Designing for health – Reducing occupational health risks in bored piling

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Abstract

Insitu concrete bored piling is a common foundation solution for both major building and civil engineering projects. The technique is used both for individual or grouped piles topped with a pile cap, or a line of piles, contiguous or secant, topped with a capping beam as part of a basement or abutment construction.

There are many health hazards associated with bored piles. One of the main risks is the breaking down of the unwanted pile-top, typically using hand-held pneumatic breakers. This operation creates particular problems for hand arm vibration syndrome (HAVS), dust and noise. But there are several viable alternatives to this procedure that remove or significantly reduce these risks. These innovations have been developed by the construction supply chain and are readily available.

D^{4}h, a UK Government-funded research project by Loughborough University and the European Construction Institute, has demonstrated that designers can play their part in encouraging their adoption, without straying into the perceived danger of specifying means and methods. If designers are willing to identify pile-top break down as a significant residual risk in their health and safety assessment, thus requiring the Principal Contractor[1] to provide proposals to address this risk – this may be the only push needed to get the industry to eliminate the major HAVS problem from insitu bored piles.

This paper will benefit the health and safety research community, especially those working on designer intervention. The paper will also be of use to industry practitioners, providing innovative solutions to a significant occupational health risk as well as challenging designers to take construction health and safety more seriously.

Key Words: *Occupational health, vibration, HAVS, piling, innovation, design*

Introduction

This paper presents results from D^{4}h – Design for Health, a two-year UK Government-funded research project developing a strategy for best practice in designing construction projects to account for the occupational health of those involved in the construction process. The project produced an interactive CD for designers. The paper briefly summarizes D^{4}h and presents piling case studies where health hazards have been designed-out prior to the construction phase through close involvement with the construction supply chain – this aspect has been developed from a presentation at the Safety in Design Symposium, Portland, Oregon, September 2003 (Gibb et al., 2003). Data from a comprehensive survey of designers as part of an Association of Planning Supervisors' project is also analyzed and discussed.

[1] Principal Contractor is the term used in the UK to denote the organisation responsible for construction.

D^{4}h is one of several recent related projects by Loughborough's Construction Health and Safety Group. These projects include Accident Causality (ConCA); Health and safety benefits and implications from offsite production (HASPREST); better, safer, easier design via CDM; the CIRIA Site Health manual; CHSG Kerbs (manual handling of highway kerbs).

Relevance to researchers and industry practitioners

This paper will benefit the health and safety research community, especially those working on designer intervention and more broadly on effective uptake of innovations in a conservative industry. The paper provides industry practitioners with innovative solutions to the significant occupational health risks due to insitu concrete bored piling operations as well as challenging designers to take health and safety during the construction phase more seriously. The paper also includes rigorous evaluation of real world data from a survey of industry practitioners.

Why both occupational health and the need to design-out hazards are important

For many years, health has been the 'poor relative' of safety in 'health and safety' considerations. This is an important issue where little in-depth work exists although it is rapidly becoming a key issue for many countries. The European Temporary and Mobile Construction Sites (TMCS 92/57/EEC) Directive has stimulated a change in design culture in many EU states with designers being expected to explicitly acknowledge health and safety in their designs and seek to reduce or remove risk to construction workers. Research in the UK has supported this emphasis on design concluding that almost half of the 100 accidents studied in a Loughborough project for the Health and Safety Executive (HSE) demonstrated causal links to the permanent works design phase (Haslam et al, 2003). This number is increased if the effect of action by temporary works and equipment designers is taken into account. A survey of 120 construction professionals by the Institution of Civil Engineers (ICE) (Whitelaw, 2004) found that 87% agreed that designers could do more to design-out health and safety risks during construction and also emphasized that more input from the contractor makes designs safer to construct. However, there are strong views that challenge the extrapolation of these findings to blaming designers for construction site accidents, with 62% disagreeing with the statement that 'most accidents are down to poor design'. This paper argues that the most effective solution seems to be close collaboration between design and construction teams.

Countries that have developed legislation on designers' duties, which are mainly in Europe, have understandably been more active in this area. Nevertheless, the topic has been raised elsewhere, for example through the US Construction Industry Institute's work (Hinze and Gambatese, 1996). The Life-Cycle Safety (LCS) initiative in Oregon has also demonstrated that effective design intervention is feasible and beneficial, even where the legislation does not require it and custom, practice and even some legal opinion is against it (Gibbons et al, 2003).

The argument is that, the earlier in the design phase that action is taken to eliminate or reduce construction risk, the greater the benefit and the higher the chance of the benefit being realized (Figure 1 – Weinstein et al, 2004). It is also argued that such action, taken early in the design phase, will have less, if any, detrimental effect on the out-turn cost of the project.

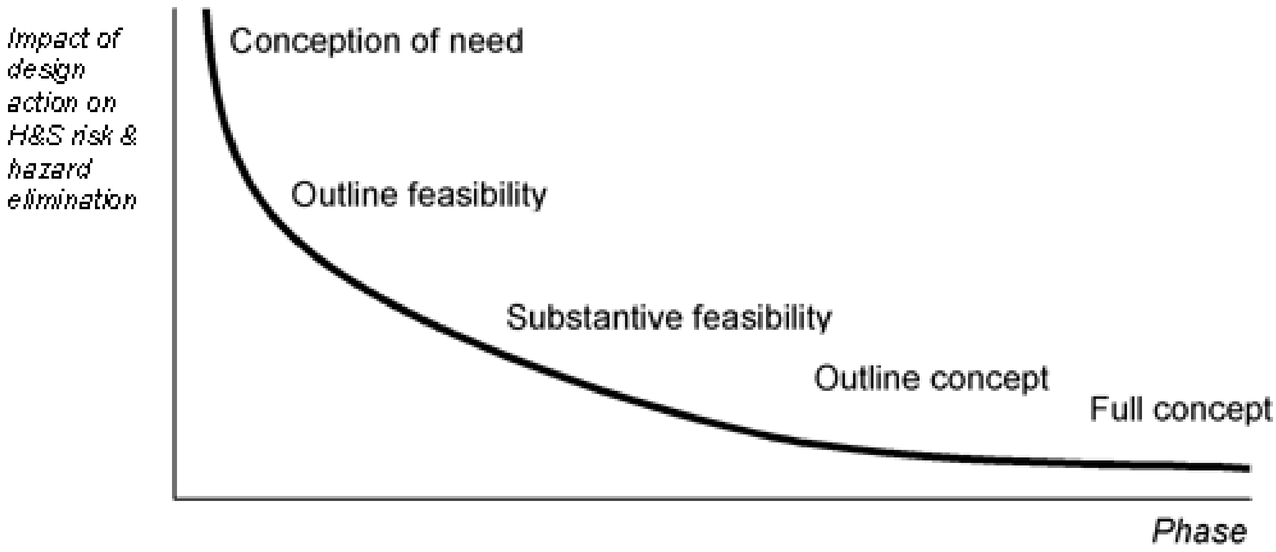


Figure 1 Impact of design action on health and safety risk and hazard elimination
Adapted from Szymberski in Gambatese (2003)

However, almost all the concentration so far has been on safety, to the exclusion of occupational health, except for issues surrounding hazardous substances. The case for more emphasis on Occupational Health has been made elsewhere (Smallwood et al., 2000; Gibb et al., 1999 & 2002). More recently the emphasis, at least within the UK, has been increasing with a series of high profile awareness campaigns. In the UK construction sector, between 2001 and 2002, 79 people died and there were 3959 serious accidents. However, in addition to this a staggering 137 000 people in UK construction suffered from an illness they believed was caused or made worse by their jobs (Bray, 2003) and this illustrates the extent of the occupational health challenge for construction.

D^4h has confirmed the paucity of good design practice in this area (Horne et al 2003). A D^4h survey of designers found that CDM had brought about little or no change to their design practices. This lack of impact is emphasized by a recent survey by the UK's Health and Safety Executive (Anon, 2003) where they found that only a third of designers were found to have sufficient knowledge of the designers duties under the Regulations (TMCS Directive – CDM in the UK). Furthermore, only 8% had received any training on the Regulations. When this sad state of affairs is combined with the poor regard for health compared to safety, the situation is desperate. The importance of designing-out risk still has to be emphasized, despite the Regulations being more than ten years old. A Health and Safety Commission paper (Smith, 2003) has had to make the point that 'hazards are introduced at the earliest stages in a project's life through the processes of procurement and design. Hazards can often be eliminated and risks reduced through the design process, especially during the 'first steps'.

These facts have created a real challenge for the D^4h team and their published response to the question: 'What are designers doing for construction workers' health?' was 'Not a lot!' (Anon, 2002). The challenge has been to produce practical guidance incorporating best practice exemplars when there have been so very few.

However, it has been determined that the supply-chain as a whole has been innovating to reduce both health and safety risk. Furthermore, they have been doing this in the 'design stage' in it's fullest sense, in other words 'prior to' the construction work commencing. However, these initiatives have rarely been driven by the main client's design team and may even have been employed without their knowledge. There is still the culture in many organizations in Europe, despite the TMCS Directive, to say 'Let's leave that up to the contractor'. This situation is further exacerbated by the narrow interpretation of 'design', at least in the UK construction sector. Design, viewed holistically by non-construction experts such as ergonomists and human factors personnel, includes all aspects of the work up to the actual execution of the task. In other words, they would see design encompassing work-site layout and even task design. However, in the built environment, design is typically viewed as only the domain of the client's architect or engineer and any pre-construction input by other stakeholders tends to be relegated to 'tinkering around the edges of design'. Notwithstanding the above, the supply chain has identified and developed a number of innovative techniques to reduce the occupational health risk of construction workers and some of these are presented in this paper, concentrating on piling operations. Some of these exemplars have been developed from work by the authors on a related Loughborough project called Better, Safer, Easier Design via CDM for the UK HSE via consultant Greenstreet Berman.

D^4h guidance for designing-out health risks

D^4h provides guidance for designers at both concept and detailed design stage. Concept guidance is strategic in nature and advises the development of a project-wide strategy with 'buy-in' from all stake-holders. One of the key implications from this is the major benefits from obtaining early expert advice as many of the innovations have been developed by the supply-chain, as explained earlier. The detailed design stage advice provides a break-down of construction projects into generic elements such as substructure, superstructure, cladding, and related activities. The health hazards for the activities are identified and designer actions to reduce or remove the risk proposed. Wherever possible, cases are cited showing where and how risks have been reduced by effective designer action. To illustrate this aspect of the D^4h tool, this paper presents some innovations in insitu piling techniques and discusses their effect on the occupational health of construction workers.

Piling operations and health hazards

Figure 2 shows the seven main steps in the sequence of an insitu bored pile, used either singly or in rows as a contiguous or secant pile wall:

1 Auger fitted with appropriate head;

2 Auger drilled into ground to required depth;

3 Concrete poured down hollow core of auger whilst auger is removed;

4 Steel reinforcement cage pushed into wet concrete;

5 Wet concrete overspill at ground level;

6 Ground level reduced and top section of pile 'broken down' to desired level, and

7 Pile cap or capping beam constructed.

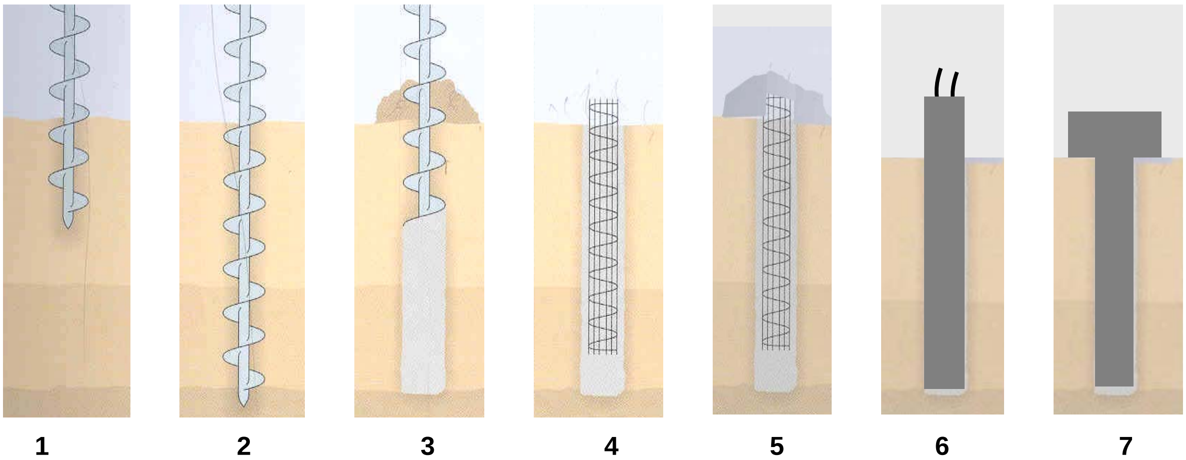


Figure 2 Main steps in traditional bored pile installation

Most student text books only include steps 1 to 4 and ignore steps 5 and 6, assuming that the work naturally and seamlessly leads to the completed pile and pile cap in Step 7. As an aside, this poses another real challenge, this time for the educationalists, to ensure that their lectures are realistic and are not compounding designers' invalid assumptions that a clean straight line drawn on the CAD system is simply produced on site as a clean straight line.

There are many health and safety hazards during pile operations – the main health hazards for each step are as follows:

1 Manual handling aspects to changing auger heads;

2 Contaminated land hazards;

3 Dermatitis and other cement-related hazards;

4 Manual handling and injury risks in placing rebar cage along with cement-related hazards;

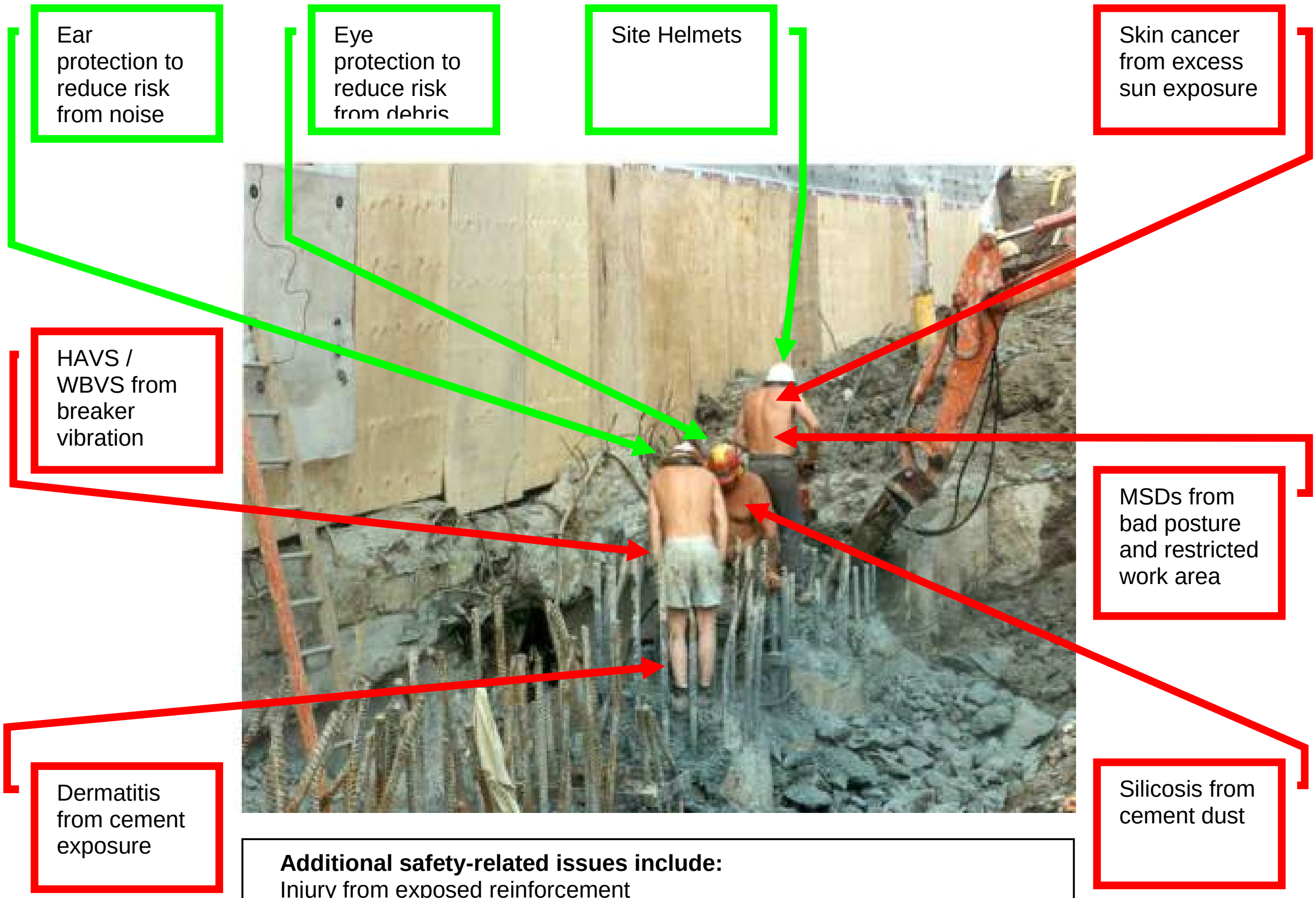
5 Cement related and manual handling hazards such as excess concrete typically removed by hand;

6 Major hand-arm and whole body vibration syndrome hazards (HAVS / WBVS), noise, dust and other manual handling hazards, and

7 Insitu concrete hazards - many and various.

Most of these hazards are prevalent in many construction operations and as such are not remarkable to those experienced in construction – more worryingly they are frequently just accepted as the norm. Furthermore, there are additional non task-related risks that should not be under-estimated, which ancillary risks have been identified by Loughborough's HSE ConCA research as one of the major causes in construction accidents (Haslam *et al*., 2003).

The D^{4}h research identified step 6, breaking down of the pile-top, as the most hazardous operation in terms of occupational health. Figure 3, extracted from the D^{4}h CD, illustrates this with a real-life photograph, mainly showing poor practice, but clearly demonstrating the key issues.



Additional safety-related issues include:
Injury from exposed reinforcement
Unsecured ladder
Struck by machine
Falls / trips on debris
PPE – eg boots, overalls, hi-visibility vests
Undermining timber hoarding

Figure 3 Health risks from pile top breakdown – extracted from D4h

The significance of this operation is emphasized by acknowledging that, under current UK legislation, the use of impulsive action tools such as hand-held pneumatic breakers for more than thirty minutes daily is likely to expose the operative to levels in excess of the prescribed limits. What this means is that, effectively, hand-held breaking of pile-tops is virtually impossible to achieve whilst complying with current legislation (Charlton Smith, 2003).

HAVS is an issue that has traditionally only been addressed at site level and there have been a number of recent developments to produce better tools and equipment to reduce the vibration exposure (Edwards and Holt, 2007). Nevertheless, the risk remains for many civil engineering operations (Lamont, 2003) and this paper concentrates on the elimination of the risk by effective action during the design and pre-construction phases.

Alternatives to conventional insitu-bored piles

D^4h helps designers to develop a strategy to remove or reduce occupational health hazards for construction workers. One of the sections of the CD suggests alternatives to the traditional approach for each element.

Figure 4 Precast concrete piles *(Courtesy Roger Bullivant)*

Offsite production

The alternatives to traditional insitu bored piles include pre-assembled piles, either concrete or steel and either driven or vibrated into place (Figure 4). There are also a number of screwed pile systems.

Pre-assembly, or offsite production is one of the often quoted 'solutions' to reduce health and safety risks on site, and at the same time increase productivity and improve quality. Another Loughborough project, HASPREST has found that manufacturing in the UK is around six times safer than traditional insitu construction in terms of fatalities and major accidents. This occurs in a number of ways, partly by removing some of the hazards such as manual handling, but more usually, moving the hazards from the site into the factory environment where they are easier to control - cement exposure constitutes an example. In addition, as mentioned earlier, the off-task hazards are reduced as the number of people working on site is reduced through the increased use of off-site production. However, along with the obvious benefits there are also challenges – some of the risks remain, and their consequences can be more severe although the likelihood of them occurring is reduced.

An example of this rationale is the comparison of insitu brick and blockwork with brick-faced precast concrete cladding. Insitu brickwork has many hazards with a high incidence rate although a relatively low consequence, whereas a precast concrete panel, if dropped from the crane is likely to have very serious consequences although the likelihood is greatly reduced.

Furthermore, there are obviously additional 'new' hazards with driven or vibrated piles such as noise and vibration, although the screwed pile option, which is mainly suitable for relatively low load situations, does not generate significant levels of noise or vibration.

These options only remove the HAVS risk if the system is designed such that pile-top break-down is avoided. This necessitates a pile-pile cap connection detail that can cater for the variation in pile-top level achieved on site.

Cementation sacrificial guide wall

Contiguous piled walls used in basement construction where a more accurate alignment is required need a temporary, sacrificial concrete guide wall to be cast in advance of the piling operations and through which the piling auger passes. This acts as a control for the piles final cast position and is eventually replaced by the permanent capping beam later in the construction process.

In order to prevent the abortive work of the early guide wall, which in the final permanent state is usually replaced by a concrete capping beam of similar dimensional proportions, a system has been developed that combines the temporary guide wall and permanent capping beam. The combined system utilizes precast concrete guide blocks placed into position and retained in that position by non-structural concrete around the outside of the blocks.

Circular voids in the blocks allow the piling auger to pass through and the position of the pile to be predetermined and achieved. Adjacent voids are protected with circular 'lids', made from plywood, to prevent them being filled with concrete or piling arisings. Figure 5 shows the guide blocks being placed along the line of the wall, the auger drilling 'through' the precast guides and the blocks removed after the piling operation illustrating that the pile is poured up to cut-off level, thus avoiding the need for pile-top break down. Step 3 also shows the mould left by the blocks acting as the kicker for formwork for the capping beam, eliminating this additional site operation. This solution, by Cementation Foundations Skanska, was prompted by a desire to reduce on site labour time and material use for the preparation of the capping beam. Cementation have now developed options for incorporating the precast guide blocks into the permanent capping beam, further reducing the on-site works needed.

Figure 5 – Cementation sacrificial guide wall *(courtesy Cementation)*

Table 1 shows the risk evaluation carried out on this technique as part of the HSE-funded 'Better, Safer, Easier Design' project by Loughborough for consultant Greenstreet Berman (Wright et al, 2003).

Main operations affected	H&S risk removed or reduced
Setting out	Less working in a muddy uneven trenches - therefore reduced slip and trip risk
Pile drilling	Reduced cement-related risks (eg dermatitis) – as less concrete work on site
Breaking the pile down	Avoids vibration and noise hazards by removing the need to break down the pile-tops and thus avoids associated vibration related disorders such as Vibration White Finger (VWF)
	Avoids manual hazards associated with shovelling waste concrete
	Avoids moving vehicle hazards posed by waste removal
Formwork for capping beam	Avoids the use of power tools (eg electric saws) - therefore reduced power related accidents
	Reduced working in a muddy uneven trenches - therefore reduced slip and trip risk

Table 1 Risk evaluation for precast concrete sacrificial guide wall

Removal of pile-top

As mentioned earlier, the breaking down of the pile-top poses a particular risk to the occupational health of those involved in the operation (Figure 3), and also to others in the vicinity, due mainly to the noise hazard. The previous two methods can avoid the need to 'over-pour' the pile in the first place, but there are situations where over-pouring is still required. A number of techniques exist to eliminate the HAVS risk by removing the need for hand-held breaking of pile-tops. Three such methods are summarized here:

1. Elliott crack propagation method;
2. Recepieux chemical crack propagation method, and
3. Taets mechanical break method.

Elliott crack propagation method (http://www.elliott-europe.com)

This technique involves the removal of the unwanted pile section in one piece, exploiting the physics of crack propagation. Steel reinforcement above the final cut-off level is prevented from bonding with the concrete by fixing isolating sleeves to the bars before the cages are lowered into position (Figure 6).

When the pile is finally exposed, a 51mm diameter hole is drilled horizontally into the concrete at cut-off level to just beyond the centre of the pile. A standard hydraulic splitter is inserted and activated and, after around 30 seconds, the concrete cracks across the desired level. Then an excavator is used to lift off the surplus in a single piece via a lifting eye cast into the top surface.

Elliott claims that the operation cuts the hand-arm vibration risk by more than 90%. It will work on pile diameters from 300mm to 3m and typically takes around 10 minutes (Anon, 2000).

Figure 6 – Elliot method (*Source http://www.geopages.co.uk/news/pr020.html)*

Recepieux chemical pile breaking method (http://www.recepieux.com)

Similar to the Elliott method, Recepieux's technique involves the removal of the unwanted pile section in one piece, again exploiting the principle of crack propagation. However, in this case the crack is induced using an expanding grout. The steps are illustrated in Figure 7 as follows:

1 Foam sleeves are fixed over the reinforcement over the length to be removed;

2 A series of PVC tubes and cones is assembled;

3 The tube and cone assembly is pushed into the wet concrete;

4 The tube assembly is checked for level and funnels fixed to the top of the tubes;

5 The temperature of the pile concrete is measured;

6 The expanding grout is mixed and batched into individual containers;

7 The grout is poured into the tubes via the funnels;

8 The grout expands in the cones set at 'cut-off' level propagating a horizontal crack through the pile, and

9 The top, unwanted section of the pile is removed using a crane.

Recepieux have now amended their method by pre-filling the cones with grout and fixing them to the steel reinforcement cage prior to its insertion into the wet concrete. The heat generated by the curing concrete activates the grout which expands, propagating the crack. This avoids the need for inserting the tube and cone arrangement in the wet concrete.

Taets Hydraulic Pile Breaker (http://www.taets.nl/#B)

The Taets system from the Netherlands (Figure 8) replaces hand-held pneumatic breaking with a large scale hydraulic breaker. The breaker is suspended from an excavator and makes a horizontal fracture in the pile at cut-off level. Each hydraulic cylinder drives a chisel into the concrete producing a horizontal fracture as the breaking force built up this way always seeks the shortest way through the concrete. This stage takes about 25 seconds. The steel chisels do not have to penetrate beyond the reinforcement bars. After the fracture is made, the chisels penetrate further into the concrete, usually 25-40 mm.

Due to the shape of the chisel, in combination with the reaction forces on the concrete by the steel reinforcement, the concrete breaks into pieces and can removed without the need for further breaking. This approach can also be used for precast concrete piles.

Similar equipment is available from other manufacturers, for example Mantovanibenne from Italy.

Figure 7 - Recepieux chemical pile breaking method (http://www.recepieux.com)

Figure 8 Taets Hydraulic Pile Breaker

Health-related comparison of pile alternatives

Expert evidence was used to compare the pile innovations described above in terms of their effect on the health hazards related to pile-top removal (Table 2). In all cases the health hazards seem to have been significantly reduced compared to traditional hand-held pneumatic breaker methods (Figure 3), however, some residual hazards remain. There are other health benefits and implications to the remaining piling tasks, but they are outside the scope of this paper.

Additional benefits

The initial drivers for these piling innovations were not improved health and safety of construction workers. Rather, the methods were prompted, in the main, by a desire to increase construction speed and reduce overall costs.

There are also other benefits, for example, the methods where the unwanted pile-top is removed in one piece facilitates crushing and subsequent re-use of the concrete as hardcore fill, thus reducing the environmental impact. Typically, traditional pile-top break downs are 'contaminated' by other material and cannot be re-used – they often end up in land-fill. Furthermore, the methods that avoid the need to over-pour the piles in the first place, obviously lead to additional environmental benefits, by using less material and reducing waste.

Designer's abilities, knowledge and role

A common defence for designers against the challenge to design-out health and safety risks includes the argument that they are not able to effectively determine the actual hazards involved in construction operations as they do not have the knowledge. In a survey for the Institution of Civil Engineers (Anon, 2004), 79% of respondents indicated a need for more information to assist designers to design for safety.

Table 2 Health benefits and implications during pile-top removal using alternative piling methods

Method	*Health hazards reduced / removed*	*Residual health hazards*
Cementation sacrificial guide wall	The need for over-pouring of the concrete pile is removed as the pile is poured to the correct cut-off level, protected from contamination of the surrounding ground by the precast guide wall. *Note that this method has been developed for contiguous piling rather than individual pile construction*	Additional operations involve the placement of the precast guide wall units which may involve some MSD hazards.
Elliot crack method	'Manual' removal of pile-top is avoided by the crack splitter resulting in a large concrete section removed by crane	One 51mm hole is drilled into the pile with some associated vibration hazards (approx 5 minutes task time). Some MSD hazards may remain in the manoeuvring of the pile-top section.
Recepieux chemical method	'Manual' removal of pile-top is avoided by the chemical technique resulting in a large concrete section removed by crane	COSHH issues with the grout and increased work required to the wet concrete during pile construction[2]. Some MSD hazards may remain in the manoeuvring of the pile-top section.
Taets hydraulic breaker	'Manual' removal of pile-top is replaced by a crane-handled hydraulic machine.	Some MSD hazards may remain in the manoeuvring of the hydraulic breaker and in the ultimate removal of the broken concrete.

Furthermore, some claim that they are not aware of the construction options available, and even if they were, they would not be able to specify means and methods to competent contractors.

[2] The COSHH risks have been significantly reduced by the replacement of the tube and cone installation into the wet concrete

The authors conducted a survey in collaboration with the Association of Project Safety to test these suppositions. The survey was conducted at a series of regional workshops, with attendees from various design and project management disciplines. Table 3 provides a breakdown of the primary and secondary job functions declared by the attendees. This was a convenient sample, which nevertheless provides a useful spread of the main pre-construction functions, namely engineer, architect; quantity surveyor[3], and CDM coordinator[4]. The secondary function demonstrates that many CDM coordinators are actually primarily designers and fulfil the coordination role as a secondary function.

Region	Primary job function					Secondary job function					Total
	Engineer	Architect	Planning Supervisor	Quantity Surveyor	Other	Engineer	Architect	Planning Supervisor	Quantity Surveyor	Other	
N Scotland	3	8	3	2	2	1	1	15	0	1	18
N England	5	5	6	3	4	1	2	16	0	4	23
London	5	12	17	1	9	1	1	28	0	14	44
SE England	8	2	15	3	12	2	3	24	0	11	40
N Ireland	2	5	6	3	3	5	0	11	0	3	19
SW England	5	2	16	3	8	6	2	18	0	8	34
Wales	6	7	3	7	0	0	0	19	0	4	23
SC England	0	5	18	0	4	5	2	13	0	7	27
E Anglia	3	1	8	1	11	2	0	15	0	7	24
Midlands	3	0	11	4	6	7	2	11	0	4	24
E Midlands	3	8	13	0	3	3	3	14	0	7	27
W Scotland	7	13	5	4	1	0	3	19	0	8	30
E Scotland	11	15	7	7	3	2	5	26	0	10	43
Yorkshire	6	11	9	0	10	1	2	21	0	12	36
NW England	4	11	7	3	8	2	0	21	0	10	33
Totals	**71**	**105**	**144**	**41**	**84**	**38**	**26**	**271**	**0**	**109**	**445**

[3] Quantity Surveyors are typically responsible for the financial management of the construction project.
[4] At the time of this study the UK Construction (Design and management) Regulations 2001 were in force. Under CDM 2001, the Planning Supervisor was the person or organisation identified as having responsibilities for coordinating the design for health and safety, including action to eliminate or remove risk to construction workers – In CDM2007, a similar role is played by the CDM coordinator.

Table 3 Job functions of workshop attendees

The attendees were provided with a description of the piling tasks as reflected in Figure 2 and the related text. They were asked to rate a number of health hazards for each task (H=High; M=Medium; L=Low) as though they were assessing the risks. The hazards provided for consideration were musculoskeletal disorders (MSDs); hand-arm vibration (HAVS); dust; noise and skin disorders. There had been no prior discussion regarding bored pile operations or associated health and safety issues. These ratings were allocated numerical values (H=9; M=4; L=1) and the aggregated results for all the workshops are shown in Table 4 and Figure 9. By observation, the data in Table 4 were categorized into High, Medium and Low (H_{ave}= >7.0; M_{ave}=3.0-6.9; L_{ave}= <3.0) and these have been colour-coded in Table 4 (High = yellow / red; Medium = blue / black; Low = white / black).

Task / Hazard	MSDs	HAVS	Dust	Noise	Skin disorders
Auger fitted with appropriate head .	**4.8**	**2.6**	**2.4**	**4.6**	**1.8**
Auger drilled into ground to required depth	**2.5**	**3.5**	**3.5**	**6.4**	**1.6**
Concrete poured down hollow core of auger whilst auger is removed	**3.8**	**3.4**	**2.4**	**4.8**	**6.6**
Steel reinforcement cage pushed into wet concrete	**6.3**	**3.2**	**1.5**	**3.0**	**6.2**
Wet concrete overspill at ground level removed	**3.6**	**2.0**	**1.7**	**1.9**	**7.6**
Ground level reduced and top of pile 'broken down' to cut-off	**6.3**	**8.3**	**7.5**	**8.4**	**3.4**
Pile cap or capping beam constructed.	**4.4**	**3.9**	**2.5**	**4.3**	**5.2**
Overall pile activity .	**4.53**	**3.84**	**3.07**	**4.77**	**4.63**

Table 4 - Aggregated ratings of health hazards for bored pile tasks

Whilst these allocations are somewhat arbitrary they do illustrate that the attendees identified the following hazards as being more significant than the others:

- Skin disorders from wet concrete overspill at ground level cleared away, and
- HAVS, dust and noise from ground level reduced and top of pile broken down to cut-off level.

Due to the arbitrary nature of the numerical values allocated, a check calculation was completed with H=10; M=6; L=3 and the results were broadly the same, in that the same main hazards were identified. This data also supports the previously stated assumption that pile-top break down is a major concern with respect to occupational health. There were no significant differences in ratings given by those from different primary or secondary job functions, which indicates that intelligent, concerned professionals can assess risk effectively provided the tasks are explained to them, even when the tasks fall outside of their domain knowledge. There were also no significant regional variations in ratings.

Attendees were then asked for their knowledge and experience of the following bored pile innovations:

- Precast concrete sacrificial guide wall (Cementation-Skanska);
- Hydraulic pile splitter (Elliott);
- Chemical pile break (Recepieux), and
- Crane-handled hydraulic break (Taets).

The results presented in Table 5 and Figure 10 demonstrate that the majority of the designers had not even heard of these innovations. Only a very small number knew them well or had actual experience of their use. Now, these figures must be interpreted in the light of the attendee sample, with a high number of architects rather than engineers. Nevertheless, it does suggest that, despite the significant benefits, both for health and safety as well as for other typical project measures such as time, cost, environment, the message is clearly not currently reaching those who are best placed to influence their adoption.

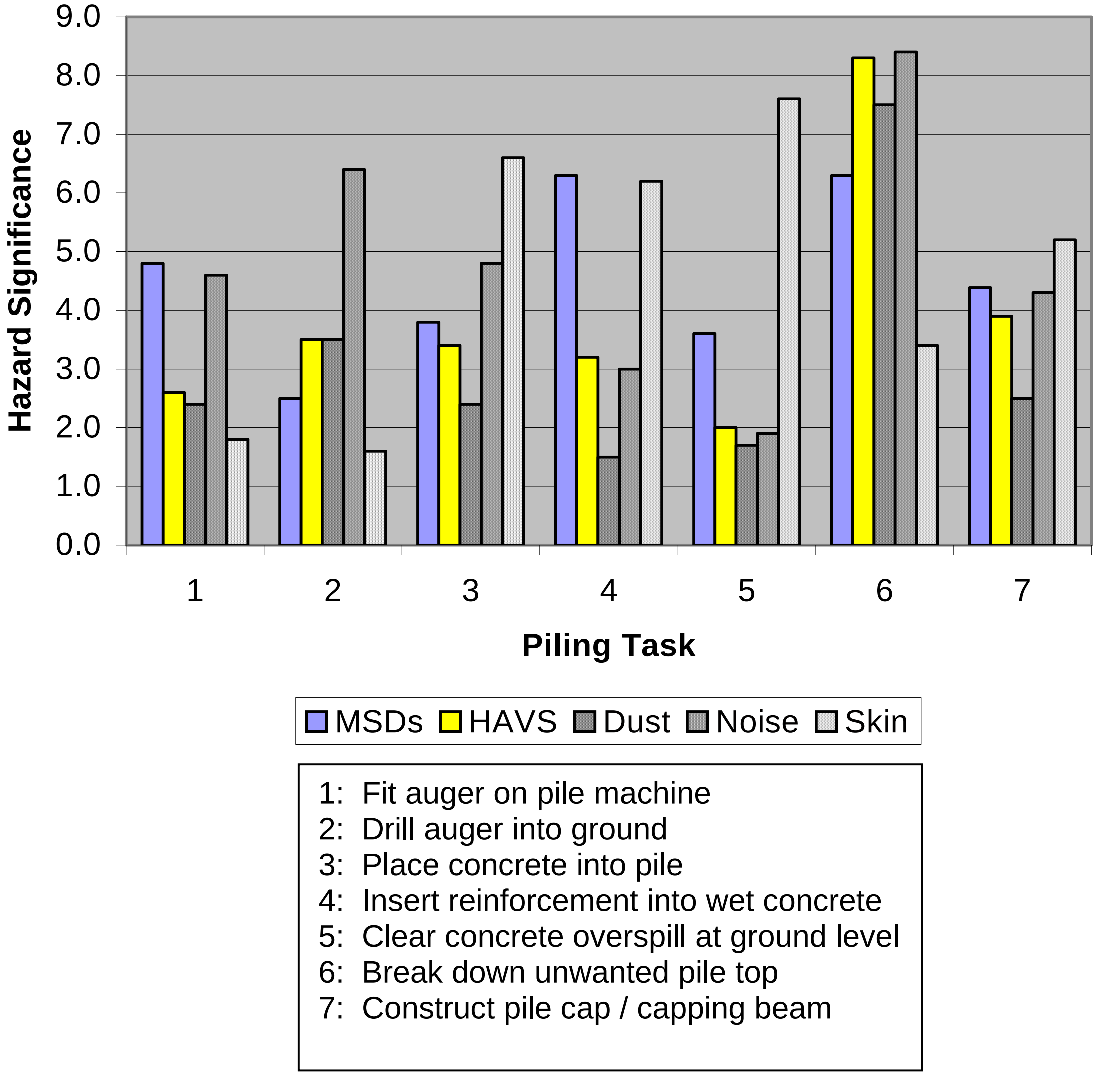
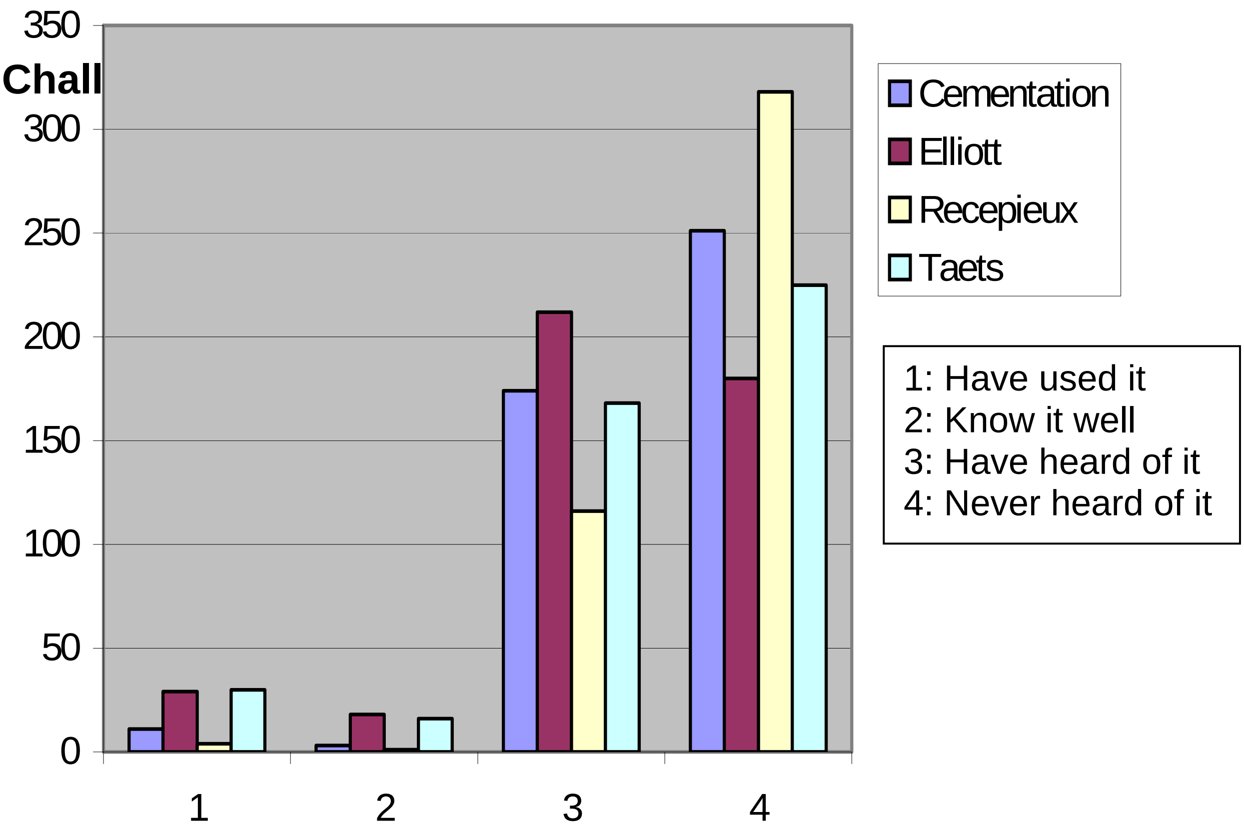


Figure 10 – Hazard significance from piling tasks

	Have used it (%)	Know it well (%)	Have heard of it (%)	Never heard of it (%)
Sacrificial guide wall - Cementation-Skanska	2.5	0.7	39.6	57.2
Hydraulic pile splitter - Elliott	6.6	4.1	48.3	41.0
Chemical pile break - Recepieux	0.9	0.2	26.4	72.4
Crane-handled hydraulic break - Taets	6.8	3.6	38.3	51.3

Table 5 Knowledge of bored pile innovations



Challenges for designers

The innovations described in this paper are typical of those identified in D⁴h and have been initiated and developed by the supply-chain rather than by the client's design team. The challenges for such design teams include:

- Ensuring that they are aware of the innovations - some of the innovations in this paper have been available for several years, but have still not been universally accepted, and many designers are not even aware that they exist;
- Ensuring that the project team has mechanisms in place to access appropriate construction expertise at an early stage in the project design process. However, this will have implications for project procurement routes;
- Ensuring that their designs do not preclude the use of such innovations - specifications can inadvertently prevent non-typical alternatives being adopted;
- Being proactive in the encouragement of such design innovations:
  - designers should not sit back and wait for others to do the work – they must get involved;
  - this does not mean that designers need to be drawn in to 'specifying' means and methods, and
  - designers can identify pile-top break down as a major residual risk in their design-phase health and safety assessment, thus requiring the Principal Contractor to provide proposals to address this risk – this may be the only push needed to get the industry to eliminate the major HAVS problem from insitu bored piles.

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