HS2

HS2 ground investigations

A non-technical guide

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Department for Transport

High Speed Two (HS2) Limited has been tasked by the Department for Transport (DfT) with managing the delivery of a new national high speed rail network. It is a non-departmental public body wholly owned by the DfT.

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Essential Q&A

This document is a guide to the ground investigation work being carried out as part of the development of the High Speed Two (HS2) railway. It explains why HS2 Ltd is undertaking the investigations and describes each of the main techniques that will be used.

What is HS2?

High Speed Two (HS2) is the new, high-speed north-south railway. Phase One of HS2 will connect London with Birmingham and the West Midlands. Phase Two is split into Phase 2a, linking the West Midlands and the North via Crewe, and Phase 2b, which will extend the route to Manchester and Leeds.

What is ground investigation?

Ground investigation (GI) is the examination and study of the soil, rocks and groundwater below the surface. A number of methods are used to obtain samples and to monitor and test them.

Boreholes are usually formed by a mechanical rig. However, in all instances this is preceded by surveys and hand digging a pit to avoid interference to existing utilities.

Ground investigation may also require manual or mechanical excavation of a trial pit or trench.

Laboratory tests are also carried out on many of the samples to supplement the information gathered on site. The aim is to discover the properties, especially the strength, of the soils and rocks in a particular place, and the nature of the groundwater, in order to provide information before design and construction of the railway begins.

Why does HS2 Ltd need to undertake ground investigation?

Primarily, we need information about the ground that we want to build the railway on (or in). This information will enable designers to develop solutions for the structures we want to build, such as bridges, viaducts, tunnels, stations and depots. It will also provide information for the design of road and river diversions, tunnels, cuttings and embankments.

The ground investigation will also provide information on the nature and extent of potential contaminated land and landfills which could be disturbed by the main works, as well as confirming the location of utilities and potential utility diversions.

Ground data from ground investigation will ensure that the contractors designing and building the main works can do so safely, economically and efficiently. The information will also reduce the risk of encountering unexpected ground conditions and groundwater during construction.

In civil engineering and building, unexpected ground conditions are the most common reason for projects ending up significantly late or over budget. It is vital to know about the conditions before construction will begin.

What does HS2 Ltd hope to gain from the ground investigations?

Information obtained from the ground investigation will provide engineering data about the existing ground conditions, which will enable the new railway to be safely and economically constructed. For example, we will use the information to confirm the best methods for excavating tunnels and the most appropriate foundations for bridges, viaducts and stations.

Does HS2 Ltd have existing information that it can use instead?

Early work on the project relied on records of previous ground investigations and other geological information held by the British Geological Survey and others. This information on its own is insufficient for HS2 and information is sparse in some of the areas, particularly the rural ones and in many cases does not reach to sufficient depths or include adequate details of material properties.

Where are the ground investigation sites and how many are there?

The ground investigation will take place along the route of the new railway and also outside the line of route and stations – for example, at the sites of proposed depots or highway or utility diversions.

Ground investigation work will take place at numerous individual locations affecting different landowners.

How long will the ground investigation works take?

The investigations are split into a number of works packages, each relating to a specific length of the route (or, for example, a tunnel, station or depot area). Each package typically takes several months to complete, including work on site, laboratory testing and reporting of the results. Investigations on site can take a matter of hours, or days, depending on the location.

Additional investigations may have to take place if something unexpected is found and further information is required.

Does HS2 Ltd have permission to undertake the work?

The High Speed Rail (London – West Midlands) Act 2017 came into force on 23 February 2017, authorising the construction of Phase One of HS2. The High Speed Rail (West Midlands – Crewe) Act followed on 11 February 2021, authorising the construction of Phase 2a.

The Acts mean the Secretary of State for Transport may authorise entry to non-residential land within 500 metres of the proposed route of a high-speed railway line in Great Britain, for survey purposes.

As there is not yet a Bill or Act for Phase 2b, we can only access the land required with the landowner's permission. 'Access licences' are required for ground investigations and these are negotiated with the landowner.

Given the scale of the investigations, each works package (that is, a number of site locations grouped together) will be assessed to see whether any planning or environmental consent would be needed, and to help ensure that the contractor does not start work until given consent.

Where appropriate ground investigation contractors will need to obtain Section 61 consents from the local council. A Section 61 consent is an agreement between the contractor and the council. It covers noise levels, hours of work and various other requirements.

What will the public see?

The ground investigation works are not very different from the type of works that we see on our roads and pavements every day – for example, in towns or cities you may see barriers around a small section of a pavement or road, with a diversion around it for traffic or pedestrians.

Many of the ground investigation site locations are in rural areas and will not be visible from the road; some may be on private property with no public access – in a farmer's field, for example.

What will the sites look like afterwards?

Following completion of work our contractors will be required to leave every site as they found it – whether that means laying new turf on a patch of grass or tarmacking a small section of road. Landowners will be compensated for any damage arising from works, although the timing of investigations and access routes will be negotiated to minimise the effects of the disturbance. Sites will always be left in a safe condition.

How will HS2 Ltd make sure that the ground investigations are safe?

Safety is a top priority for the ground investigations. We will ensure that the site risks associated with the ground investigations are identified, assessed and managed. Prior to commencement of work, we will assess the contractors' health and safety performance. Security will be managed at all stages, so sites are safe and secure during and outside working hours.

In-ground investigation techniques

This is a summary of the main investigation techniques used to undertake ground investigation. This is what people will typically see on a site or behind a hoarding or barrier.

Plate load tests. Image courtesy of Structural Soils.

Plate Load Tests

Plate load tests are a simple, commonly used technique for measuring the stiffness and strength of the ground. The test involves applying a load to a plate of known size while measuring how much the ground moves as a result. This test is typically undertaken at the ground surface or at the bottom of a trial pit but can also be carried out at the base of boreholes.

Cable percussion borehole

This technique uses a mobile A-frame rig, around seven metres high, to drill a small borehole into the ground. The rig is towed into position by a truck or pick-up before being assembled. A diesel engine is used to power the rig. Occasionally, if access is very difficult, the rig is transported in parts and assembled on site.

A variety of tools are raised and lowered, either by a cable and winch or a series of steel rods, to drill the borehole, take samples or carry out tests in the borehole.

Cable percussion borehole. Image courtesy of CH2M.

In addition to the noise of the engine, short bursts of noise may occur as tests are performed or samples are taken using a percussive action. Temporary steel casing is generally used to prevent the sides of the borehole from collapsing; this casing is periodically driven into the ground as the borehole is deepened.

A range of tests can be carried out in the borehole while it is being drilled to establish the properties of the ground.

The core can be sunk to a depth of 30-40m.

A rig is typically in place for a few days, depending on the depth of the borehole required and the hardness of the ground.

This method is used in rural and urban locations. It requires two people, working in an area of around 40 square metres (m2).

On completion, the borehole is either back-filled with the excavated soil or instrumentation is installed – for example, to monitor water levels. Where an installation remains in place, the only thing visible is a small cover, level with the ground, or a small steel barrel to provide protection.

On completion, boreholes are filled or further instrumentation installed. Image: HS2 Ltd.

Drilling of a small borehole via a rotary core rig. Image: HS2 Ltd.

Rotary core borehole

This technique uses a drill, mounted on the back of a truck or towed into position, to drill a small borehole into the ground. A diesel generator is needed – either on the truck or on a separate trailer.

A variety of steel bits can be used to drill the hole. These either form an open hole with no sample recovered, or they recover a core of rock or soil for examination and laboratory testing. The boreholes typically range from 20-40m deep, but where we need to investigate the soils and rocks at and below tunnel level, they may be up to 100m deep.

A range of tests can be carried out in the borehole while it is being drilled to establish the properties of the ground.

The rig may be in place for as long as a few days, depending on the hardness of the ground being examined. This method is used in rural and urban locations and requires two people working over a large area (around 50m2).

On completion of the work, the borehole is either back-filled with excavated soils or instrumentation is installed – for example, to monitor water levels. Where an installation remains in place, the only thing visible is a small cover, level with the ground, or a small steel barrel to provide protection.

Hand auger borehole

An auger is rotated by hand into the ground to the required depth (around 0.5 to 2.5m) so that a sample can be retrieved, recorded and tested.

This technique generally has limited use, but can be appropriate in places where access is difficult.

Concrete core (structural investigation)

This technique is used to investigate the thickness and composition of existing concrete structures, such as bridges, retaining walls, buildings and pavements. A small piece of concrete is cored, extracted from the structure and sent for examination and laboratory testing, and the hole is filled in.

This method requires only one person and can usually be completed in a matter of hours.

Hand auger borehole. Image courtesy of Archway Engineering.

Concrete core (structural investigation). Image courtesy of CH2M.

Cone penetration testing

This technique involves pushing a small cone (a steel point, around 5cm in diameter) into the ground on the end of a series of rods. The cone is mounted inside a truck or a smaller vehicle, which powers a motor that pushes the cone downwards.

The cone is generally used to investigate soft soils. Sensors on the cone can measure a variety of properties of the ground, including resistance, friction and water pressure. The results enable us to produce a profile of the layers the cone passes through and to assign properties to the different materials. This technique is normally used in rural locations where the ground is soft, such as river flood plains. It requires two people, but tests are generally short (30-60 minutes) so they can carry out multiple investigations each day.

Cone penetration testing. Image courtesy of CH2M.

Dynamic probing

This technique can be considered a simpler version of cone penetration testing, as the equipment is usually wheeled into position by hand and requires only one person to operate it. The operator uses a motor-driven hammer to push a cone into the ground.

The tests can also be carried out using equipment mounted on small drill rigs, such as those commonly used for window and dynamic sampling.

As with cone penetration testing, the technique measures the density of the soil and tests for pressure. The results are used to create a profile of the relative strengths of the materials.

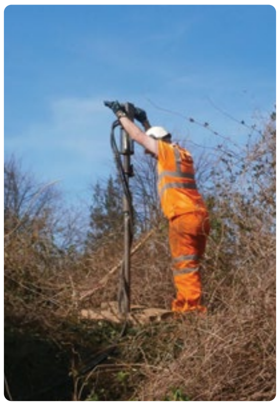
The probe reaches a depth of up to 10m depending on the ground conditions and many locations can be investigated in one day. The equipment can be used in urban and rural locations, and on difficult-to-access sites.

A motor-driven hammer pushes a cone into the ground for dynamic probing. Image courtesy of CH2M.

Window and dynamic sampling

Window sampling uses a small rig that is wheeled into place on tracks.

A steel tube is rotated into the ground to a depth of up to 5 metres. The tube is then extracted and a section removed, or a flap is opened, to view a sample of the sub-surface soil profile and structure. Samples can be taken for laboratory testing. This technique can be used in multiple locations in one day, and in both urban and rural locations. The equipment requires one or two people to operate.



In difficult-to-access locations, hand-held equipment can be used. Image courtesy of CH2M.

Surface water sampling.
Image: HS2 Ltd.

Surface water sampling

This technique is simply the collection of a water sample at a particular location. Some simple tests can be carried out on site, but generally the sample is sent to a laboratory.

Pits and trenches

Pits and trenches are dug to investigate soil conditions and conduct other tests. A pit is typically 1m x 4m in area and is dug to a depth of 2-3m, using a mechanical digger (or shovels, if the area is not accessible to vehicles).

A trench is a pit typically around 1m wide and 10m long. It is dug to around 4-5m in depth.

Pits and trenches enable us to observe the profile of the ground from the surface and obtain samples for testing. If it is critical to closely examine the ground, the sides of the excavation are shored with timber or a purpose-made support system before any work is carried out. Excavations reinforced in this way are called either observation pits or trenches.

Pit or trench dug to investigate soil conditions from the surface and to obtain samples. Image: Hs2 Ltd.

Geophysical surface testing techniques

This is a summary of each of the testing techniques used to undertake ground investigations. These techniques are efficient, discreet and cost-effective ways to collect data and identify underground features.

Electromagnetic conductivity. Image courtesy of AGS.

Electromagnetic conductivity

Electromagnetic conductivity tests the ability of the ground in a given area to conduct an electric current. Variations in conductivity reflect the presence of different soils and rock, groundwater and buried objects.

Electromagnetic conductivity surveys are fast and accurate – the instruments are portable and easy to carry around a site, and don't need to be in contact with the ground.

Surveys can locate underground metal tanks, utility pipes and potentially contaminated groundwater. They are used to identify areas that need further geophysical or 'in-ground' investigation.

Large-scale ground-penetrating radar can be attached to a van. Image courtesy of Macleod Simmonds.

Ground-penetrating radar

Ground-penetrating radar (GPR) uses radar pulses to create a profile of what the ground appears like beneath the surface.

GPR can be used in a variety of ground conditions, including rock, soil, pavements and structures. The radar can detect objects, changes in material, voids and cracks. The radar may reach up to 15m underground or only a few centimetres, depending on the type of soil and terrain.

The GPR can be pushed along by hand, attached to a buggy or – on a larger scale – can be attached to a van or tractor.

Magnetometer

A magnetometer measures the strength and sometimes the direction of a magnetic field. By detecting changes in an area's magnetic field, a magnetometer can indicate the presence of buried objects.

No ground contact is necessary.

Magnetometer.
Image courtesy of AGS.

Microgravity

Microgravity surveys are typically used to detect underground cavities (both natural and man-made) or changes in ground density.

Minimal ground contact is necessary.

It is vital to identify possible voids underground (for example, unrecorded, abandoned chalk mines at shallow depth) before construction begins; otherwise, the ground could become unstable and hazardous.

Microgravity.
Image courtesy of AGS.

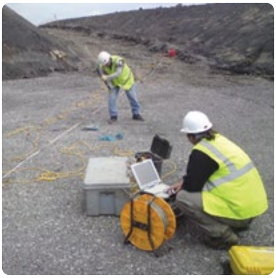
Resistivity

Electrical resistance meters are used to detect and map underground features and patterns.

The technique uses steel pegs inserted into the ground at regular points. Resistance is measured by introducing an electric current into the ground via the pegs and recording the resistance between other sets of pegs.

A series of measurements is used to build up an image of the underground features.

Resistivity.
Image courtesy of AGS.



Seismic refraction and reflection. Image courtesy of AGS.

Seismic refraction and reflection

These methods use seismic waves. They measure the soil and rock layers in order to understand the ground conditions and structure.

Seismic waves are generated by striking the ground with a hammer. Monitoring instruments called geophones, laid out in a line along the ground, record when these waves reach the surface again.

Refraction and reflection are closely related – in the refraction method, the waves change direction when they reach boundaries between layers of different material, before ultimately returning to the surface.

Reflection relies upon the seismic waves bouncing off the surface of stiffer layers of material and returning to the surface.

By studying the timing of the waves returning to the surface, it is possible to build up a profile of the ground and its variation in physical stiffness.

The testing programme overlaps with the taking of samples on site, and is therefore carried out in phases. A test may take anything from a few minutes to several days; the whole programme for each testing contract may last a few months.

Laboratory testing

Laboratory testing is carried out on samples collected during the ground investigation. It allows us to understand the properties and behaviour of the ground beneath a specific site. In this way, it supplements tests carried out on site and any relevant published information.

Core samples undergo physical and chemical laboratory testing. Image: HS2 Ltd.

Laboratory testing is divided into two broad categories: physical and chemical.

Physical tests

Physical tests provide information on the strength, stiffness, compressibility and permeability of different soil and rock types. We are also interested in how these qualities vary naturally within each material, either with depth or across a particular site.

The test results are interpreted by geotechnical engineers and used in calculations for the safe and cost-effective design of foundations, ground retaining structures, earthworks, tunnels and excavations.

Chemical tests

Chemical tests provide information on any negative effects that soils and rocks may have on construction materials, in particular, concrete. Testing also confirms the type and extent of any contamination that could affect construction workers, nearby residents, agricultural land / livestock, or the environment.

The knowledge gained from testing allows us to identify contamination sources and hazards and deal with them appropriately and safely, during and after construction.

In addition, we use this information to determine where we can appropriately dispose of any waste materials.

Notes

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