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Safer foundations by design

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Safer foundations by design

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In the light of evidence that designers, through lack of information and training, are still failing to exploit the potential they have to eliminate and reduce risks on site, BRE was commissioned to provide simple guidance for designers of groundworks and give feedback to HSE. Through an understanding of foundation design and the hazards that arise from different foundation construction processes, this project has provided methods by which designers can take account of hazards in design. Specifically this project has also provided drafts of TGN notes for designers so that they can make management of the risks arising from various ground engineering processes easier.

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Executive Summary

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Through an understanding of foundation design and the hazards that arise from different foundation construction processes, this project aims to provide methods by which designers can take account of hazards in design. Specifically this project will provide TGN notes for designers so that they can make management of the risks arising from various ground engineering processes easier.

This report is the final report for the project, giving a brief assessment of the project, in the context of geotechnical design, and text for the guidance documents. The project has progressed satisfactorily and produced a suite of geotechnical TGN’s and GN's.

The final drafts were approved at a meeting with the Project Officer, Hash Maitra, on the 13th December 2004.

Introduction

The Construction Industry gives rise to a disproportionately high number of deaths and serious injuries. Some risks arise from traditional forms of construction and project management, others may be due to new design and construction techniques. The demand for new construction, both in buildings and infrastructure, is growing.

Although CDM is 10 years old, and despite time, effort and money there is evidence that the designer aspects are still not working well; the latest research shows that designers are still failing to exploit the potential they have to eliminate and reduce risks on site.

HSE interventions with designers show that designers are often uncertain of their responsibilities and lack both information and training.

CDM places certain specific duties directly on designers:

- to eliminate hazards where feasible;
- to reduce risks from those hazards that cannot be eliminated;
- to provide information on residual risks if they are significant.

Through an understanding of whether CDM has had an impact on foundation design and the hazards that arise from different foundation construction processes, this project aims to provide methods by which designers can take account of hazards in design. Specifically this project has provided TGN notes for designers so that they can make management of the risks arising from various ground engineering processes easier.

The project tasks were as follows.

1. Draft TGN's

The scope and purpose of the guidance notes (TGN's) for designers, was discussed and the groundworks areas to be covered at a first meeting with the Technical Officer, Hash Maitra. A number of HSE drafts were made available in confidence to BRE ahead of their release. Some common themes already covered were to be referred to in the new notes.

The simple guidance was intended for use by small and medium sized consultancies, who may not have wide experience in any one area. It was emphasised that language should be accessible, and concepts simple. The use of rules of thumb will be considered carefully and used with suitable caveats where it is judged they would be useful.

A total of 6 draft guidance notes were produced, subjected to peer review and agreed with the HSE project officer; the content of these is reported in Appendix 1.

2. Approaches to contractors

Contractors views are to be sought in each area of technical interest in order to ensure that the TGN's covered all relevant hazards and to identify examples of good practice. The records of Health and Safety returns made to ASUC*plus*, an Association of medium and small contractors in piling, mini-piling and underpinning were made available for study by BRE and a number of key hazards identified. Further information on hazards during piling operations was supplied by members of the Federation of Piling Specialists (FPS).

3. Final report

The next section gives a short report of the project in the context of geotechnical design for safe construction.

Project Report

1.1 Introduction

The Construction Industry gives rise to a disproportionately high number of deaths and serious injuries. Some risks arise from traditional forms of construction and project management, others may be due to new design and construction techniques. The demand for new construction, both in buildings and infrastructure, is growing.

Although CDM is 10 years old, and despite time, effort and money there is evidence that the designer aspects are still not working well; the latest research shows that designers are still failing to exploit the potential they have to eliminate and reduce risks on site.

This project has provided some simple guidance on designer input to safe construction in a number of areas from SI to foundation construction. This short report is intended to draw these together.

There is little data on the rates of accidents in the ground engineering sector. However, studies by the French FNTP in 2001[1] indicated that within the French construction industry, accidents were both more prevalent and more severe in the ground engineering sector than in construction as a whole (these statistics may or may not include tunnelling).

Table 1 : Statistical health and safety information in French construction industry in 2001 with reference to the Geotechnical sector

Ratio		1991	2001	Comments
Frequency Index	Construction	72	57.6	Regular decrease between 1991 and 2001 (-20%)
(no of accidents x 1000000/working hours)	**Geotechnical works**		**64.6**	**12% higher than average**
Severity Index	Construction	3.19	2.95	Regular decrease between 1991 and 2001 (-8%)
(no of days lost x 1000/working hours)	**Geotechnical works**		**4.33**	**47% higher than average**
Number of Occupational diseases	Construction	1193	2959	Number x 2.5 between 1991 and 2001

Clearly a large number of accidents result from factors outside the control of the designer. For example some plant is specifically covered by European or British Standards[2] and many safety aspects are the responsibility of the contractor. However, some accidents that result from, for example, scope and processes involved in the works, access or working conditions could be influenced by the designer. Against this background, this report focuses on how geotechnical

[1] *Statistiques accidents du travail et maladies dans les Travaux Publics, FNTP, 2001*

[2] *EN791 Drilling rigs, EN 996 Piling rigs - bored and CFA, BS 7121 Code of practice: safe use of cranes*

design is carried out and how increased awareness of safety issues by designers may result in a reduction of risks to the construction workforce.

1.2 Hazards to geotechnical construction workers

Whilst each geotechnical construction process will entail specific hazards, some generic hazards common to many processes can be listed:

- Exposure to dangerous substances, noise or vibration - fluids used by processes and those in the ground as contaminants or services
- Manual handling
- Interactions with heavy plant - this may be in circulation around the site or in the process itself, may be struck by or trapped by the machinery
- Poor access to or organisation of the workplace - working in confined spaces or in poor conditions underfoot
- Workplace stability - excavations or near temporarily unstable structures or machinery
- Falls from height - whether into excavations or working in excavations
- Falling objects or debris

Whilst it may not be immediately obvious that a designer can influence these areas, the table below shows some ways in which they can do just that.

Table 2: Examples of designer-led opportunities for improved safety

Hazards	Designer opportunity
Exposure to dangerous substances, noise or vibration	Ensure SI provides good assessment of service locations and contamination and pass the information on. Design to eliminate manual pile cut-offs where possible.
Poor access to the workplace	Design adequate working platform for access by plant and workers, ensure SI is designed to give ground parameters and understand drainage at shallow depth.
Workplace stability	Design takes stability of neighbouring buildings into account, ensure excavations are stable in temporary condition or parameters are known such that adequate temporary shoring can be designed.

1.3 The geotechnical design process

This report does not attempt to cover in detail the geotechnical design and construction process. However, key elements of the process can contribute to a greater awareness of safety during design. These areas have been gleaned from discussions with both designers and contractors.

The planning, environmental and structural requirements are interlinked with the geotechnical ones on any site and indeed when environmental considerations are required, increased dialogue between the various parties responsible for a construction may ensue that can have great benefit.

The design process should form an iteration with site investigation, structural requirements and construction processes providing information. In practice this is relatively rare and often contracts are parcelled up such that demolition, site investigation, design and construction are carried out with limited or no continuity of personnel. At each stage detailed below some 'design input' is required, although it may well be from different designers.

Site investigations

The scope and detail of a ground investigation should be specified by a geotechnical engineer based on a knowledge of the site history and geology (desk study) and some form of walkover survey. This must also take into consideration the likely structural requirements for the construction.

The site investigation designer can refer to a myriad of technical guidance as well as British Standards to determine best practice. The latest guidance refers to the site investigation as a means of identifying geotechnical hazards and forming a conceptual model of the site. The identification and minimisation of geotechnical risk should follow from a good SI. In this context geotechnical hazards and risk are defined in terms of risk to the project (delays) or final construction. Best practice in site investigation is limited by the budget available. Often less than 0.1% of the construction budget is spent on SI, leaving significant geotechnical uncertainty to be dealt with by both designer and contractor.

None of the sources of best practice guidance expresses how SI might be carried out with safety in the construction process in mind. SI could be specified such that information is retrieved that will be required for increases in safety in the design and during construction. On many projects this would require an increase in the quantity, and potentially also quality, of SI information retrieved and may be best procured in a staged manner. After a preliminary SI and outline design, a more detailed SI could cover information required to ensure safe construction both in relation to the design and the likely construction processes.

Design and Specification

Design and specification are in general carried out with an understanding of the processes involved in construction. However, it is not clear that this knowledge always translates into designs that are optimised for safe construction as well as economy. The geotechnical contracting sector is also highly innovative and so may be difficult to obtain and maintain a detailed knowledge of changing processes.

There is little guidance on the optimisation of design for safe construction in geotechnics. Where a partnering arrangement operates, or a contractor is on board early in the project, useful dialogue between designer and contractor can result that improves both economy and safety.

Construction

Many projects, particularly smaller contracts, no longer have 'design supervision' in the form of a Resident Engineer. It will be critical that, where this is absent, or present but through an inexperienced engineer, the design philosophy is understood by those in control of the construction process. This will be particularly important where variations to the planned design or processes are undertaken.

1.4 How to design with safety in mind

A simple flowchart can be used to illustrate the process. Designer input into safe construction can be described by:

- Designing for ease of construction and to minimise hazardous situations
- Where possible, providing sufficient information that plant and processes can be used and carried out in a stable environment
- Ensuring that the assumptions made in the design are clear

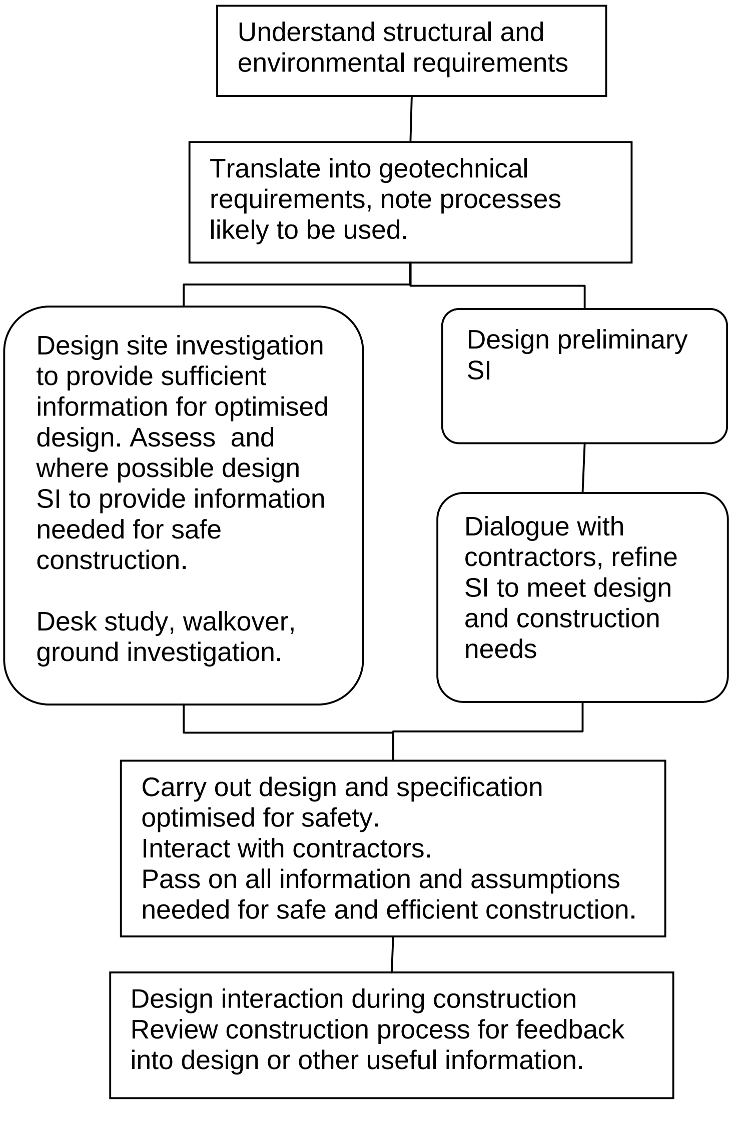

Figure 1 Geotechnical design flowchart for safer construction

1.5 Examples of good and bad practice

a) At one site where the ground was very marshy, a critical geotextile membrane was relied upon to prevent the stone from a piling platform being displaced into the peat. To remove an obstruction the construction companies dug a trench in the piling platform, which damaged the critical geotextile membrane. The trench was then poorly backfilled. When a piling rig crossed the trench the ground settled under one side causing the rig to overturn and fell across the passenger and freight railway lines.

Possible improvement for safer design? Understanding of the critical nature of the geotextile to the design of the working platform should have been understood by all.

b) An automatic pile load testing schedule was specified by BRE on a long term research project. Over 30 tests have been conducted using a system that automatically controls the loading sequence and tests for the safe response of the pile and loading frame.

On one test the loading frame distorted more than was satisfactory and the test shut down automatically before structural failure of the load frame occurred; the system also provided data on the reason for the fail-safe tripping out. The load was automatically reduced and engineers were able to re-arrange the test such that it could resume safely.

An improved specification avoided the need for anyone to enter an area where large loads were being applied. This was made possible by communication with the piling/testing contractor.

c) When a detached house suffered severe subsidence the designer and specialist contractors followed an unusual construction sequence to ensure that the risk of instability of the building during underpinning was minimised.

The house walls were first stabilised by deep reinforced masonry beams, formed by reinforcing the existing brickwork. These provided structural stability but would allow some ductility of the brickwork as traditional underpinning was carried out. Final repairs to minor cracking of the brickwork was carried out after underpinning prior to redecoration.

The design of major structural repairs before any other construction was carried out ensured temporary stability was increased before underpinning works.

d) A contaminated site formerly used for a variety of industrial processes was remediated using cement stabilisation and solidification in order to construct a new school. A soil mixing machine, normally used in conventional cement stabilisation, was used to treat contaminated material in-situ not only by 'locking in' contamination but also by improving the engineering properties of the ground.

The designed remediation solution provided a safe working platform for the construction plant and also reduced the risk posed by contact with any contaminants during construction whilst reducing the costs associated with removal of material.

Appendix 1 – Guidance for designers

The project has developed basic guidance for designers in a number of areas of geotechnical design. Many areas of construction safety management cannot be addressed by designers. However, there are some cases where designers can aid the management of construction safety through design considerations or in the provision of information.

Designing site investigations to provide adequate information and assist in identifying hazards in the ground

INTRODUCTION

1. Designers of site investigations can play a major part in providing the information which could be used to make it easier to manage the hazards on a construction site.

2. There is a distinction between the more comprehensive term site investigation and the more narrowly defined term ground investigation.

a) Site investigation (SI) involves acquiring all relevant types of information, which could include historical, hydrological, meteorological and environmental conditions as well as the ground conditions.

b) Ground investigation (GI) describes the subsurface investigation which aims to identify geotechnical and geoenvironmental properties of the ground, including groundwater and any adverse ground conditions.

3. Ground-related hazards can present a risk to both construction work and to the completed project. Site investigation has usually focused on the latter risks and ground investigation has concentrated on determining the engineering parameters needed to produce a practical and economic design.

4. The health and safety of construction workers is directly linked to the methods by which the work is performed. This guidance aims to make designers aware of the importance of the site investigation addressing safety issues concerned with construction work. It gives information on how the design of the SI can help to make construction safer.

5. Certain risks are attached to working on sites during the SI, but issues concerned with safety during investigation work are not specifically covered in this guidance note (see references).

HAZARDS ASSOCIATED WITH CONSTRUCTION

6. The actual process of construction may impose more extreme conditions on the ground than does the completed structure. Thus excavations for foundations may require steep side slopes and contaminated ground may be excavated.

7. The construction process may expose site workers to particular risks from ground-related hazards associated with:

a) Excavations;

b) Contamination;

c) Temporary works instability; and

d) Machine instability

WHAT DESIGNERS OF SITE INVESTIGATIONS SHOULD DO

8. The SI should be an evolutionary process and include a desk study, site walkover and ground investigation respectively, with each stage informing the next.

9. SIs should be designed to identify variability in the ground on a site and to identify construction-related hazards and provide the necessary information to help in avoiding or reducing the risks posed by either physical or chemical hazards.

10. SIs should be carried out early enough in the development process such that major hazards can be identified and, if possible, designed out. The site investigation should be carried out in stages, so that hazards identified at each stage can be accommodated in the investigation process. It will be important that information on the proposed development and its likely form: footprint likely foundation types and construction:, is utilised in the SI design. A good SI can inform the development layout such that hazardous ground can be avoided e.g. swallow holes or processes such as cut and fill could be minimised.

11. A full site investigation should comprise three sections as follows:

a) A desk study, which gathers information from a variety of sources, e.g. Ordnance survey maps for previous history including mining or wells, and is a vital first stage in identifying the hazards that may be present on site. The desk study should identify the following in order to address construction hazards:

i) previous site development and ground history including archaeology

ii) old foundations

iii) possible underground services

iv) other structures

v) effect of neighbouring structures on proposed development and vice versa

b) A Walkover survey, which would ensure that information on safety-critical matters such as access and overhead services can be identified and enables issues identified in the desk study to be confirmed on the ground.

c) Ground investigation, which should identify the controlling parameters that enable both the design of the structures and of the construction process to be carried out. Generally it is the deeper soils that are characterised for foundation design purposes, but the soil parameters at shallower depth could be required for:

i) design of working platforms for construction plant (upper 1-2m);

ii) assessment of temporary excavation stability (upper 1-3m);

iii) assessment of contamination;

iv) The proposed site levels should be taken into account – if a cut and fill operation is carried out that changes site topography the SI information should cover the new ground surface. The assessment of the site level in relation to the foundation process will also be important e.g. avoiding the installation of driven piles from an elevated ground level that need to be cut off later.

12. The identification of variability will often be key. On brownfield and filled sites, an increased density of investigation positions is likely to be required because of the potential for extreme variability compared with a greenfield site.

HOW TO RECOGNISE A COMPETENT SI

13. The amount and complexity of a SI should be related to the degree of risk – for example: for a single storey development on a previously undeveloped stiff clay site less information will be required compared to a process requiring the use of heavy plant over recently deposited made ground. Basic SI information should be available early in the project design life cycle supplemented by more detailed information as required. The site investigation should have been designed, supervised and carried out by a competent person as defined in the Site investigation in construction documents.

14. A competent SI would incorporate the steps set out in 11.

15. In addition it would. take into account:

a) the nature of the site e.g. brownfield;

b) the controlling depth and spatial extent of substructure works that will be required;

c) the likely construction process e.g. cranes handling heavy loads will require a temporary platform that needs design information;

d) the need for temporary works e.g. parameters to ensure the stability of temporary excavations.

16. And provide the following:

a) Locations of all intrusive investigation points and ground levels at the time;

b) Engineering properties of both foundation level and near-surface ground – see 11 c) ii),.

c) The depth of the water table and seepage rates, if applicable;

d) Accurate location of all trial pits, which, if not backfilled adequately, could leave areas of poorly compacted ground.

e) Accurate and detailed soil descriptions, including the constituents of fill or contaminated ground

17. The techniques for investigation in the GI must be appropriate to the soils tested. The uncertainty associated with measured parameters should have been assessed and listed in the report.

18. There is a wealth of guidance on the procurement and conduct of good site investigation as well as the appropriateness of techniques used. A good SI should take account of this.

USEFUL REFERENCES

Code of conduct for site investigation. Association of Geotechnical and Geoenvironmental Specialists, Beckenham, Kent. 1998

Guidelines for good practice in site investigation. Association of Geotechnical and Geoenvironmental Specialists, Beckenham, Kent. Version2, 1999.

Guidelines for combined geoenvironmental and geotechnical investigations. Association of Geotechnical and Geoenvironmental Specialists, Beckenham, Kent. 2000.

A guide for safe working on contaminated sites. CIRIA Report 132, 1996.

Site investigation in construction. Part 1: Without SI ground is a hazard. Part 2: Planning, procurement and quality. Part 3: Specification for ground investigation. Part 4: Guidelines for the safe investigation by drilling of landfills and contaminated land. Institution of Civil Engineers Site Investigation Steering Group. Thomas Telford, London, 1993.

British Standards:

BS5930:1999 Code of practice for site investigations.

BS10175: Investigation of potentially contaminated sites – code of practice.

BRE Digests relating to Site investigation for low-rise building:

Digest 383 Soil description

Diest 318 Desk studies

Digest 348 The walk-over survey

Digest 411 Direct investigations

Digest 381 Trial pits

Digest 322 Procurement

Digest 472 Optimising site investigation

A simple guide to in situ testing. Part 1 What is it and why do it?

Designing ground works to minimise risks posed by contamination during construction

INTRODUCTION

1. Designers of ground works can play a major part in making it easier to manage the hazards on a construction site arising from contamination.

2. The stages in design that can play a major part are site investigation (SI), identifying the hazards, and in the design of the construction works.

3. The health and safety of construction workers is directly linked to the methods and sequencing of the work. This guidance aims to make designers aware of the importance of

safety issues concerned with construction work and gives information on how design can help to make construction safer.

4. Certain risks are attached to working on potentially contaminated sites during the SI, but issues concerned with safety during investigation work are not specifically covered in this guidance note, nor are the risks to the environment or later users of the construction works.

HAZARDS ASSOCIATED WITH CONTAMINANTS

5. The process of construction may result in greater exposure to contaminants than post-construction, when cover layers or other works are in place. Contaminants can cause short or long term health impacts and exposure to them may be via dermal, inhalation or ingestion. Other hazards may include explosives or combustible chemicals.

6. During construction of ground works, site stripping, shallow and deep excavations and deep drilling works may be necessary. Disturbance of shallow and/or deep contaminants may occur. In each case, potential exposure to ground-borne, air-borne or water-borne contaminants can occur.

7. Care should be taken in the importation of fill to ensure it is not contaminated.

WHAT DESIGNERS OF GROUND WORKS SHOULD DO

8. Designers should give adequate regard to ensuring that construction works can be carried out safely. Designers can help in several ways including:

a) Avoidance of foreseeable risks from the hazards; or

b) Reducing the risks from the hazard; and

c) Providing sufficient information to allow persons in control of the work to manage the hazard effectively.

9. The SI should identify construction processes and provide the necessary information to help in avoiding or reducing the risks posed by chemical hazards.

10. The designer should be aware of the risk posed by the presence of contaminants and evaluate this using the source-pathway-receptor model. If any one of these links can be broken then the risk will be reduced. For example, pile types that do not generate can reduce the risks posed by contact with contaminants.

Designing to avoid foreseeable hazards

9. The SI should be carried out early enough in the development process such that major hazards from contamination can be identified early. A good SI can inform the development layout such that excavation in contaminated ground could be avoided or treatment of contaminated ground could be carried out prior to the main works.

10. Some treatment processes designed to address physical properties of the ground may also impact on the risks posed by contaminants. Heavy compaction of domestic refuse can increase risks posed by generation and migration of landfill gases; alternatively in some loose deposits

compaction can reduce permeability and hence mobility of contaminants and the physical soil improvement enables shallow foundations to be used.

Designing to reduce the hazards - Reducing risks by reducing exposure to a hazard.

11. Where choices of foundation processes are available, processes that minimise excavations or spoil can be used to reduce exposure to contaminants that remain in the ground. In some cases regulations related to the creation of migration paths for contaminants may govern.

12. Where different temporary works solutions are available, those that minimise both spoil and the potential for transport of contaminants into the working area may be preferable. For example combinations of sheet piles and slurry walls have been used to control ingress of contaminated water into excavations as well as provide physical stability.

Providing information to allow the risk to be managed

13. The designer should pass on to the contractor

a) all information from the SI relating to contamination;

b) pre and post-treatment contamination

c) assumptions relating to the contamination made in the design

USEFUL REFERENCES

Code of conduct for site investigation. Association of Geotechnical and Geoenvironmental Specialists, Beckenham, Kent. 1998

Guidelines for good practice in site investigation. Association of Geotechnical and Geoenvironmental Specialists, Beckenham, Kent. 1998

Guidelines for combined geoenvironmental and geotechnical investigations. Association of Geotechnical and Geoenvironmental Specialists, Beckenham, Kent. 2000.

A guide for safe working on contaminated sites. CIRIA Report 132. CIRIA, 1996.

Guidelines for the safe investigation by drilling of landfills and contaminated land. Site investigation in construction, Thomas Telford, London, 1993.

Designing to make management of hazards associated with ground treatment easier

INTRODUCTION

1. Where construction is to take place on poor ground, one option is to treat the ground to improve its properties prior to construction. Ground treatment has been defined as the controlled alteration of the state, nature or mass behaviour of ground materials in order to achieve an intended satisfactory response to existing or projected environmental and engineering actions.

2. It is important that all parties to a ground treatment contract are aware of their particular responsibilities to ensure that the works are carried out in a safe manner. Designers can play a major part in making it easier to manage the hazards associated with ground treatment.

3. This guidance aims to make designers aware of the issues and gives information on how they can help to make safer three commonly used ground treatment methods; vibrated stone columns (“vibro”), dynamic compaction and rapid impact compaction.

4. The installation of vibrated stone columns forms the most commonly used ground treatment method in the United Kingdom. Treatment is effected by penetrating the ground with a larger poker vibrator and forming a dense column of stone in each cylindrical cavity formed by the vibrator from the maximum depth of penetration up to the ground surface. The vibrator is suspended from a crane or supported by a base machine.

5. In dynamic compaction the ground is compacted by repeated impacts of a heavy weight. The weight is dropped in free fall from a considerable height by a large crane. Rapid impact compaction is a variation of this technique in which a hydraulic piling hammer impacts an articulated foot which remains in contact with the ground surface.

6. This guidance note aims to make designers aware of the issues and gives information on how they can help to make ground treatment works safer through their designs.

HAZARDS ASSOCIATED WITH GROUND TREATMENT

7. The hazards that are described should be taken as common to vibrated stone columns, dynamic compaction and rapid impact compaction unless it is specifically stated that a hazard refers to a particular treatment method. All three methods necessitate the use of large machines, such as cranes, on the site and treatment which involves penetration of the ground.

8. The machine operator can be exposed to risks associated with:

(a) Instability of the machine during ground treatment or when moving to another treatment position.

(b) The machine coming into contact with overhead power lines or buried services.

(c) Ground treatment causing disturbance of the ground to depths greater than buried services such as gas mains and electricity cables.

9. Personnel, vehicles and structures in the vicinity of ground treatment can be exposed to risks associated with:

(a) Movement of the machine which can cause injury to workers in the vicinity.

(b) Instability of the machine during ground treatment or when moving to another treatment position.

(c) The heavy weight falling onto the ground surface in dynamic compaction presents an obvious but most serious hazard for anyone or any object under the impact point. Additionally, flying debris constitutes a hazard to personnel, vehicles and structures in the vicinity of the impact point.

(e) Noise can be a problem for personnel in the vicinity of rapid impact compaction which is a process similar to pile driving with high airborne noise levels generated during impact.

(f) Vibrations resulting from ground treatment can affect adjacent structures or industrial processes. This is much less of a problem with vibrated stone columns.

WHAT DESIGNERS SHOULD DO

10. Designers should give adequate regard to ensuring that ground treatment works can be carried out safely and that work required to be done can also be carried out safely. Designers can help in several ways including:

a) Avoidance of foreseeable risks from the hazards; or

b) Reducing the risks from the hazard; and

c) Providing sufficient information to allow persons in control of the work to manage the hazard effectively.

11. Guidance on the use of cranes can be found in General Information Note I 002 Provisions for the safe use of cranes on construction sites.

Designing to avoid foreseeable hazards

12. Carry out proper site investigations to identify groundwater levels, contaminated, unstable or problematic ground (including slopes) and utilities.

Machine instability

13. A working platform should be designed which is adequate to support all the machines which will be used during ground treatment. This is a particularly onerous requirement for the large crawler cranes used in dynamic compaction. The effect of sloping ground should be considered. Inspection and maintenance procedures should be built into the design. Dynamic compaction will inevitably cause disruption of the working platform and continuous remedial work is required.

14. Potentially highly unstable ground, such as that undermined by solution cavities or mine adits, should be identified in the site investigation and the effect of the ground treatment assessed during the design.

Overhead powerlines

15. All oversite services need to be identified. Where necessary these should be diverted or an exclusion zone defined so that machines do not come near to them. This may require design of alternative ground treatment or foundations in these areas.

Buried services

16. The location and depth of local buried services should be identified. Where necessary these should be diverted or protected. In some cases it may be necessary to define an exclusion zone within which ground treatment is modified or some different design solution is adopted.

Flying debris

17. Protective screens should be provided to shield vulnerable targets during dynamic compaction. This will need to be moved so that they remain close to the impact point.

Noise

18. The ground treatment scheme should be designed such that the noise levels both on and offsite are controlled to reasonable levels. General guidance on noise can be found in Health Guidance Series H 20.002 Designing to make management of noise in construction easier.

<u>Vibrations</u>

19. Likely vibration levels should be evaluated by the designer and their possible effects on adjacent structures and people assessed. Where necessary, monitoring should be specified. Vibration levels can be reduced by designing different ground treatment processes or by designing protective measures such as trenches.

Designing to reduce the hazards - Reducing risks by reducing exposure to a hazard.

20. The risks associated with hazardous materials [on contaminated sites] can be eliminated by first designing and carrying out a suitable remediation scheme.

<u>Machine movement</u>

21. Situations in which workers have to work close to machines should be minimised. Where this is unavoidable, as in transporting stone to the location where a stone column is being formed, machine movements should be carefully controlled.

<u>Falling weight</u>

22. When dynamic compaction is underway, an exclusion zone should be defined around the crane within which no personnel are permitted. If more than one rig is used on the site, they should be separated by at least 30 m. Operations by the main contractor should be delayed until the treatment operations are sufficiently remote.

<u>Providing information to allow the risk to be managed</u>

23. Generally, designers should pass onto the Planning Supervisor and the Contractor information about residual risks. This should, at least, include:

a) The location of utility services;

b) The results of any site investigations to allow the Contractor, to:

i) identify the nature of the ground [type and engineering properties], to allow proper design of the working platform,

ii) locate hidden obstructions confirmed by the site investigation,

iii) assess whether there is a gas migration problem,

iv) the extent, nature and concentrations [ppm, mg/ml, etc] of all ground contamination,

v) information about stability of adjacent structures [including how close machinery can work];

c) Any assumptions that the design is based on, eg, space allowed for plant;

USEFUL REFERENCES

Specifying vibro stone columns. BRE Report BR 391. BRE Bookshop, 151 Rosebery Avenue, London EC1R 4GB. 2000

Specifying dynamic compaction. BRE Report BR 458. BRE Bookshop, 151 Rosebery Avenue, London EC1R 4GB. 2003

A guide to ground treatment. CIRIA Report C573. CIRIA, London, 2002.

Designing to make management of hazards associated with constructing foundations easier (shallow foundations)

INTRODUCTION

1. Designers can play a major part in making it easier to manage the hazards associated with constructing foundations.

2. Shallow foundations are those less than 3m deep. These may be prefabricated or cast-in-situ. In most cases the construction requires some form of ground preparation and excavation and involves the use of plant.

3. This guidance aims to make designers aware of the issues and gives information on how they can help to make shallow foundation works safer through their designs.

HAZARDS ASSOCIATED WITH CONSTRUCTING FOUNDATIONS

4. The most common form of hazard associated with erecting foundations is collapse of excavations, which often happens without warning. Excavations deeper than 1.5m are particularly hazardous. Excavations can collapse if:

a) The sides of the excavation are not sufficiently self-supporting or are cut into a pre-existing slope;

b) Surcharges from spoil, adjacent foundations, stored materials, plant or temporary works-imposed loads overload the ground adjacent to an excavation;

c) Groundwater ingress reduces the strength of the ground and can lead to unexpected inundation of excavations;

d) Excavation supports are removed prematurely, to facilitate backfilling or compaction.

5. Other hazards related to constructing foundations could include:

a) Instability of, or falls due to, excavations, slopes or spoil mounds

b) Operation of machinery for excavation or concreting close to people and excavations;

c) Working in contaminated ground

d) Working in the vicinity of services

e) Cumulative health problems caused by working in unergonomic positions, eg, fixing re-bar

f) Undermining existing structures while excavating for foundations

g) Falls into unmarked excavations, slips or trips.

Work carried out in an excavation may require temporary works for stability, formwork or steel fixing. Placement of concrete or precast units may require tracking near the edges of excavated ground.

WHAT DESIGNERS SHOULD DO

6. Designers should give adequate regard to measures that would make it easier to construct the foundations safely by::

a) Eliminating, where it is possible to do so, the causes for the foreseeable hazards listed in 4 and 5; or

b) Designing in provisions to help a contractor to mange the residual hazards; and

c) Providing sufficient information to allow persons in control of the work to manage the hazard effectively.

Designing to avoid foreseeable hazards

7. Initial decisions about the building footprint are key decisions, because this will decide where the foundations will be and whether:

a) Constructing foundations can avoid requirements for tracking over or near excavations,

b) Problematic ground can be avoided –see 9;

c) On sites where buildings have been demolished, the possibility of reproducing the old building footprint fully, or in part, will allow reuse of existing foundations.

d) Excavations are likely to be destabilising influences, e.g.:

i) close to existing buildings,

ii) close to the foot of an embankment

iii) undermining utilities, etc

8. Carry out proper site investigations, which will allow proper identification of:

a) Bearing capacities,

b) Groundwater levels,

c) Large and small obstructions, eg, existing foundations,

d) Contaminated, unstable or problematic ground (including slopes) and utilities.

9. The risks associated with hazardous materials [on contaminated sites] can be eliminated by first designing and carrying out a suitable remediation scheme or designing to avoid excavations in contaminated areas, if it is possible to do so, eg, by the use of screw piles, or piles with precast foundation beams.

10. Excavating close to existing foundations is always hazardous. Therefore, designers should consider the effects of excavations on any adjacent structures and, if necessary, provide solutions, which would move excavations away from them, eg:

a) By using cantilever foundations; or

b) Piles;

c) By routing drain and other service runs a safe distance away.

Designing in provisions to help a contractor to manage the residual hazards

Collapse of excavations

12. Practical design solutions should include using the SI – see 8, to understand the maximum safe depth of the excavation, and could include reducing the depth of an excavation for a foundation by:

a) Determining, as accurately as possible, the engineering properties of the ground and using this information to reduce the depth of any foundations;

b) Designing foundations with the minimum depth by, for example, using reinforced bases, instead of deeper mass concrete ones;

13. In addition, the need for excavations could be eliminated by

a) Using pile foundations or prefabricated shallow foundations;

b) Not requiring destabilising processes, which may undermine the slope of any excavation above the foundation, eg, moving shear-toes for walls away from the foot of the slope;

c) When space, site layout or other restrictions allow, the design of the permanent works should allow excavations to be located so that they can be constructed with side-slopes that are safe for the time that the excavation will be open , which do not require additional support.

d) Where (e) is not possible, allow for sufficient working space to install effective temporary supporting works.

e) Where appropriate use permanent, lightweight formwork or shuttering in conjunction with prefabricated steelwork.

14. Where the design allows for items to be lifted into trenches, consider the position of the lifting device in relation to the excavations. Lifting devices need space and are covered by a number of other regulations.

However, if this is not possible and the installation lends itself to precast foundation units and trenchless techniques for services, they should be given serious consideration.

Reducing risks by reducing exposure to a hazard

15. The risks can also be reduced by minimising the time that people have to spend in an excavation, because excavations deteriorate with exposure to the elements. Therefore, designers should consider:

a) Detailing work items so that they can be fabricated away from the excavation and lifted in, e.g., reinforcement for bases, precast manhole rings, etc.

b) Designing permanent shuttering, which can be left in place;

c) Casting the concrete against natural ground;

d) the possibility of using pre-cast assemblies;

e) Investigate the possibility of reusing existing foundations;

Reducing hazards to health

16. Many steelfixers suffer back injury, because they have to work in unergonomic positions to fix re-bar. Therefore, consider detailing the re-bar so that it can be prefabricated away from the excavation and lifted into position. To achieve this, designers will have to provide a cage with sufficient stiffness and with specified lifting points.

17. Long runs of foundations may have to be poured in sections. In such situations detail the foundations so that there is no need to scabble the day joint.

18. Detail pile heads so that they are compatible with some of the mechanical breaking techniques that are available.

19. On heavily contaminated sites, the possibility of piled foundations, using techniques which do not create spoil should be investigated, eg, using screw piles.

Dealing with services

20. Ideally, foundations should be positioned to avoid the need to work around or close to buried services– see 8 and 10 c). However, if this is not possible, the foundations should be designed to accommodate them, eg, bridging them rather than undermining them.

21. Services will, inevitably require maintenance or repair at some time during a building's service life. Therefore, where utilities are unavoidably close to foundations, eg, existing utilities on constrained sites, the foundations should be designed so that any excavation to expose these services does not undermine the foundations.

Providing information to allow residual hazards to be managed

22. Generally, designers should pass onto the Planning Supervisor and the Contractor information about residual hazards. This should, at least, include:

a) The location of utility services;

b) The results of any site investigations to allow the Contractor, to:

i) identify the nature of the ground [type and engineering properties], to allow proper design of the support works,

ii) locate hidden obstructions confirmed by the site investigation,

iii) assess whether groundwater could be a problem [it would be useful to know rate of seepage],

iv) assess whether there is a gas migration problem,

v) the location, extent, nature and concentrations [ppm, mg/ml, etc] of all ground contamination, highlighting any which are above action levels;

vi) Approximate quantities of contaminated spoil, to allow a contractor to make appropriate arrangements for tipping;

vii) information about stability of adjacent structures [including how close an excavation can come to them];

c) The maximum depth of excavations;

d) Any assumptions that the design is based on, e.g., space allowed for plant;

e) Maximum permissible surcharges;

23. Accurate location of trial pits - carry out proper site investigations to identify bearing capacities, groundwater levels, large and small obstructions, eg, existing foundations, contaminated, unstable or problematic ground (including slopes) and utilities.

Designing to make management of hazards associated with construction of foundations easier (deep foundations)

INTRODUCTION

1. Designers can play a major part in making it easier to manage the hazards associated with constructing foundations.

2. For the purposes of this guidance, deep foundations are those greater than 3m deep. These may be prefabricated or cast-in-situ. In most cases the construction requires some form of ground preparation and excavation and/or the use of heavy plant.

3. This guidance note aims to make designers aware of the issues and gives information on how they can help to make foundation works safer through their designs.

HAZARDS ASSOCIATED WITH DEEP FOUNDATIONS

4. Some of the hazards related to deep foundations include:

a) Instability of machines working close to excavations and unsuitable ground;

b) Falls due to poor access or ground conditions

c) Operatives working on and near to machinery for excavation, drilling or concreting

d) Working in contaminated ground

e) Working in the vicinity of services

5. The most common forms of accident associated with deep foundations involve falls and machinery.

WHAT DESIGNERS SHOULD DO

6. Designers should give adequate regard to designing in measures, which could ensure that a deep foundation can be constructed safely. Designers can help in several ways including:

a) Eliminating the foreseeable hazards listed in 4 and 5; or

b) Designing in provisions to help a contractor to manage the residual hazards; and

c) Providing sufficient information to allow persons in control of the work to manage the hazard effectively.

Designing to avoid foreseeable hazards

7. Initial decisions about the building footprint are key decisions, because this will decide where the foundations will be and whether:

a) constructing foundations can avoid requirements for tracking over or near excavations,

b) problematic ground can be avoided;

c) on sites where buildings have been demolished, the possibility of reproducing the old building footprint fully, or in part, will allow reuse of existing foundations.

d) Excavations are likely to be destabilising influences, eg:

i) close to existing buildings,

ii) close to the foot of an embankment

iii) undermining utilities, etc

8. Some of the hazards associated with safe plant operation can be reduced by the provision of an appropriate working platform. These work platforms need space. Therefore, designers should confirm that such space is available.

9. Provision of safe access can be promoted by not designing works that require difficult access or can only be constructed in a sequence that necessitates such access. In some cases the risk from difficult access can be reduced by designing works that can be constructed by smaller, lighter plant, such as small diameter piles.

10. Falls into deep excavations can be protected against by some simple measures. For example, cofferdams can be designed to project 1.0m above the edge of the excavation to act as a barrier.

11. Piles should be detailed to allow proprietary methods of break out to be used.

12. Where basements form part of the permanent works, the basement walls should be checked for the surcharges that passing [loaded] plant might apply.

13. Deep foundations have the potential to create large amounts of spoil. This could be hazardous on sites where the ground is contaminated. Therefore, designers should consider foundation systems, which minimise the amount of spoil, eg, screw piles, driven piles.

14. Extraction of temporary earth retaining equipment can be problematical and designers could consider their incorporation into the permanent works.

15. All plant requires space, including lifting devices.

Providing information to allow the risk to be managed

16. Generally, designers, as appropriate, should pass onto the Planning Supervisor and the Contractor information about residual hazards. This should, at least, include:

a) The location of utility services;

b) The results of any site investigations to allow the Contractor, to:

i) identify the nature of the ground [type and engineering properties], to allow proper design of temporary works,

ii) locate hidden obstructions confirmed by the site investigation,

iii) assess whether groundwater could be a problem,

iv) the extent, nature and concentrations [ppm, mg/ml, etc] of all ground contamination,

v) information about stability of adjacent structures;

vi) The exact location of any trial pits, so that backfilled pits do not pose a threat to the stability of plant.

c) Any assumptions that the design is based on, eg:

i) space allowed for plant – see 8;

ii) propping requirements – see 12

USEFUL REFERENCES

HSG 185 Health and safety in excavations – Be safe and shore 0-7176-1563-5

HSE General Information Series I 002 Safe Working with Cranes.

Designing to make management of hazards associated with underpinning easier

INTRODUCTION

1. Designers can play a major part in making it easier to manage the hazards associated with underpinning.

2. Underpinning works are carried out in order to improve the stability of existing construction. This means that workers must operate:

- near to potentially unstable structures
- in and around excavations
- with machinery for excavation, piling or lifting
- in confined situations.

3. This guidance note aims to make designers aware of the issues and gives information on how they can help to make underpinning works safer through their designs.

HAZARDS ASSOCIATED WITH UNDERPINNING

4. Some of the foreseeable hazards related to underpinning include:

(a) Structural instability of the building to be stabilised, or surrounding structures

(b) Collapse of temporary works equipment

(c) Instability of excavations, slopes or spoil mounds

(d) Operation of machinery for excavation, piling or jacking

(e) Work in confined spaces, eg, basements

(f) Working in contaminated ground

(g) Working in the vicinity of services

(h) Falls from height and into excavations are also occasional hazards

Structures, which are particularly vulnerable to premature collapse include:

(i) Buildings with random stone walls;

(j) Buildings that have been altered, because load paths may have been changed;

(k) Badly dilapidated buildings, eg, buildings with

a. bulging walls,

b. deteriorated fabric

c. decayed brickwork or timber

WHAT DESIGNERS SHOULD DO

Underpinning can be a hazardous operation. Therefore, designers of the permanent works should, in the first place, consider whether it is absolutely necessary. And having decided that it is, they should provide sufficient information to allow persons in control of the underpinning work to manage the hazard effectively.

Designing underpinning to avoid foreseeable hazards

<u>Structural instability of the building to be stabilised, or surrounding structures</u>

5. Structures that require underpinning to ensure stability may be severely damaged. The design of the underpinning scheme should take into account the current stability of the structure, ie, it should: identify load paths and critical components in the structure being underpinned, and of surrounding structures, during the initial stages of investigation.

6. Where schemes require monitoring during the underpinning works, designers should inform contractors about how to recognise emerging dangerous situations, eg, limits on monitored movement: cracks and levels, to ensure that monitoring is effective.

7. Traditional underpinning techniques necessitate excavation beneath the structural foundation either by machine or by hand. The size and sequence of excavations should be designed to ensure that the building loads can always be carried through stable parts of the structure with capacity to do so –see 6.

8. When techniques involving piling are specified, they may reduce the amount of excavation required beneath the structure but may still reduce lateral support in places and impose other forms of loading, such as vibration.

9. Where a scheme dictates that piling operations have to be carried out from within the building, ensure that there is sufficient space to get the machines in.

10. Maintenance of the stability of the building may require temporary supports such as scaffolding or props during the construction activity. Where this is necessary, designers should pass on to contractors information about the loads to be supported by the temporary works. Alternatives to underpinning, or works that can be carried out to stabilise the building before

underpinning, e.g. brickwork reinforcement, should be considered that may reduce the risk of instability.

11. Temporary support schemes should allow adequate space for the operation of plant. It may be beneficial to design propping schemes with an overcapacity that can accommodate impact from plant.

<u>Collapse of temporary works equipment</u>

12. Where the underpinning design is such that temporary works equipment is required, eg, props for the stabilisation of the foundation during insertion of an underpinning beam, the design should consider the current condition of the foundation and its suitability for support.

<u>Instability of excavations or slopes</u>

13. Excavations [> 1.5m] are vulnerable to collapse. The site investigation prior to design should reveal the following:

a) nature of the subsoil being excavated,

b) the location of the water table, and

c) drainage around the site so that safe excavations can be designed.. Particular care should be taken where there is a risk of flooding of excavations.

14. The wider context of the excavation should be considered in the site investigation and by the design, for example nearby slopes or embankments that could be destabilised by the works.

15. Spoil is generated from all forms of excavation and the arrangements for storage and disposal of the spoil should be taken into account when designing the excavation and/or its supports. This can be a particular problem where space is limited.

16. Further information on designing for safer excavations is given by the HSE.

<u>Falls from height or into excavations</u>

17. The underpinning scheme should be designed to minimise the time or other activities required between excavation and concreting of bases.

<u>Operation of machinery</u>

18. The safe operation of machinery depends in part on the suitability of the ground support. Therefore, before specifying processes that require plant, the designer should consider whether the ground is able to provide the required reaction for such plant, eg, piling rigs. If a working platform is required for the machinery, the space requirements for this platform should be confirmed.

19. When the work is close to fragile structures, the effects of vibrations caused by plant operating close by should be taken into consideration, and, if vibrations pose a hazard, the design should be modified to make the process unnecessary.

20. Machinery exhaust fumes and noise can be hazardous, especially in enclosed or confined spaces, eg, in basements. The effects of fumes and noise should be given careful consideration and, if possible, alternative techniques adopted. In some cases electrical

equipment can be used, or powerpacks for hydraulic equipment located away from the confined space.

Working in contaminated ground

21. The site investigation should be so designed to identify whether contamination is likely, and if so to properly identify the risks. Excavation in contaminated ground should be minimised.

Working in the vicinity of services

22. The site investigation should be so designed to locate buried or oversite services that may interfere with the works. Ideally, services should be diverted. However, where services cannot be diverted the underpinning design should ensure that they are avoided by the works.

Providing information to allow the hazard to be managed

23. Generally, designers should pass onto the Planning Supervisor and the Contractor information about residual hazards. This should, at least, include:

(a) The location of utility services;

(b) Information about stability of the structure to be underpinned and adjacent structures [including how close an excavation can come to them] – see 6;

(c) Loads to be supported by temporary works, to allow a contractor to develop a viable solution – see 9;

(d) Information about tell-tale signs about imminent instability – see 7;

(e) The results of any site investigations to allow the Contractor, to:

identify the nature of the ground [type and engineering properties], to allow proper design of the support works,

locate hidden obstructions confirmed by the site investigation,

assess whether groundwater could be a problem for excavations [it would be useful to know rate of seepage],

assess whether there is a gas migration problem,

the extent, nature and concentrations [ppm, mg/ml, etc] of all ground contamination,

(f) The maximum safe depth of any excavations;

(g) Any assumptions that the design is based on, eg, space allowed for plant;

USEFUL REFERENCES

HSG 185 Health and safety in excavations – Be safe and shore 0-7176-1563-5

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