Guidance on the design of hand excavated pipejacks

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1 SUMMARY

The purpose of this document is provide guidance on best practice to clients, designers, specifiers and contractors on the limitations, to include lengths, of hand excavation in pipe jacking. The Pipe Jacking Association recommends that hand excavated pipejacks should only be undertaken if mechanical excavation methods are not reasonably practicable, and then only at limited lengths

2 INTRODUCTION

The Pipe Jacking Association publishes "An introduction to pipe jacking and microtunnelling design" and also a "Guide to best practice for the installation of pipe jacks and microtunnels" and together with five participating water companies, has invested and continues to fund research and development programmes into aspects of pipejacking at Oxford and Cambridge universities.

These documents and research programmes, whilst referring to the general aspects of health, safety and the environment, are principally concerned with the design, installation and scientific improvement of the technique for the benefit of the industry.

This guide draws upon the extensive experience of the members of the Pipe Jacking Association in the installation of hand excavated pipe jacks to comply with the requirements of health, safety and environmental legislation and codes of practice.

Health, safety and environmental legislation places significant responsibilities and duties on the promoters, designers and installers of pipe jacks. The principal legislation and standards are given in Appendix 1 of this guide and take precedence over this document.

3 DESIGN ASSESSMENT

Significant advantages are to be obtained by the use of pipe jacking over conventional tunnelling:

- Inherent strength of reinforced jacking pipes
- Reduced risk of settlement due to smaller face "cut"
- Smooth internal finish giving low roughness factor, k_S
- No requirements for secondary lining
- Major reduction in joints compared to tunnel segments
- Prevention of ground water ingress due to pipe ring seals
- A virtually maintenance free installation
- Reduces manual handling

In general, the use of "no dig" techniques, such as pipe jacking, are Environmentally beneficial in that the movement and disposal of large quantities of excavated material and replacement with quarried backfill materials are avoided.

Surface disruption to the immediate area is also avoided and these benefits support pipe jacking as a sustainable method of infrastructure provision and maintenance.

In common with tunnelling however, pipe jacking is a construction method dealing with working underground in confined spaces.

As such the Health, Safety and Environmental impacts of the method on the local area and the personnel employed in construction, maintenance and repair must, as with tunnelling, be carefully considered at the initial design phase of a project.

The principal health and safety hazards to be considered include:

- Noise
- Manual handling
- Vibration
- Heat
- Dust & Chemicals
- Contaminated water or soils
- Inundation
- Methane and other atmospheric contaminants
- Fire & smoke
- Access & rescue
- Oxygen deficiency
- Working space

It can be clearly seen that consideration of the above will have an impact on the designed size and length of a pipe jack to be carried out, and the excavation technique.

Historically "no dig" techniques relied heavily on hand excavation methods and the use of vibratory hand held tools and whilst the industry has moved to mechanised excavation, the need for hand excavation will continue in areas such as shaft sinking, repair and maintenance of existing shafts and tunnels, connections, short cross adits, blind tunnels, timber headings and short pipejacks for which machines are impracticable.

Promoters and their designers must therefore carefully consider the risks associated with the above, and other project specific hazards when designing pipejacks.

For example:

- If there is a risk of flooding/inundation – how much time will be required for escape/ rescue the of miner(s)? – length and size of pipejack?
- If there may be a change in ground conditions at the face – how will this affect the vibration exposure of the miner(s)? – will health screening and surveillance be required?
- Can mechanical excavation methods be reasonably used – design out hand excavation risks? – consider whole body vibration if mechanical excavation used?
- Can future maintenance in an operating condition be safely carried out – size and length of pipe jack?
- What is the likely shift time for the miner(s) to limit exposure to less than the required action levels for vibration and noise? – anticipated ground, soft or hard?

These are only a few simple considerations but may have a major effect on the personnel constructing and maintaining the asset and the true outturn cost of the project.

Guidance is given on the design of hand excavated pipe jacking in section 5 of this guide and has been prepared from a consideration of the above. Detailed risk assessments must be carried out for all projects at design stage and designers should consult with contractors on the maximum lengths of drives.

4 CONSTRUCTION

Constructors of hand excavated pipe jacks, shafts, headings etc must equally take regard of the above but in addition ensure that their management systems include procedures to control the remaining residual risks that have not been designed out.

No legislation should be viewed as seeking to ban hand excavated pipe jacking, but as more knowledge has accumulated on the long term health effects of over exposure to the hazards, particularly those of noise and vibration, so successive legislation has placed further limitations on exposure levels, to the extent that these now have a significant effect on the level of resources needed for this method of working.

Generally contractors are aware of legislative requirements, have developed the appropriate controls, and put these into practice.

However, assessment of the matters referred to above can be complex and time consuming and in some areas, for example vibration exposure assessment, reference documentation or research material has historically not been readily available or understood.

The introduction of the Noise at Work Regulations in January 1990 and the HSE guidance book on hand – arm vibration published in 1994 brought into focus the long term effects of these hazards if not correctly managed.

The recent changes in legislation with the publishing of the Control of Vibration at Work Regulations on the 6th July 2005 and the introduction of the New Control of Noise at Work Regulations 2005 on the 6th April 2006 significantly reduces the action levels.

It is with these changes in mind and to promote improved health and safety practice that the Pipe Jacking Association recommends limiting the use of hand excavated pipe jacks.

5 RECOMMENDATIONS

Considering the foregoing The Pipe Jacking Association recommends:

- **The use of hand held vibratory tools for excavating in pipe jacks should be the last method adopted by designer and contractor alike in order to avoid the long term health risks from Hand Arm Vibration Syndrome (HAVS) and Noise.**
- **The adoption of mechanised excavation whenever possible.**
- **The use of equipment and work methods and practices to ensure that the hand-arm vibration Exposure Action Level of 2.5m/sec2 and the noise Exposure Action Level of 80dB(A) (New limit from 6th April 2006) is not exceeded in an 8hr period.**

Reference must be made to the current Regulations, HSE Approved Codes of Practice and guidance.

Pipe Jacking Association guidance on the limitations of hand excavated pipejacks

Pipe I/D	Ground	Guide Length
<1200mm	Not acceptable	N/A
1200mm and greater	Soils – Cohesive	25m. Not more than two drive lengths.
1200mm and greater	Soils – Non Cohesive	40m. Not more than two drive lengths.
1200mm and greater	Rock	Not recommended

The above is an initial guide only and a more detailed assessment of the variables is recommended. Designers should reference the attached Tunnelling and Pipejacking: Guidance for Designers issued jointly by the Health and Safety Executive and the Pipe Jacking Association. It should be noted that the PJA has applied more specific guidelines than the HSE based on its experience of the technique and also taking into account diverse ground conditions.

6 VIBRATION REGULATIONS

The practical difficulties of on site measurement of vibration exposure, caused by changes in ground, personnel, efficiency of the equipment, maintenance of equipment and changing trigger times, to demonstrate proper management control of HAVS are considerable and costly.

Assessments should be made at preliminary design stage and if possible design out the risk and where excavation by hand is proposed, prior to work commencing on the actual work.

These are only assessments and due to the significant variables, a certain amount of measurement of actual vibration exposure is inevitable to monitor and modify working arrangements to ensure compliance.

The introduction of The Control of Vibration at Work Regulations 2005 and the publishing of the HSE Guidance L 140 on these regulations, requires the pipejacking (and tunnelling) industry, both designers and contractors, to further consider the need and desirability for hand excavation techniques.

The regulations introduce the Vibration Action and the Vibration Limit Exposure Levels of 2.5m/sec2 and 5.0m/sec2 normalised for an 8hr period.

Exposure above the Action Level will require the introduction of preventative measures and planned health surveillance and monitoring programmes.

Reference should also be made to "The management of hand-arm vibration in tunnelling, Guide to Good Practice", published by the British Tunnelling Society and which is available free on their website: www.britishtunnelling.org

APPENDIX 1

Principal Legislation and Standards

Health and Safety at Work Act 1974
The Control of Pollution Act 1974
The Noise at Work Regulations 1989
Environmental Protection Act 1990
The Environmental Protection (Duty of Care) Regulations 1991
Management of Health and Safety at Work Regulations 1992
The Manual Handling Operations Regulations 1992
The Personal Protective Equipment at Work Regulations 1992
The Workplace (Health, Safety and Welfare) Regulations 1992
Construction (Design and Management) Regulations 1994 (under formal review)
The Control of Substances Hazardous to Health Regulations 1994
The Construction (Health, Safety and Welfare) Regulations 1996
The Confined Spaces Regulations 1997
The Provision and Use of Work Equipment Regulations 1998
The Control of Vibration at Work Regulations 2005
The New Control of Noise at Work Regulations 2005 (from 6th April 2006)

BS 6164:2001 Code of Practice for safety in tunnelling in the construction industry
BS 8005-3:1989 Sewerage – Guide to planning and construction of sewers in tunnel

Attention is drawn to the fact that equivalent legislation exists in Northern Ireland and Scotland.

Noise, Hand-Arm and Whole Body Vibration exposure calculators are available free on the HSE web site.

Tunnelling and Pipejacking: Guidance for Designers

This document is a best practice consensus agreed between the Health & Safety Executive, the Pipe Jacking Association and the British Tunnelling Society.

Not Acceptable

Avoid

Acceptable

Internal dimensions for pipejacks and tunnels below 3.m diameter and indicative drive lengths

Table 1 – Nominal internal diameter of pipeline or tunnel linings

Excavation technique	<0.9m	0.9m	1.0m	1.2m	1.35m	1.5m	1.8m	>1.8m
Pipejack – machine; remote operation from surface	Acceptable (See Table 2)							
Pipejack – machine; operator controlled below ground	Not Acceptable			Acceptable				
Pipejack – hand dig	Not Acceptable			Avoid				
Tunnel – machine operator controlled + mechanical erector	Not Acceptable					Avoid		Acceptable
Tunnel – hand dig + mechanical erector	Not Acceptable					Avoid		
Timber heading – hand dig	Not Acceptable			Avoid				

Table 2 – Indicative drive lengths (e.g. between shafts) and maximum number of drives

Excavation technique	<0.9m	0.9m	1.0m	1.2m	1.35m	1.5m	1.8m	>1.8m
Pipejack – machine; remote operation from surface	Drive length limited only by capacity of jacking system			250m		400m	>500m (See note 7)	>500m (See note 7)
	Man entry not acceptable		Avoid man entry					
Pipejack – machine; operator controlled below ground	Not Acceptable			125m	200m	300m	500m	>500m (See note 7)
Pipejack – hand dig (See note 6)	Not Acceptable			*25m – 2 drive lengths	*50m – 2 drive lengths	*75m – 2 drive lengths	*100m – 1 drive length. Plan to use minidigger if over 2.1m dia	
Tunnel – machine operator controlled + mechanical erector	Not Acceptable					*250m	*500m	>500m (See note 7)
Tunnel – hand dig + mechanical erector (See note 6)	Not Acceptable					*50m – 1 drive length	*100m – 1 drive length. Plan to use minidigger if over 2.1m dia	
Timber heading – hand dig (See note 6)	Not Acceptable			*25m – 2 drive lengths Minimum cross section inside frames 1.2m high x 1.0m wide				

Notes

1) This guidance should be read in conjunction with BS 6164:2001. It is intended to be used only by those competent to design pipejacks and tunnels.

2) This guidance for designers has been agreed by the HSE and the tunnelling industry (BTS/PJA). It is based on experience of the occupational health and safety risks arising from heavy physical work, including the use of vibrating tools, in a confined space along with the need to be able to evacuate quickly/effect a rescue in a range of reasonably foreseeable situations.

3) Complying with the guidance does not relieve the designer of the duty to consider the risks arising from the foreseeable hazards of pipejacking/tunnelling including manual handling, noise, heat, vibration and confined space working. Neither does it relieve the designer of the duty to ensure there is potentially adequate space to allow a safe means of access and egress along with adequate working space within the tunnel/pipejack. The minimum diameter required for construction may in some cases be determined by the criteria above rather than by consideration of the hydraulic requirements for or the intended use of the pipejack/tunnel.

4) Indicative drive length and the number of drives of that length, have been determined from consideration of access and escape requirements. Again, complying with the guidance does not relieve the designer of the duty to consider the risks arising from the range of foreseeable emergency events which could arise and which could necessitate escape or rescue of those underground.

5) The drive lengths given in Table 2 are indicative. Designers should note that for entries not marked * it is **acceptable** to exceed the indicative drive lengths by up to 25% however exceeding these lengths by over 25% should be **avoided.** Exceeding the indicative lengths by over 75% should be considered to be **not acceptable.**

6) All hand dig is categorised as **"not acceptable"** or **"avoid"** – the lengths given in Table 2 for items marked * are indicative and are already in the category **"avoid".**

7) Drive lengths exceeding 1000m should be considered **not acceptable** unless the pipe/tunnel is of sufficiently large cross section to allow the contractor to incorporate an access envelope 0.9m wide by 2.0m high within the pipe/tunnel and clear of services including ventilation duct and spoil conveyor.

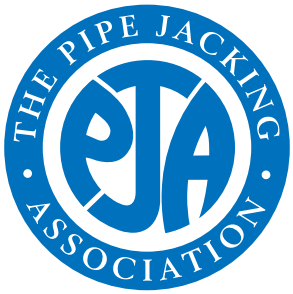
8) For guidance on side connections see relevant PJA publication.

Definitions

ACCEPTABLE – designers should undertake an assessment of the risks normally associated with small size pipejacking/tunnelling and specify the appropriate mitigation measures.

AVOID – designers should undertake a robust technical assessment and risk assessment to justify their decisions to deviate from "acceptable" criteria. Designers should identify appropriate risk mitigation measures. They should seek the advice of the Planning Supervisor/Co-ordinator and only proceed if the Planning Supervisor/Co-ordinator is satisfied that due attention has been paid to health and safety in undertaking the design and that appropriate risk mitigation measures have been identified. Contractors being asked to construct a pipejack/tunnel in this category should also seek advice from the planning supervisor/co-ordinator on the adequacy of their risk mitigation measures.

NOT ACCEPTABLE – designers should not specify the use of pipejacking/tunnelling of this size and construction method. An alternative design solution should be sought.



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