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Chapter 40

The ground as a hazard

An appeal for an intelligent view of the ground

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CONTENTS

How humans interact with hazardous ground conditions governs the resultant ground risk. Potentially hazardous ground conditions frequently attract engineering development because of important aesthetic or economic considerations. Many are successfully undertaken, but success requires sufficient investment, sound ground knowledge and an appropriate design. Yet in many projects, the ground is the least well-understood material, and this can lead to expensive problems being discovered during the construction phase.

This chapter encourages the reader to become actively knowledgeable about the ground of their project by first discussing the main types of geological hazard which may be encountered on a UK engineering site or project. Secondly, sources of ground information (many of which are now freely available online) are discussed, along with a system by which these can be interrogated to increase knowledge of ground conditions and design an effective site investigation. Finally, the use and communication of an intelligent understanding of these conditions has been shown to be extremely important in the success of engineering projects, ensuring that the engineer avoids becoming a victim of potentially hazardous ground.

40.1 Introduction

Humans often see the ground as hazardous. However, the Earth is simply influenced by gravity, water, heat or lack of it, plants and animals, and the sun. Humans often make the ground hazardous (or rather, it is how we behave that increases risk) by where we have chosen to live and work. For example, crumbly cliffs may be hazardous, but they do not represent a risk until humans decide they like the view from the steep crumbly cliffs overlooking the sea, and make their home there. The success of humans as a species has propelled us to develop, live and work in areas which were previously uninhabited (e.g. steep mountains, bogs), often for good economic or social reasons. We have remarkably short memories of risks related to hazardous ground events and we frequently emotionally weight an advantage (e.g. a lovely view) over a disadvantage (unstable ground). Fortunately, because of modern advances in civil engineering, there are few environments that we cannot engineer if enough money, a good understanding of the ground and a suitable design are invoked. Ultimately, ground hazards only become risks if they are unforeseen and unmitigated (for detail on ground profiles see Chapter 13 *The ground profile and its genesis*). This introduction is therefore an encouragement to understand the ground better before attempting to engineer it.

Geotechnical engineering is one of the most challenging of engineering specialities because the ground is far more diverse and variable than any man-made material. Considering how important the ground is in the success of most construction projects (amazingly, it frequently keeps buildings upright, sometimes for many hundreds of years), it is one of the poorest understood of the materials we utilise on a regular basis. On the majority of projects, for example, we have a far better sampling and testing regime and an infinitely better understanding of the behaviour of concrete and grout mixes on site than we have of the ground – our ultimate material. The exception is, of course, when a contractor wants to make a claim for unexpected ground conditions.

On some projects it is clear that people end up as victims of the ground rather than understanding and mastering it. ‘Understanding the ground’ is, however, not the same thing as doing a ‘preliminary investigation’ (see Chapter 43 *Preliminary studies*) and a ‘design investigation’ (see Chapter 44 *Planning, procurement and management*). Understanding is the process by which ground information is made into a ground model, augmented if necessary, communicated to all the relevant parties in the project, and if possible, added to throughout the project.

Why bother understanding the ground better? Why not, as an engineer once asked, just drill a couple of boreholes, test what comes up and base your design on that? My response was to use an analogy: if the ground is represented by a wedding cake at the bottom of a black plastic bag, and the borehole is your hand reaching into the black plastic bag, completely blind, to grab a piece, you may end up basing your design on a rosebud. Boreholes represent a miniscule fraction of the ground and, moreover, the ground frequently does not consist of straight lines between two boreholes. Hence the ground in between the boreholes will not necessarily be the same as that recovered in the boreholes.

Many companies try to save money by having a ‘cheap’ site investigation, and this is a process in which data may be lost. As Chapman amply discusses in Chapter 7 *Geotechnical risks and their context for the whole project*, saving money with a ‘cheap’ site investigation is practically the worst investment in the construction industry over the long term – hence the inverted commas. However, despite improvements in standards of site investigation over the past few years (see Chapters 42 *Roles and responsibilities* to 48 *Geo-environmental testing*), there will always be economic downturns. 'Cheap' site investigations will always be sought and may not be avoidable, but can miss important changes in the ground. This is not only because fewer boreholes, maybe of a cheaper type, will give you less data, but because low-paid staff are frequently poorly trained in what they are logging – taking samples for testing, and the testing itself. Even with a full EC7-approved site investigation it is possible for important information about the ground to slip through the cracks between the specification and the interpretative report. So it is important to make the most of every piece of available information.

In geotechnical engineering we can compensate for less adequate site investigations by adopting a conservative design – by taking no risks, or alternatively by taking the basic minimal information available and taking the risk that the ground will be fine. However, those extremes have been shown repeatedly (Chapman and Marcetteau, 2004) not to be the smartest and most cost-effective solutions. Understanding the ground to the best of our ability, and designing with the ground in mind, makes the best economic sense (see also Chapter 2 *Foundations and other geotechnical elements in context – their role*).

40.2 Ground hazards in the UK

Most of the common types of hazardous ground in the UK are dealt with in this volume and the relevant sections are linked. These ground hazards can generally be grouped into three categories: geological hazards, geomorphological and topographical hazards, and anthropomorphic hazards, and are discussed below.

40.2.1 Geological hazards

This category includes the results of events that occur naturally on Earth which we consider unreasonable. Examples include dramatic geohazards such as volcanic activity – resulting in debris or mudflows, and earthquakes – resulting in the possibliliy of tsunamis. In the UK we are generally considered low risk for these hazards since we are a long way from tectonically active centres. However, we do have occasional earthquakes in certain areas and have (in the past) had tsunamis due to earthquakes or underwater landslide failures. Seismic hazards do therefore need to be considered for long-life projects, sensitive projects (such as large tunnels, nuclear power stations) and coastal projects. Volcanoes are even less common in the UK – the last ones to erupt on the UK mainland were probably about 55–60 million years ago. However, bear in mind that *many* of our soils and rocks contain layers of volcanic ash laid down or reworked within them, and these ash deposits frequently contain swelling clays which may precipitate or exacerbate landslips, slow down tunnelling operations, and impede soil handling and re-use (see section 40.2.2). If in doubt, the clay minerals need to be analysed.

The British Geological Survey (BGS) has very useful information, historical data and risk maps for these tectonism geohazards on their website.

The second part of this category includes ground types which are harder, weaker, softer, looser, have more and bigger holes or caves in them, are more variable, less stable, more aggressive, or contain water or gas at higher pressures than would be desirable. These types of ground are discussed in great detail in Section 3: Problematic soils and their issues, while folded or faulted rocks are dealt with in Chapter 18 *Rock behaviour*.

In an ideal engineering world, all geological deposits would be laterally extensive, of uniform and predictable thickness, and homogeneous in nature. Unfortunately the ground is usually variable. While it is possible to be exceptionally lucky and encounter tens of meters of thickness of well-behaved, unweathered, unfaulted, horizontally-bedded strata across an entire project site, it is actually not the norm. The reason for this is the variability of processes which contribute to the deposition of soils and rocks, and which alter them afterwards (see Chapter 13 *The ground profile and its genesis* for more detail). Generally the most uniform, homogenous and laterally extensive rocks are marine sediments, which can be deposited as essentially the same type of soil or rock over hundreds of thousands of kilometers; but do not be lulled into a false sense of security. Even amazingly thick, fully marine deposits sediments like Chalk, Carboniferous Limestone and London Clay vary vertically in strength, texture and permeability due to changes in water depth while they were being deposited. The nearer to the shore we get with environments of deposition, the more variable the sediments get (think Carboniferous Coal Measures, which were deposited in swamp to delta environments, or the Mercia Mudstone Group, which varied from desert to floodplain in origin). In addition, with worldwide fluctuations in sea level and the extremes of climate variation over geological time, we can end up with a stack of potentially very variable sediments indeed. Once we superimpose on this the deposition or intrusion of igneous rocks, or start to look at the processes of folding, faulting and metamorphosis, this variability increases further. However, it is important to remember that variability is still only a potential risk if it is not anticipated.

40.2.2 Geomorphological and topographical hazards

This category includes all the hazards which are primarily concerned with how gravity and erosion affect the ground, and how water interacts with the ground near or above its surface. Landslips and landslides, mudslides, coastal erosion and flood risk all come into this category. Tectonism (the action of the Earth's tectonic plates moving in relation to each other, resulting in, amongst other things, mountain-building events) has a lot to answer for. Topographically higher ground is (in geological terms) just waiting for gravity to act on it, to be weathered and fall down, to be talus until it falls further and gets washed into a river, and eventually it breaks down into sand and gets deposited in the sea as sediment. It is important to recognise once more that humans love to build in high places, near the sea and everywhere in between – but that hilly areas can fall down, and that coastal and low-lying areas often flood.

40.2.3 Anthropomorphic hazards

In the last few thousand years, humans have had an enormous impact on the surface and sub-surface of the Earth. In the last 200 years we have changed the planet more than in all the previous several thousand years put together. Our skills as humans have, in this short time, enabled us to use fossil fuels to drive transport and industry (often leaving large holes in the ground where they were abstracted from) and our skills in civil engineering have enabled us to master many formerly forbidding environments and locations.

An awareness of how an area has changed over time may reveal a wide range of human activities, many of which will have implications for particular projects. For example, in the area of east London where I used to live there was, in chronological order: a Bronze Age trackway development (archaeology), a coal gas production plant (probable contamination), Joseph Bazalgette's Northern Sewage Outfall (Victorian tunnels and obstructions), and past and present industry associated with the London Docks (archaeology, pollution *and* obstructions). Superimposed on these layers and issues were the abundance of munitions dropped in the area during the Second World War 1939–1945 (possible unexploded ordnance), the relatively new Dockland Light Railway and its tunnels, and normal everyday services. There are many companies who will, for a reasonable fee, help steer a way through this potential multiplicity of man-made hazards, provide site-specific environmental risk information and historical mapping for a given site area.

40.3 Predicting what the ground may have in store

Using personal computers, we are fortunate to be able to access more information about the ground of a potential site faster than ever before. Programs such as Google Earth can give us aerial imagery which previously required long waits or searches, and possibly special viewing equipment. Not only can we look up our site in seconds, but in one click we can discover what volcanoes or earthquakes have occurred nearby (try ticking Gallery in the Layers folder and then go to Old Hawkinge in Kent if you want to find an earthquake in the UK), the approximate elevation, and distances between interesting points. Using Street View within Google we can get a close-up of topography and buildings in the area. Using the Historical Imagery facility (in the View dropdown menu) we can even see if the area has changed over the previous few years – useful for landslip or redevelopment projects.

Armed with Google Earth and a geological map of your site area, it is possible to assemble a great deal of quality information to assist your understanding of the ground in your project area within an hour or so, using the topography–water–anything odd (TWA) system:

Topography Running the cursor over the aerial view of the site and the surrounding area will give you an idea of variations in topography. The next question to ask is – does the topography make sense and, if not, why is it like this? If you look at the geological map, is there an obvious reason?

Water Where is the water in this area? Is it in rivers, streams, lakes, marshes, an estuary, the sea? Does it make sense where the water is, or is there poor drainage due to impermeable strata? Is the site in an obvious flood risk area (i.e. at or near sea level, or at the same level as the local rivers run)? Is there no water at all in this area? Why? Where could it have gone?

Anything odd? Is there anything that does not seem quite right, or any colours or shapes on the ground that do not make immediate sense in terms of natural or human activity? Are there any areas where buildings 'should be' but are not? Road names can be useful indicators of geological or former engineering hazards. Are there road or lane names near your site which include such words as: Watermeadow, Flood, Spring, Cave, Swallow or Swallowhole (possible flood or solution hazards), Brick, Kiln, Mine or Quarry (former mining or quarrying), Undercliff, Zigzag, Slip (possible ground instability problems)? Cave or Dene can also indicate natural or man-made cavities. In Google Earth, Street View can be another useful source of information, picking up uneven ground surfaces, major cracks in walls, and repeatedly re-made roads.

If, for any reason, you cannot use Google Earth, there are an increasing number of other remote viewers which are free to use such as Yell.com and Bing Maps, both of which allow 3D inspection of built sites in UK cities.

40.4 Geological maps

Geological maps can, to the average engineer, be slightly confusing. They use bizarre colours and odd symbols. However they do contain vast amounts of useful information if you have a little patience. If you want help, ask a geologist or put 'how to read geological maps' into a search engine. A note of caution: engineers often consider geological maps to be 'gospel'. They are not – they are produced by clever geologists who do a lot of field work, incorporate as many good quality boreholes as possible, and then extrapolate their findings. Without X-ray vision, their geological maps, while a very good best guess of what the ground consists of, can occasionally be wrong. Another important point to mention here is that just because a geological formation is called Kimmeridge Clay, or Lias Clay, or Gault Clay, etc., it does not mean that the formation is only clay. Likewise, formation names with 'sand' at the end (e.g. Lower Greensand, Arden Sandstone) rarely consist entirely of sand. Soils and rocks of any age or name usually contain naturally occurring harder layers, or weaker layers, or indeed sandier layers – be prepared and read the geological map carefully. Again, the BGS has very useful tools on their website such as the lexicon of named rock units (also useful for looking up soils – 'rock' means rock *or* soil in this instance). The BGS onshore borehole historic database is now largely free, too, and in combination with the lexicon will probably tell you far more than you ever thought you needed to know about the strata in the area of your project, and this information will act as the basis for a refined ground model based on a well-designed site investigation.

40.5 Conclusions

Having a better understanding of the ground is a huge leap forward and will help enormously in planning and designing for a project, but what appears to make the greatest difference is communicating this understanding to others (Skipper, 2008). I first experienced this principle in 2003 when working on the Dublin Port Tunnel, where I found that communication of the ground model to *all* levels of staff (from site investigation staff to designers and foremen to site workers) made a huge difference to their collaboration, communication and feedback. This improved level of understanding allowed the use of the observational method in what was complex and challenging geology in a very sensitive location (Long *et al*., 2003). Since then I have been involved in the use of this principle in a wide range of projects from the small to the very large. I have seen it result in a wide range of improvements, from better specified site investigations to improved ground descriptions and interpretations, in turn leading to optimised design and better risk management. So to conclude, an intelligent understanding of the ground makes the best technical and economic sense, and communicating this understanding with, and to, others, maximises this value to engineering projects.

40.6 References

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40.6.1 Further reading

Bryant, E. (2004). *Natural Hazards*. Cambridge, UK: Cambridge University Press, 328 pp.

Griffiths, J. S. (2002) (Comp). *Mapping in Engineering Geology*. London, UK: The Geological Society, 287 pp.

Mitchell, C. and Mitchell, P. (2007). *Landform and Terrain, the Physical Geography of Landscape*. Birmingham: Brailsford, 248 pp.

40.6.2 Useful websites

British Geological Survey, borehole record viewer; www.bgs.ac.uk/data/boreholescans/home.html

British Geological Survey, Earth hazards information and contacts; www.bgs.ac.uk/research/earth_hazards.html

British Geological Survey, lexicon of named rock units; www.bgs.ac.uk/lexicon/

Google Earth; www.google.com/earth/index.html

Ground viewers/remote sensed imagery; www.yell.com/map/ and www.bing.com/maps/

It is recommended this chapter is read in conjunction with

- Chapter 7 *Geotechnical risks and their context for the whole project*
- Chapter 8 *Health and safety in geotechnical engineering*
- Chapter 13 *The ground profile and its genesis*

All chapters in this book rely on the guidance in Sections 1 *Context* and 2 *Fundamental principles.* A sound knowledge of ground investigation is required for all geotechnical works, as set out in Section 4 *Site investigation.*