good building guide

CI/SfB (11)

Simple foundations for low-rise housing

GBG 39

Part 1

Site investigation

This Good Building Guide brings together essential information on the selection of foundations for low-rise housing in the UK. It deals with the key features of a site investigation, the information needed to decide whether an engineered design is called for or whether a 'rule of thumb' design is appropriate, the application of the rule of thumb approach, and the key features of good site work for foundations.

Other parts to this Guide

For strip footings and trench fill foundations – see Part 2

No building of any significance should be constructed without first collecting sufficient information about the site to be aware of any features that might affect the support given to the building by the ground on which it will stand. For low-rise housing it will also be essential to consider carefully whether a 'standard' solution can be safely adopted or whether what is learned from the site investigation points to the need to consult someone qualified to design 'special' foundations.

There are three main routes to the information needed:

- the desk study,
- the walk-over survey,
- the direct investigation.

They normally need to be taken in that order, and together they constitute the 'site investigation'.

The main objectives of the site investigation are given in the box, page 2.

The extent of the site investigation will depend on the size of the project and on the extent to which initial examination reveals unusual conditions that need more detailed investigation.

Ground support can change unexpectedly

Photograph courtesy of Eastern Counties Newspapers Ltd

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Main objectives of site investigation

- Assess the suitability of the site for the proposed construction.
- Determine whether site conditions are such that a 'standard' foundation can be safely used.
- Provide information that, whether a standard or an engineered design is used, will enable a design to be produced. This will need to take account of the support offered by the ground to the loads imposed by the building, and of potential variation in support with time or with location within the site.
- Assess the impact of the work on adjacent sites/properties.

Sources of information for the desk study

British Geological Survey
Kingsley Dunham Centre, Keyworth,
Nottingham NG12 5GG.
Tel 0115 936 3143 (Enquiries).

Murchison House, West Mains Road,
Edinburgh EH9 3LA.
Tel 0131 667 1000.

London Information Office (BGS),
Earth Galleries, Natural History Museum,
Exhibition Road, London SW7 2DE.
Tel 020 7589 4090.

There is information about the British Geological Survey at www.bgs.ac.uk

Ordnance Survey Customer Information
Romsey Road, Southampton SO16 4GU.
Tel 023 8079 2912.

Landmark Information Group
Environmental and Property Information,
The Chandlery,
50 Westminster Bridge Road, London SE1.
Tel 020 7721 7695.

Catalytic Data Ltd
The Spinney, 19 Woodlands Road,
PO Box 606, Bromley, Kent BR1 2ZR.
Tel 0870 606 1700.

The opportunity will be taken at the same time to examine and record many features that are relevant to development of the site but which do not bear on the choice of foundation type. Such issues are not considered here.

The desk study

The essential feature of the desk study is that it brings together for examination all available documents that bear on the character and history of the site. It seeks answers in turn to two crucial questions.

- What is the nature and condition of the ground below (and around) the proposed construction?
- What are the implications for the design of the structure and, particularly, its foundations?

The desk study therefore sets out to:

- identify the materials and thicknesses of the strata below (and near to) the proposed construction,
- estimate the angle of slope of the ground surface,
- identify all information that may reveal a potential hazard to the new foundations or to the proposed use of the site.

All of this information will later be used to guide the subsequent site reconnaissance, 'the walk-over survey', in such a way as to confirm and extend knowledge that thus far has been acquired only from documents.

British Standard BS 5930 *Code of practice for site investigations* suggests that prerequisites of the desk study are:

- location of the site on maps,
- location of site boundaries and building lines,
- identification of contours,
- check for records of changes in use of the site,
- check on indications of the potential for flooding,
- check for indications of existing and earlier constructions.

At this stage the principal information about the soil strata below the site can be obtained from geological maps, particularly those covering 'drift' or 'solid and drift' strata wherever possible. These, together with the relevant handbooks, *British regional geology guides* (or, where available, the explanatory sheet memoirs) from the British Geological Survey, should enable the subsoil type to be at least broadly identified. In some cases they will also identify landslip locations but, since they do not always do so, it is advisable to seek evidence of landslip from aerial photographs of the site taken at both recent and earlier dates. Distortion of hedgerows or other linear features will often be obvious in aerial photographs of areas where landslip has occurred, and thus the potential instability of slopes will become apparent.

Organisations that, for a fee, may provide air photographs are listed in the box, page 3. The National Association of Aerial Photographic Libraries (NAPLIB) published the first *Directory of aerial photographic collections in the United Kingdom* in 1993, obtainable from ASLIB (see box, page 3).

Ordnance Survey maps at appropriate scales will show from contour lines where slopes cross the site and, with knowledge of the soil type, enable assessment of the potential for land slip. Ordnance Survey maps at 1:25 000 scale show water features such as watercourses, ponds and springs. The locations of wooded areas can be located from Ordnance Survey maps, and changes in this and other ground cover will be revealed by examination of maps drawn at differing dates.

Information from some of the above data sources, particularly relating to past land use and ground contamination, has been collected on a national basis by commercial firms such as Landmark Information Group and Catalytic Data Ltd. Searches for data on particular sites are available for a fee.

Sources of aerial photographs

Sites in England
NMR Enquiry and Research Services
National Monuments Record Centre
Great Western Village , Kemble Drive
Swindon SN2 2GZ
Tel 01793 414600

Sites in Scotland
Royal Commission for Historical Monuments of Scotland
National Monuments Record of Scotland
John Sinclair House , 16 Bernard Terrace
Edinburgh BH8 9NX
Tel 0131 662 1456

Sites in Wales
The Welsh Office
Central Register of Air Photographs
Planning 9, Rm G-003
Crown Offices
Cathays Park, Cardiff CF1 3NQ
Tel 029 2082 3815

Royal Commission for Wales
RCHMW
National Monuments Record of Wales
Plas Crug
Aberystwyth, Ceredigion SY23 1NJ
Tel 01970 621233

Sites in Northern Ireland
Ordnance Survey Northern Ireland
Colby House, Stranmillis Court
Belfast BT9 5BJ
Tel 028 9066 1244

ASLIB
Publications Department,
The Association of Information Management, Information House,
20–24 Old Street, London EC1V 9AP
Tel 020 7253 4488; Fax 020 7430 0514

The map libraries at The British Library and county libraries hold historical maps which can be used to determine past uses of a site.

The information obtained from the desk study should enable fairly firm conclusions to be drawn, subject to confirmation by subsequent direct investigation of:

- the nature of the ground below the site,
- the likelihood of landslip,
- the possibility of mining or quarrying activity (Mining and quarrying may be identifiable from records held by Local Authorities and the Health and Safety Executive. Note too that 'mining' does not necessarily imply coal mining: other possibilities include chalk, flints, limestone, gypsum, metallic ores, common salt, and sand and gravel),
- the presence of (and past changes in) vegetation on the site,
- the probability and nature of past usage of the site,
- the presence of water courses or ponds and springs,
- the possibility of filled ground within the site,
- the possibility of solution features,
- the possibility of ground contaminants,
- the possibility of soft compressible ground.

This leads in turn to a further phase of the desk study, in which all that has been learned must now be interpreted in terms of its likely consequence for foundation design, and the provisional conclusions drawn used to sharpen the focus of the next stage: the walk-over survey. In preparation for the walk-over survey it is useful to draw up a plan of the site at a fairly large scale and annotate it with the information so far learned. See also BRE Digest 318.

The walk-over survey

Safety!

All site operations are potentially hazardous so exercise care and caution, especially on potentially contaminated ground and when handling samples. Follow the advice given in BS 5930.

The walk-over survey provides information that cannot be obtained from the study of documents alone. It enables first-hand examination of the site (almost certainly revealing new information) and it provides an opportunity to obtain valuable local information by directly questioning local sources. A camera should be freely used to record all features best illustrated by photographs. The subject, location and direction of view should be listed immediately each photograph is taken.

The first task in the walk-over survey is a systematic search of the site to confirm and add to the site plan drawn following the desk study. Each of the points raised by the desk study should be related to observations made on site and in each case a note should be made as to whether site observation confirms or conflicts with the desk study.

In particular, notes should be made of features not identified in the desk study. Evidence that may be vital in updating knowledge of the site includes:

- indications of unsuspected water features or high water table, indications of flooding,
- evidence suggesting areas of filled ground or tipped rubbish,
- indications that subsoil type changes with location,
- significant slopes (ie steeper than about 1 in 10) where the desk study has indicated clay subsoil,
- trees, and especially stands of trees, which have apparently grown at a common angle to the vertical,
- natural terraces, marked changes of slope or obvious lumpiness, in the ground surface,

Reeds and willow suggest a high water table

The face of a cutting can provide much information at no cost

- local depressions in the ground surface that may indicate solution features (especially where the desk study has indicated chalk subsoil),
- soft wet depressions (can be indicated by water-loving plants, eg reeds),
- sewers, pipelines or other underground features,
- wells,
- existing old foundations, basements, cellars, fuel storage tanks, hardstandings,
- overhead lines or other obstructions to equipment for the subsequent direct investigation.

Where the desk study has indicated clay subsoil a detailed note should be made of the species, height and location of trees and other major vegetation, relating their location to the expected locations of the new buildings. An estimate should be made of how close any tree is to maturity. It may be useful to attach a leaf to the walk-over survey report for later confirmation of species. The positions of any stumps of felled trees should also be noted.

Next, the surrounding ground should be examined, seeking in particular any differences between it and the site that might suggest the possibility of variable ground within the site.

Existing buildings or other structures near the site should be examined, interpreting causes from the nature of any damage and recording especially damage that might suggest foundation movements. The extent of this examination will be guided by the information already obtained in so far as it indicates potentially difficult ground and consequent possible risk to foundations. Any discrepancies between what structures are present and what structures are shown as existing on the site plan should be noted.

A more detailed examination will follow at the direct investigation stage but it is often useful if the walk-over survey includes a preliminary sampling of soil at the expected depth of the new foundations. Samples taken with a small corkscrew auger and put into re-sealable plastics bags, with a note of the location (cross-referenced to the site plan) and approximate depth from which each sample came, can help later decisions about where trial pits are best dug.

As an important part of the walk-over survey, the opportunity can be taken to seek information directly from local sources, eg:

- local Building Control Officers,
- County Minerals Officers,
- Public Utilities (eg local water and sewage companies, local gas and electricity suppliers),
- local builders and national contractors operating in the locality.

Information obtained by direct questioning should be appended to the walk-over survey report, together with their attribution. See also Digest 348.

The direct investigation

The direct investigation takes site investigation into its last stage. Like the desk study it aims to establish the nature of the ground and so to provide a basis on which foundation design can take support by the ground into account. In the specific context of low-rise housing it aims to discover whether, as will often be the case, a simple 'rule of thumb' foundation design will be adequate or alternatively what type of 'engineered' foundation might best suit the conditions.

The desk study provided broad geological information about the strata underlying the entire site. The direct investigation now provides information about specific locations on the site. In particular, it will identify:

- soil type,
- bearing capacity,
- soil conditions,

- liability to volume changes affecting the ground in which the foundations will be located.

The location and nature of any of the potential physical hazards listed in the section on *The walk-over survey* can now be confirmed. Many of these will be the subject of special investigation. Indications of variability in the soils on the site will also prompt more intensive investigation.

In many ordinary cases, however, only a small number of locations on the site need to be inspected in detail. Typically no more than one trial pit per dwelling will be needed, and any doubt about the extent to which their soil profiles are representative can be addressed by probing, on regular grid lines, using a dynamic penetrometer. This equipment does not provide soil samples but measures resistance to penetration of the soil by a small-diameter steel rod. Disturbance of the soil is negligible. The information obtained will either confirm that the trial pit findings can be assumed to apply generally across the site or identify areas that differ in penetration resistance and at which further trial pits or boreholes are therefore needed.

It is important to remember that, whatever investigative method is used, it is not practicable to obtain total coverage of the site. An element of risk is therefore always present, but it is unwise to try to meet that difficulty by sampling the soil immediately below the proposed foundation location: back-filled trial pits are not ideal foundation supports.

Foundation depths for low-rise housing will commonly be less than 3 m, and often much less. Soil investigation in most such cases therefore need not go deeper than 5 m. However, where fill or made ground has been identified it should be expected to be highly variable in materials and bulk density. Any hazardous materials in the fill will need to be identified. The investigation should seek suitable supporting ground below the infilling material. If such supporting ground is not present at reasonable depth, then expert advice should be sought on further investigation and design of appropriate foundations.

British Standard BS 8103 *Structural design of low-rise buildings* advises that a 'rule of thumb' foundation design should not be used (and a suitably qualified person should be consulted) if at 2 m depth the ground is unsuitable for the proposed foundations. Suitability can be assessed using the simple field tests listed in Table 7 of BS 8103. Additionally, a specialist geoenvironmental firm should be consulted if there is a possibility of significant ground contamination.

BS 8103 advises that a suitably qualified person should also be engaged, both to carry out the investigation and to design the foundations, if any of the hazards listed in the box, left, is found.

For digging trial pits it is convenient to use an excavator of the hydraulic 'back-acter' type if trench sides are capable of standing temporarily without support. This provides several advantages:

- soil can be examined in the bucket without the need for someone to enter the trench,
- samples can be taken from the bucket, rather than the trench, using a weighted tape to identify the depth from which each was obtained.

Similarly, a weighted tape can be used to measure the depths and thicknesses of strata apparent in the trench sides.

Groundwater levels can often be determined by observation in trial pits or boreholes, although there will usually be a long delay before the level becomes constant. Groundwater pressure can be measured using one of several types of piezometer. Water samples, taken for the purpose of identifying contaminants in the soil, must be taken in a way that does not introduce irrelevant contaminants.

The location of every trial pit or borehole should be precisely identified on the site plan, and records should show unambiguously which soil profile

Site hazards requiring investigation by a suitably qualified engineer

- Clay sites with slopes greater than 1 in 10
- Reclaimed ground or peat layers
- Refuse tips
- Below-ground watercourses
- Existing services
- Pits, both natural and man-made; soft ground
- Potential mining subsidence
- Wells and mine shafts
- Old foundations
- Presence, introduction or removal of trees
- Potential for flooding, or for a water table above foundation level
- Potentially significant concentrations of aggressive chemicals including soluble sulfate salts and organic and mineral acids

Safety!

A trench more than 1.2 m deep should not be entered unless it is adequately shored.

relates to each pit.

Thorough compaction should be the aim when back-filling trial pits even if they are remote from the footprint of the proposed construction. Soil can often be adequately compacted using the excavator bucket, provided that the soil is replaced in thin layers.

The most valuable information to arise from this final phase of site investigation is an accurate description of the soil at, and below, any probable foundation level. British Standard BS 5930, Section 6, provides a recognised common basis for soil descriptions and representational symbols.

Laboratory testing of the soil samples obtained can determine soil density, organic content, strength, consolidation and compaction characteristics, permeability and, for clays, moisture content and plasticity index, but accurate soil descriptions alone often go a long way towards identifying, in principle, an appropriate foundation design.

Site contamination

There is a further issue to be addressed before a firm decision can be taken: site contamination. Soil samples for the purpose of assessing contamination are usually taken at 500 mm, 1 m and 2 m depths. Laboratory analysis may identify contaminants potentially injurious to health (such as arsenic, cadmium, lead and mercury) and contaminants potentially injurious to building materials (such as mineral acids and soluble sulfate salts).

So-called 'spike tests' for contaminant gases may also be needed. Specialist advice will be needed if methane levels exceed 1.0% by volume or CO_2 levels exceed 1.5% by volume. The presence of radon gas will require special action as described in a BRE Report (BR211) listed in *Further information* below.

See also Digest 411. Part 2 of this *Good Building Guide* describes how the findings of the site investigation are taken into account in foundation design.

BRE Good Building Guides

Good Building Guides have been developed to provide practitioners with concise guidance on the principles and practicalities for achieving good quality building. The guides are designed to encourage and improve mutual awareness of the roles of different trades and professions.

The guides draw on BRE site experience and research, and on other reliable sources, to provide clear technical advice and solutions. Every effort is made to ensure that the guidance given is the most authoritative at the date of issue.

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Further information

BRE

Digests

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Radon: guidance on protective measures for new dwellings. BR211. Garston, CRC, 1999

The Stationery Office

Building Regulations (England and Wales) 1991, Approved Document A

British Standards Institution

BS 5930: 1999 Code of practice for site investigations
BS 8103:– Structural design of low-rise buildings
Part 1: 1995 Code of practice for stability, site investigation, foundations and ground floor slabs for housing

NHBC

Registered Housebuilders Foundations Manual: Preventing foundation failure in new buildings.
NHBC Standards. Chapter 4: Section 4.1 Land quality: managing ground conditions.

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