplied by local authorities. Often noise control measures will come about through neighbourhood complaints.

The damaging affect of noise is related to the total noise dose the ear receives. This dose is the product of the noise level and exposure duration. Therefore, a trade off becomes possible between the dose exposed to and the duration of the exposure. As a 3dB(A) increase is taken to indicate a doubling in the damage causing ability of the noise, the time exposed needs to be reduced by half to bring the daily personal dose received back to the same level.

Noise Levels



CHAPTER 5

BRITISH STANDARDS

Introduction

A selection of standards related to shoring and piling operations are summarised below:

BS EN 996:1996 – Piling equipment Safety

This British Standard is a very useful guide into the required minimum safety standards for piling equipment. The only problem with this standard is that it attempts to cover a whole myriad of equipment including accessories, hammers, but mainly piling rigs. It does included however some very useful normative annexes, which constitute part of the standard.

The standard specifies safety requirements suitable for the following purposes: - Construction of foundations, slurry walls or retaining walls, using piles or other longitudinal elements; the removal of piles; the installation of drains or injection elements.

BS 5228 Part 1:1984

Noise control on construction and open sites - Part 1 Code of Practice for basic information and procedures for noise control

This standard was produced prior to the Noise at Work Regulations 1989, and so relates its content to the previous 1975 version of BS5228, Environmental Acts and the HSWA. BS5228 consists of four parts, yet only part 1 and 4 have any application within this report. Part 1 of BS5228 is not based purely around piling, but considers it as one of several noise producing techniques. It is applicable within the scope of this report, as there are many instances when small 'piling' hammers, will be used.

BS 5228 represents a standard of good practice and despite its age, it stands up well. The true strength of this standard compared to other noise and vibration standards is that it contains substantial information with regards to predictions as well as monitoring and control. Therefore, this guide is extremely useful in planning stages of construction works, as well as being a method of control on existing sites.

BS 5228 has been adopted under Section 71 of the Control of Pollution Act 1974 and as such, its use is mandatory under certain circumstances. This Act gives to Local Authorities powers to enforce their requirements for the control of noise and vibration.

Under section 60 of the Act, Local Authorities may stipulate and impose their restriction prior to and during piling operations.

The Appendices provide more detailed methods of predicting noise levels, monitoring noise and actual sound level data.

BS 5228 Part 4: 1992

Noise control on construction and open sites - Part 4 Code of Practice for noise and vibration applicable to piling applications

Typically, the main use for this British Standard, is vibration level prediction and control. Vibration levels produced by piling equipment are most frequently a consideration when working near buildings. This is especially true in the case of shoring applications, which typically are based, in closer proximity to neighbouring buildings.

The inherent problem of BS5228 occurs as the 'whole' Piling Industry is considered, and that the solutions presented, especially those, which recommend alternate techniques, typically fall outside the scope of this document and rarely address options available with proprietary shoring equipment.

Section 3 - Vibration
Vibration prediction is not an exact science, since soil type greatly affects the transmission of the vibration. Therefore, all predictions should ideally be verified by appropriate field measurement.

BS7385-1:1990 (ISO 4866)

Evaluation and measurement of vibrations and evaluations of their effect in buildings -

Part 1: Guide for measurement of vibrations and evaluation of their effect on buildings.

Like BS5228, this standard relates to ground vibrations. Part 1 is from the perspective of identifying factors, which make buildings prone to damage caused by vibration. These features being used to assist in the classification of building types. This understanding being important to ensure that all new building designs are capable of withstanding set magnitudes of vibration and also with the methodologies to ensure correct measurement of vibration in preservation efforts on existing and historic building types.

Part 1 of this standard does not state limits, these can be found in Part 2 of this standard. Further, this standard is not application specific and does not consider the sources of vibration in any detail other than discrete specifications, which may influence the effect of vibration on the structure, for example frequency.

This Standard establishes the basic principles for carrying out vibration measurement and processing data, with regards to evaluating vibration effects on buildings. A building, is defined as any above ground structure, which man frequently inhabits. This excluding structures which may be visited from time to time by operating staff.

The structural response of buildings depends upon the excitation; this standard therefore examines the methods of measurements as affect by the source. i.e. frequency, duration, and amplitude as induced by any source, such as earthquakes, explosions, wind effects, sonic booms, internal machinery, construction activities such as piling, and influence of traffic (road or rail).

BS 7385-2:1993 (ISO 4866)

Evaluation and measurement for vibration in buildings -

Part 2: Guide to damage levels from ground borne vibration.

This Part of BS 7385 provides guidance on the assessment of the possibility of vibration-induced damage in buildings due to a variety of sources. The impetus for this Part standard being, to identify whether damage can occur, what kind of damage and at what levels, to alleviate any concern arising from man-made sources of vibration.

This Part of BS 7385 sets guide values for buildings vibration based on the lowest vibration levels above which damage has been credibly demonstrated. Case history data, taken alone, has been stated as being inadequate for identifying thresholds. The values stated within this standard relating to controlled vibration studies in the vicinity of buildings.

The indirect effects on the building due to ground movement, the movement of loose objects within buildings, the possibility of damage to sensitive equipment and the effect of vibration on people are outside the scope of BS7385. Annex C does however provide an informative guide to building damage caused by soil compaction

Levels provided here being substantially higher than those found in BS 6472 (as described later), since there is a major difference between the sensitivity of people to vibration and that required to initiate or cause damage.

BS 6472:1992

Guide to Evaluation of human exposure to vibration in buildings (1Hz to 80 Hz)

This provides guidance on human response to building vibration, which can be detected by occupants and can affect them in various ways. Tentative guidance is given on vibration magnitudes at which adverse comment may arise. This is the most common standard used for environmental assessment.

Because buildings may be used for many activities, occupants inside can be found in a variety of body postures - standing, sitting and lying down. In these different postures, the response to vibration varies quantitatively according to the direction in which it is perceived. Generally, vibrations in the foot-to-head mode (z axis) are more perceptible than those in the back-to-chest (x- axis) or side-to-side (y-axis) modes. Although at very low frequency, this tendency is reversed. BS5228, makes mention to tri-axial measurement, but its predictive methods place more prominence on peak particle velocity.

When the likely posture of the occupants is known then the axis pertaining to that position should be the one measured, estimated and stated. When the likely postures are unknown, all axes should be estimated or measured and the axis with the highest dose value should be stated.

Another difference from BS5228 is that when considering human exposure to vibration, it is common for these levels to be frequency weighted in a similar way to A-weighting of noise.

Dosage is typically stated in terms of m/s 0.75 . This value is calculated using measured values of frequency weighted accelerations. This is as opposed to peak particle velocity, which is most likely the term used to describe vibration from piling operations. This standard states a ratio of 2.8, to convert ppv to acceleration (r.m.s.) as shown in Table 8 of BS6472. This enables the dose to be calculated from both the actual measured values and those obtained through the prediction method outlined in BS5228.

BS 8002: 1994

Code of practice for Earth retaining structures

This is a complete revision of the old CP2, which dated back to 1951. The main changes in BS 8002 are the recognition of effective stress as the main basis of calculation of earth pressures and the need to take into account the effect of movement, or lack if it, upon the resulting earth pressures on a retaining wall. This is a design code giving guidance to a designer conversant with theoretical and applied soil mechanics. The code is primarily applicable to walls of up to 8m retained height.

BS 6031:1981

Code of practice for Earthworks

This is the oldest of the standards included in this chapter; it is also perhaps the most cited. This code of practice is a revision of CP2003, published in 1959. Whilst this standard is still current, its methods for ground support are based on traditional methods. It is a very general standard, its content being more qualitative, than quantitative. Guidance laid down being far less specific than other standards outlined in this chapter.

This Code of Practice does state in its introduction that "newer techniques usually involve the utilization of a permanent substructure" and these are dealt with in CP2004 - which is now BS 8004:1986 and the CP document since abandoned. The methods exemplified in this publication have remained fairly constant form the 1959 edition.

Eurocodes

There are ten proposed Eurocodes all having an application within construction. The Eurocodes with specific application to this report are Eurocode 3, design of steel structures, specifically part 5 which summarises all related topics for the application of piling; also Eurocode 7 Geotechnical design. There is substantial cross-referencing between different Eurocodes making each quite difficult to read. This is compensated for by the provision of numerous annexes with an informative status.

Since the introduction of the Eurocode programme, several ENV's have since been published. ENV documents are ratified text, which will shortly be published as a BS EN. It is has been made available in advance of its formal publication to give interested parties early access to the technical information which the BS EN will contain.

European Standards only exist formally as national transpositions (i.e. BS EN for the UK) of a commonly agreed ratified text.

Part 5 of Eurocode 3 covers steel sheet piling, used for retaining and bearing applications. It is the retaining structures information, which makes this applicable, but primary interest is standardised terminology, which crosses references to the newly proposed shoring standards discussed later. The official availability date for the EN version of this standard is 2004-2006.

The adoption of Eurocodes raises some problems, which still require consideration: -

- The withdrawal of national codes and the management of the co-existence period with new European Standards
- The reference to Eurocodes outside their intended field of application (e.g. for the assessment of existing construction works.
- The development of a national programme of information and education for Civil Engineers.
- Actions for the updating of educational programmes in engineering schools and universities
- Foreseeable costs and expected benefits from harmonisation
- Maintenance of Eurocodes in the future.

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