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Site investigation for low-rise building: procurement

Site investigation must be carefully procured if reliable results are to be obtained. It should provide information on local site features and, in particular, ground conditions to ensure that safe structures are built economically. The usefulness and reliability of site investigation data depend very much on how well the site investigation work is planned and carried out.

This digest discusses the value of site investigation and the steps that should be involved, and provides guidance on contractual methods.

Site investigation can produce unreliable results for a number of reasons. The photograph below shows a severely damaged house on deep fill. Damage was caused by landslide movement which occurred during construction. During ground investigation, the extent of the fill had been correctly established but geotechnical analysis based upon the resulting parameters wrongly indicated that the site was stable. Problems such as slope instability require a very high level of geotechnical skill. A much more basic problem, not unknown in ground investigation, is shown on page 2. A general lack of supervision of fieldwork and laboratory testing by experienced geotechnical engineers has meant that in some cases work has been carried out by unacceptable methods; in other cases, as the cartoon suggests, work has been deliberately falsified to achieve faster progress.

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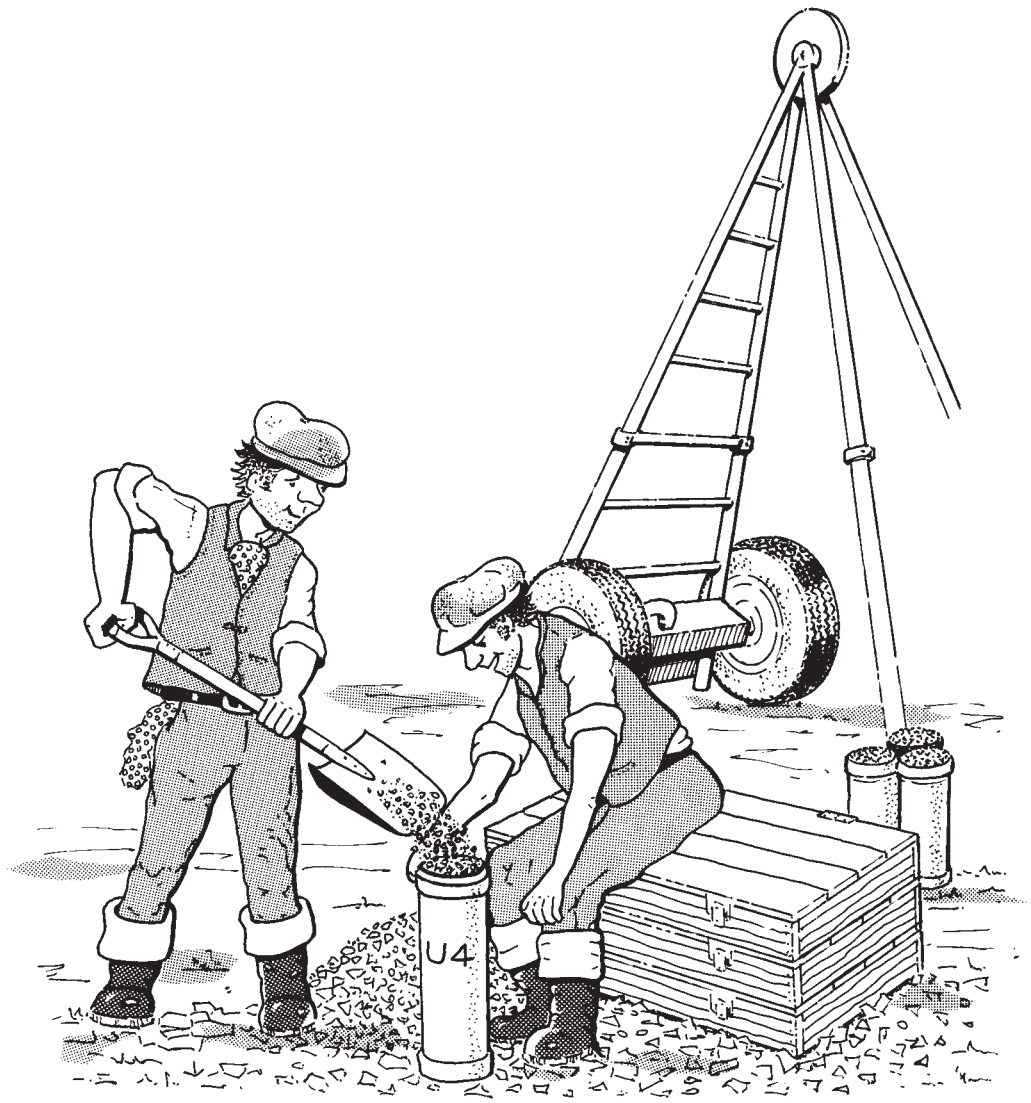

"PUT ANOTHER SHOVEL IN, FRED — REMEMBER THEY WANT FULL CORES."

Courtesy of Mott, Hay and Anderson

Site investigation: what is it?

Site investigation predicts the problems (such as slope instability, foundation failure or cracking of buildings) that might be encountered on a site. It provides the engineering parameters for the ground so that these problems can be avoided with an economic design. Site investigation is also used to assess the effects of construction on surrounding land and property and the effects of surrounding land on the development itself. It is primarily concerned with difficulties arising from local ground conditions, although the investigation of other factors, such as flooding, can be important.

Site investigation consists of a number of stages; the main ones are:

- The collection of available information on the conditions at the site. This process is carried out by means of the 'desk study' (see Digest 318) and the 'walk-over survey' (see Digest 348).

- The collection of new information required for detailed engineering design and reassessment of the information obtained during the desk study and walk-over survey. This is normally done by the so-called 'direct' methods of ground investigation such as boring, trial-pitting and soil sampling and testing.

Detailed activities which normally occur during a ground investigation are:

- preliminary desk study
- examination and interpretation of air-photographs
- site walk-over survey
- design of ground exploration programme
- exploration by trial pits and/or boreholes
- soil and rock classification by sample description and index testing
- in situ and laboratory testing of soils or rocks, for mechanical and chemical properties
- preparation of report.

Benefits and costs

Although site investigation is often seen as a routine part of the design process, in providing information for the engineering design of new works, its most cost effective function should be the detection, assessment and minimising of risks. Site investigations are most beneficial in:

- reducing construction costs through economic foundation and earthworks design
- avoiding contractual claims due to unforeseen ground conditions
- eliminating structural defects as a result of ground movements
- preventing chemical attack on foundations
- detecting health hazards from contaminated land.

Site investigation must be undertaken for every site. It is the first step in the construction process and is absolutely essential if development work is to be carried out safely, economically and to schedule. Without a properly procured ground investigation, the hidden dangers which lie beneath the site cannot be known. Once preliminary desk studies have been used to identify the probable risks presented by a site, these risks can be avoided in a number of ways: by carrying out further site work to allow a proper engineering design to be prepared, by adopting conservative designs, or by designing in accordance with general good practice based upon previous construction experience in the area. If the risks are thought to be small, it may be possible to insure against them.

Conservative design can be used to good effect when a particular risk is expected and is well understood. For example, the width of strip foundations can be increased to avoid foundation bearing capacity failure. On a small site (perhaps for houses) where this was the only problem, it might be cheaper than a detailed soil test to determine a precise value of allowable foundation bearing pressure. However, conservative design would have no effect in preventing foundation heave on desiccated clay, and would be of little use if this risk had not been identified as a result of site investigation. While experience is valuable in reducing the risks in similar ground conditions, it is of little benefit on unfamiliar ground. Site investigations are used not only to determine whether experience from previous sites can be applied but also, in the case of new ground, to provide detailed information for new designs and to alert the developer to the potential risks of the new site and to possible economies.

The objectives of site investigation are:

- to reduce construction costs
- to identify risks to the performance of the structure
- to provide sufficient information on each identified area of risk to allow it to be avoided (for example by design or by relocation of structures on the site) or to bring the risk to an acceptable level
- to defend the owners' investment by minimising long-term structural deterioration due to ground conditions
- to provide safe and serviceable structures for the user.

Since the direct cost of site investigation is normally borne initially by the developer, rather than by the owner or user, the primary considerations should be the identification of risk and the reduction, as far as reasonable, of construction costs. Excessive expenditure on drilling and testing soil and rock is not likely to serve these purposes because of the very variable nature of most near-surface soils. On the other hand, money spent on desk studies, air-photograph interpretation and planning of ground investigation will be cost-effective. Experience has shown that, in most cases, desk studies give very much better value for money in the investigation of low-rise building sites than do activities such as the drilling of deep boreholes and extensive programmes of laboratory testing. However, following a desk study, it is normally necessary to carry out some soil exploration and classification. Where possible this is done by the excavation of trial pits, so that the soil can be examined in-situ, and by tests for particle size distribution, plasticity and chemicals.

Traditionally, expenditure on ground investigations for small projects such as low-rise buildings has amounted to between 0.1% and 0.2% of the construction costs. Most of this has been spent on trial pits or boreholes. In the present climate of increasing building litigation, with increasing risks to developers, it is recommended that:

- expenditure on ground investigation should be a minimum of 0.2% of the cost of the project
- The majority of this sum should be spent on activities which bring the greatest returns in terms of risk appreciation, reduction in construction costs and increases in the effectiveness of ground investigation
- the developer should take an active role in the investigation process, particularly in instructing the amount of investigation required to be carried out to quantify each area of risk.

These recommendations require:

- a competent geotechnical adviser
- appropriate forms of contract between developer and geotechnical adviser
- emphasis during site investigation on desk studies, air photograph interpretation and considered design of fieldwork and testing
- good communication between the developer, his structural designers and geotechnical advisers during ground investigation.

Successful site investigation

Identification of geotechnical specialists

It is most important to obtain the services of a competent geotechnical adviser as early as possible during project planning. Geotechnical engineers and engineering geologists, who are qualified to do this type of work, can be found in the offices of some civil engineering consulting engineers and in most specialist site investigation contractors' organisations. A list of individuals and their employers is available from The British Geotechnical Society.

Appropriate conditions of contract

Conditions of contract in present use for site investigation work vary from extremely formal documents to simple letters of engagement. Two systems of procurement are recommended:

System I *Use of a geotechnical adviser with the separate employment of a contractor for physical work, testing and reporting as required.*

In this system the desk study, the planning and supervision of any fieldwork (such as boring, drilling, trial pitting or in situ testing) and laboratory testing work that may be necessary is carried out by the geotechnical adviser. He will often be a member of a firm of civil engineering consultants but may also be a specialist geotechnical consultant.

This system is widely used on large civil engineering projects. The geotechnical adviser will normally be employed by the developer under the Association of Consulting Engineers Conditions of Engagement, while the specialist ground investigation contractor will be chosen by competitive tender and will work under ICE Conditions of Contract. Two versions of ICE contract are in use; the ICE 5th Edition and the ICE Conditions of Contract for Ground Investigation. When using this system it is important that the developer or his advisers should check that the chosen geotechnical adviser has sufficient geotechnical skill to carry out the desk study, plan and supervise the ground investigation and interpret its results. It is possible to make use of the contractor's engineering skills only after the tendering process. Therefore the skills of the geotechnical adviser are extremely important.

The geotechnical adviser is expected to carry out a thorough desk study and plan an investigation appropriate to the needs of the developer. This is then used to prepare a specification and bill of quantities which, together with the conditions of contract, form the basis of the tender for the field and laboratory work to be carried out by a specialist contractor. Generally between three and four companies should be selected by the geotechnical adviser to tender for the field and laboratory work, on the basis of their previous experience of this type of work, the skills of their staff and the amount and quality of their equipment. The lowest submitted tender price is generally accepted but the contract is subject to remeasurement as the work proceeds. The final cost to the developer of the entire ground investigation will be the sum of the final contract price after measurement and the professional fees paid to the consulting engineer.

This system has been found to work well provided that:

- an adviser with a sufficient number of skilled geotechnical staff is engaged
- a thorough desk study, made by the geotechnical adviser, is used as the basis for the planning of any programme of drilling and testing
- not more than four specialist contractors are asked to tender and the selection of these companies is rationally and thoroughly carried out
- proper levels of supervision are provided by the geotechnical adviser in the control of field and laboratory work.

Supervision is the key to the successful use of System I. Many of the activities in ground investigation rely entirely on the use of correct methods of working to obtain a satisfactory result. For example, the Standard Penetration Test 'N' value is affected not only by its test apparatus and by the way that the test is performed but also by the way in which the borehole is made down to the level at which the test is to be done. The only way to guarantee that an 'N' value is correct is to observe the method of boring and of carrying out the test since the end result, by itself, cannot be checked.

In certain cases it may be advantageous for parts of the work to be done by the contractor on a dayworks basis. Under System I, the work to be carried out by the contractor must be closely defined before the contract is let and must be paid for at fixed rates independent of the time taken to carry it out. If the work is particularly important to the success of the investigation, if it is very complex, or if the geotechnical adviser needs to be able to vary the work as it proceeds, dayworks payments may be helpful. For example, dayworks could be used to pay for plate loading tests, for drilling and boring in key zones, or for time spent in investigating groundwater conditions. It is also possible to pay a specialist contractor to carry out the reporting of an investigation; this is better done on an hourly basis rather than by lump sums.

System I has the advantage of using forms of contract that are well known in the civil engineering construction field and it can be used to demonstrate cost-accountability through the tendering process. This is the most commonly used form of procurement for larger ground investigations and is therefore well understood. Its difficulties lie in the complexity of its contractual arrangements, the need to ensure that sufficient expertise and supervision are provided by the geotechnical adviser and the division of responsibility for the satisfactory outcome of the investigation between the geotechnical adviser and the contractor. It has frequently been said that the method of competitive tendering commonly associated with this system, and the consequent low prices paid to contractors for investigation work, is a major cause of low-quality investigation. This problem, however, is a consequence of too large tender lists prepared without detailed selection of tenderers. It is not necessarily a result of using the system.

System II *Package deal contract, with desk study, planning and execution of field and laboratory work and reporting being carried out by one company or a consortium.*

No formal conditions of contract exist for this system, although draft documents have been proposed in CIRIA Special Publication 45. Despite the lack of published conditions of contract, versions of this system are in common use to obtain ground investigations for low-rise building development. The system is also used for large site investigation contracts carried out abroad, for example in the Middle East.

In this system the developer selects up to three specialist ground investigation companies on the basis of past experience, reputation, and published information relating to specialists in the field. Information on companies and individuals is available from:

- The British Geotechnical Society
- The Association of Ground Investigation Specialists
- The Institution of Civil Engineers
- The Institution of Geologists.

The companies selected may be either ‘contractors’ or ‘consultants’ according to the British Geotechnical Society’s Directory, but they should have sufficient qualified and experienced staff to be able to carry out the proposed size of investigation. On the basis of a preliminary desk study, the companies offer to carry out a complete site investigation, including desk study, air photograph interpretation, design and execution of ground investigation and reporting, either for a lump sum or on the basis of measurement of work agreed as the investigation progresses. The specialist company that carries out the work is expected to supervise its own drilling and testing and will be liable under the 1982 Supply of Goods and Services Act both for the quality of work and for any recommendations that are made in the report of the investigation.

The advantages of System II to a developer are that a lump sum contract can be negotiated; this is obviously important when carrying out financial forecasting. A further advantage is that the responsibility for ground investigation is not divided between two parties, as in System I. Because of the cost to the tenderers of preliminary desk studies, it is unlikely that lump sum contracts can be used for very large civil engineering projects, but this type of procurement will certainly be more suited than System I to many low-rise building developments, because of its relatively simple contract documentation and its flexibility.

An advantage of this system is that the leading design professional (who might typically be an architect in the case of a low-rise building development) is not necessarily required to have geotechnical skill and experience of ground investigation techniques. If he does not possess such skill, however, it becomes extremely important that care is taken in the selection of ground investigation specialists who are suitable for the complexity of work to be carried out. A possible disadvantage of System II is the lack of well-tried and proven contract documentation. However, this does not appear to have prevented the successful use of this method of procurement in recent years. To overcome this it is suggested that the contract documents used are those given in the appendices to CIRIA Special Publication 45.

Planning and execution of ground investigations

Because the ground beneath shallow foundations is so variable, and may well have been altered in places by vegetation and previous activities of man, good planning is essential if ground investigation is to be cost-effective and provide worthwhile information of good quality. Desk studies (including examination of aerial photography) and the walk-over survey should be used to identify the likely soil conditions, and to assess the likely risks associated with building on the site under consideration. Boring and drilling, and in-situ and laboratory testing, should be planned to investigate the specific areas of engineering risk identified during the desk study and walk-over survey, using techniques appropriate to both the ground conditions and to the problems requiring solution. Examples of the information that can be obtained during desk studies are given in Digest 318. If a System I contract is to be used, it is essential that planning and supervising is carried out by a competent geotechnical engineer. Under System II the client will expect these activities to be completed as part of the package deal contract.

FURTHER READING

UFF, J F and CLAYTON, C R I. Recommendations for the procurement of ground investigation.
Special Publication 45. CIRIA. 1986.

UFF, J F and CLAYTON, C R I. Role of responsibility in site investigation.
Special publication 73. CIRIA. 1991.

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