HS2

Tunnel construction and methodology

This factsheet outlines the range of tunnelling methods that are expected to be deployed on the Proposed Scheme, the factors that influence the choice of method and the means of mitigating the potential construction and operational impacts associated with tunnelling.

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N30

1 Introduction

1.1.1 High Speed Two (HS2) is the Government's proposal for a new, high speed north-south railway. The proposal is being taken forward in phases. Phase One will connect London with Birmingham and the West Midlands. Phase 2a will extend the route to Crewe. The Western Leg of Phase 2b comprises an extension of the network to Manchester and a connection to the West Coast Main Line at Golborne, and is referred to as the Western Leg hybrid Bill. The Eastern Leg of Phase 2b currently comprises an extension of the network from the West Midlands through the East Midlands to Leeds.

1.1.2 HS2 Ltd is the non-departmental public body responsible for developing and promoting these proposals. The company works to a Development Agreement made with the Secretary of State for Transport.

1.1.3 The construction and operation of Phase One of HS2 is authorised by the High Speed Rail (London – West Midlands) Act (2017). In July 2017, the Government introduced a hybrid Bill to Parliament to seek powers for the construction and operation of Phase 2a.

1.1.1 In February 2020, the Government announced its intention to draw up an Integrated Rail Plan. This will recommend a way forward on scoping, phasing and sequencing the delivery of HS2 Phase 2b, Northern Powerhouse Rail, Midlands Rail Hub and other proposed rail investments across the north. At the same time, the Government asked HS2 Ltd to prepare the Western Leg hybrid Bill, provided it does not prejudge any recommendations or decisions that will be taken in this plan, which will be published by the end of the year.

1.1.2 It is intended to deposit a Western Leg hybrid Bill seeking powers to construct and operate this phase in Parliament in early 2022 or sooner if possible (the Proposed Scheme). The work to produce the Bill will include an Environmental Impact Assessment (EIA), the results of which will then be reported in an Environmental Statement (ES). The ES would be submitted alongside the Bill when it is introduced to Parliament. As was the case with Phase One and Phase 2a, when the Bill is introduced to Parliament the Secretary of State will also publish draft Environmental Minimum Requirements (EMRs). The EMRs will set out the environmental and sustainability commitments that will be observed in the construction of the Proposed Scheme.

1.1.3 A series of information papers were produced for the Phase One and Phase 2a hybrid Bills, explaining the commitments made in those Bills and EMRs. It is the Secretary of State's intention to follow a similar process for the Western Leg Bill. These information papers will be used to provide information about the Proposed Scheme itself, the powers contained in the Bill and how decisions on the Proposed Scheme have been reached. It is currently proposed that these information papers for the Western Leg of Phase 2b will be published at the time the Bill is introduced in Parliament.

1.1.4 The Secretary of State for Transport will be 'the Promoter' of the Western Leg Bill. The Promoter will also eventually appoint a body responsible for delivering the Proposed Scheme under the powers to be granted by the Bill. This body will be known as the 'nominated undertaker'. There may well be more than one nominated undertaker. However, any and all nominated undertakers will be bound by the obligations contained in the Bill, the policies established in the Western Leg EMRs and any commitments provided in the Western Leg information papers.

1.1.5 These Western Leg factsheets have been produced to provide information on the emerging proposals for measures to manage the design process for the Proposed Scheme and to control impacts which may arise from the construction and operation of the Proposed Scheme. These measures may then be applied to the Western Leg as commitments made through the eventual Bill, EMRs or information papers.

2 Overview

2.1.1 This factsheet outlines the range of tunnelling methods that are expected to be deployed on the Proposed Scheme, the factors that influence the choice of method and the means of mitigating the potential construction and operational impacts associated with tunnelling.

2.1.2 Tunnelling is often necessary on railway lines where, due to the rolling nature of the landscape, it would not be possible to align the track without steep inclines, which are not compatible with railway operations. This is also the case for the Proposed Scheme.

2.1.3 Tunnels have also been introduced into the Proposed Scheme for environmental reasons, for example, to pass beneath built-up areas where disruption at the surface would be severe if a tunnel was not provided.

3 Tunnels on Phase 2b Western Leg

3.1.1 A brief overview of the types of tunnel planned for the Proposed Scheme is as follows:

- **cut-and-cover tunnel** – where a trench is excavated and a concrete structure with a base, roof and walls is constructed in the trench. Fill material and soil is then used to backfill the trench and cover the top. The ground above is then restored and graded to blend it into the surrounding landscape. See Figure 1 below for the cross section of a typical cut-and-cover tunnel;

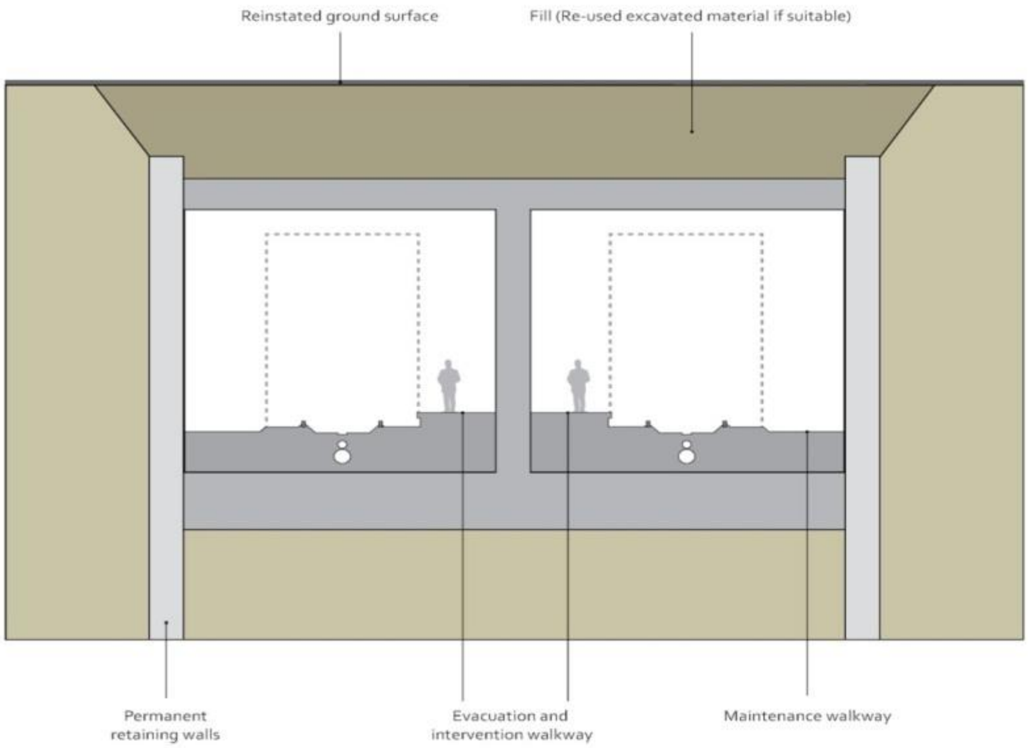
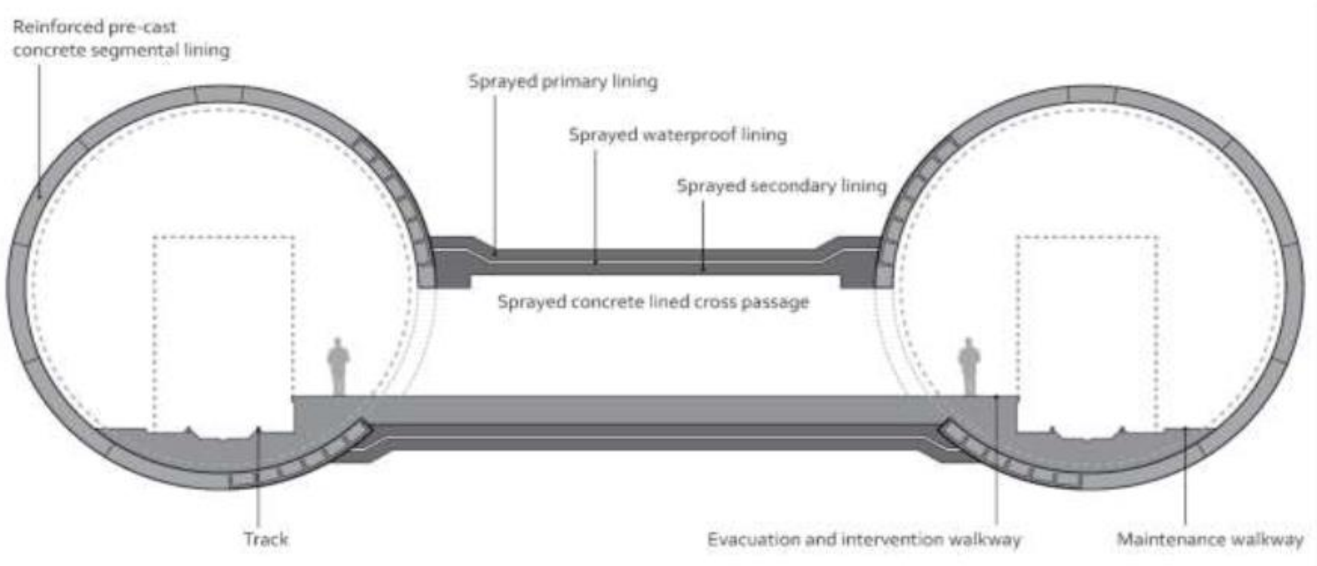


Figure 1: Cross section of a typical cut-and-cover tunnel

- **bored tunnels** – where two parallel tunnels, each containing a single rail track, are constructed. This can be done by either using tunnel boring machines (TBMs) or by excavation of a single-bore tunnel with mechanical plant. The Proposed Scheme includes approximately 19km of twin-bore tunnels (the Manchester tunnel and Crewe tunnel). These are planned to have an internal diameter of 8.8m for the Crewe tunnel and 7.55m for the Manchester tunnel. See sections 4 and 5 below for further information on tunnel construction; and

- **Mined tunnel –** similar to bored tunnels above, however this does not make use of a TBM but uses more conventional tunnelling methods including roadheaders and excavators (please see below). On the Western Leg, the tunnel cross passages on bored tunnels are likely to be mined (see below).

3.1.2 For safety reasons, when bored tunnels exceed 500m in length, they are required to have cross passages to connect the two tunnel bores as well as escape walkways that run the full length of the tunnel and are connected to the surface at tunnel portals. Cross passages and escape routes are required to provide safe exit routes and emergency services access in the event of an



emergency. Figure 2 below shows a typical cross-section of a twin-bored tunnel with cross passage.

Figure 2: Cross section of a typical twin bore tunnel with cross passage escape route

3.1.3 On long tunnels, ventilation shafts may also be required at intermediate points along the tunnel to provide further emergency service access and evacuation points. Please see the Phase 2b Western Leg Factsheet: Tunnel shafts and portals for further details.

4 Tunnel construction strategy

Bored tunnels

4.1.1 Bored tunnels can be constructed either by starting from one entrance and constructing the whole length of the tunnel or by starting from both entrances and meeting at an intermediate shaft. The expected construction strategy would be to construct tunnels from the most suitable entrance or entrances, based on:

- Sufficient space to establish a main construction compound at the starting location. The site a TBM is launched from requires a much larger construction compound than a TBM retrieval site;
- distance from sensitive locations;
- ease of access for logistics by road and/or rail;

- impact on overall construction programme (i.e. working from both ends of a long tunnel can reduce overall time to build); and
- economic use of plant and machinery.

4.1.2 Main tunnel worksites would be required for the removal of excavated material from the tunnel. They also form the main logistics area to supply construction material and operatives into the tunnel. Depending on the construction method, the main worksite may also contain an area for casting concrete tunnel segments or the treatment of spoil in the event a slurry TBM is used.

Cut-and-cover tunnels

4.1.3 Cut-and-cover tunnels are constructed either in an open excavation or in a retained excavation.

4.1.4 The open excavation method involves excavating from the surface. Once the final depth is reached the tunnel floor is constructed, followed by the walls and roof to form a twin-cell box. Cut-and-cover tunnels in open excavation are generally constructed in shorter bays. The bays gradually advance over the full length of the tunnel section, with excavation being carried out from the ends of each box section. On shorter lengths of cut-and-cover tunnel the full tunnel length could be excavated at the same time.

4.1.5 The retained excavation method involves first constructing the walls using diaphragm walling or bored piling, followed by excavation and construction of the roof. Excavation of the tunnel is then undertaken beneath the roof slab from the open ends of the box. This method is likely to be adopted where space limitations restrict the width of an open excavation with side slopes.

Mined tunnels

4.1.6 For the emergency cross-passages between the main rail tunnels, and for the ventilation connections between the rail tunnels and vent shafts, tunnels may be mined using excavators, depending on the groundwater, ground conditions and length of drive.

4.1.7 Following a short initial excavation, the primary tunnel support is installed (see Figure 3 below). This may consist of rock bolts and sprayed concrete in rock, or sprayed concrete in clays and soils. This initial excavation is then enlarged by cyclic excavation and lining to form the required tunnel geometry.

4.1.8 In the case of emergency cross-passages and connections between the rail tunnels and vent shafts, excavated materials would be removed using the TBM conveyor belt or narrow-gauge temporary railway.

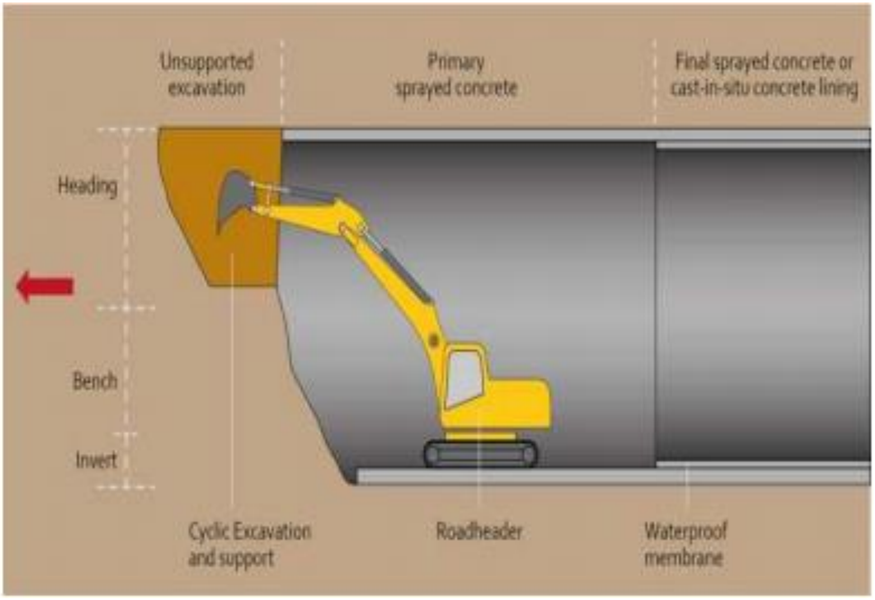


Figure 3: Mined excavation by conventional methods

5 Tunnel boring machines

5.1.1 HS2 Ltd has put together a high performance TBM specification that is specifically designed to limit both tunnel construction risk and ground movements to a practical minimum. The TBMs used to construct HS2 will be purpose-built machines, using proven state-of-the-art technology and will operate 24 hours a day, seven days a week. They will be designed specifically for the project to ensure their reliability of performance, settlement control and to cope with the range of ground conditions expected along the Proposed Scheme.

5.1.2 During the Jubilee Line extension, HS1 and Crossrail projects, bored tunnels were driven successfully through ground conditions that would once have been considered extremely difficult, and similar to the ground conditions on some of the HS2 tunnels, proving the capability of modern construction techniques.

5.1.3 There are several types of TBM that employ different methods of supporting the tunnel face during excavation depending on the ground conditions, but they all involve essentially similar construction operations in terms of logistics. More details can be found in the HS2 “Impacts of Tunnelling in the UK” September 2013 Report[1].

5.1.4 To ensure the TBMs are operating safely, information will be relayed to a dedicated monitoring room manned by suitably experienced engineers. The

[1] http://assets.hs2.org.uk/sites/default/files/inserts/Impacts%20of%20tunnels%20in%20the%20UK.pdf

monitoring room will have displays of real-time surface, subsurface and tunnel movements, together with TBM tunnel progress and TBM parameters.

5.1.5 This will ensure that the tunnel construction is being carried out to specification and that ground movements and temporary vibration effects remain within acceptable limits.

6 TBM operation

6.1.1 The TBMs will weigh over 1,000 tonnes when fully operational. They will be delivered in smaller components and assembled near the tunnel entrance.

6.1.2 Where sufficient space is available, the TBM will be fully assembled before launch, with all back-up equipment installed. Otherwise, the TBM will be advanced and a sufficient length of tunnel constructed to allow the back-up equipment to be assembled in the tunnel.

6.1.3 Where necessary, ground treatment will be carried out around the TBM launch chamber structure to allow the TBM to be buried safely. This will also allow the full stabilising effects of the TBM to be brought into operation.

6.1.4 Once the TBM is launched, the following tunnel construction cycle will begin:

- excavation will be undertaken one tunnel lining ring[2] at a time. First the TBM will excavate a short section of tunnel. Next, the tunnel lining ring segments will be built within the tail-skin of the TBM using a mechanical erector to form a complete ring. Following this the process is repeated and excavation for the next ring will be completed. The TBM is incrementally moved forwards using hydraulic jacks shoving off the previously erected tunnel lining ring; Figure 4 below shows the layout in a typical TBM.

[2] The tunnel will be built progressively through the building of joined ‘rings’ approximately 1.5 m in length.

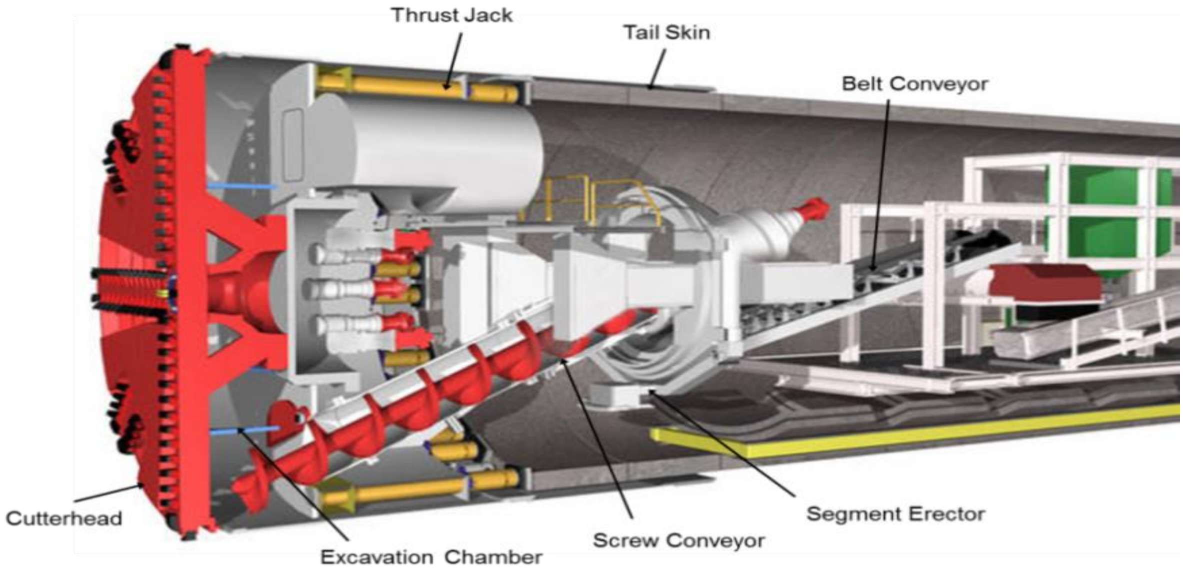


Figure 4: Sectional View of TBM Copyright Herrenknecht

- The TBM excavates a slightly larger diameter than the tunnel shield to provide space for control of the alignment. This additional space together with the thickness of the shield skin and the outside of the segmental tunnel ring means there is a gap between the excavated surface of the ground and the outside of the ring;
- The gap is filled by injecting grout around the outside of the tunnel lining rings. This is carried out as a continuous process through grout-tubes incorporated within the tail-skin of the TBM to fill the voids between the tunnel lining rings and the excavated surface of the ground behind;
- materials (such as tunnel lining rings and grouts) will be delivered to the TBMs via the portal by a narrow-gauge construction railway, special tunnel vehicles or other system such as pumping from the surface; and
- excavated materials may be removed by railway, specially designed rubber tyre vehicles, conveyors or pumping, depending on the type of TBM and the length of the tunnel.

6.1.5 TBM parameters will be monitored continuously both underground and within a dedicated tunnel monitoring control room. An excavation/grout check will be carried out to ensure all voids have been filled to minimise the risk of settlement.

6.1.6 The tunnelling operation will be continuous, which will minimise ground movements. On completion of the tunnel drives, the TBMs will be dismantled and removed from the tunnels.

7 Tunnelling Construction Phase Impacts

7.1.1 Noise and vibration due to tunnel boring during construction will be assessed based on previous experience at the Dublin Port Tunnel, the Jubilee Line Extension, HS1 and Crossrail. In general, the levels are low and occur for a limited period only.

7.1.2 As with any underground works, ground movements affecting buildings could occur during tunnel excavation or shortly thereafter. While the vast majority of tunnelling projects are successful, with very low recorded ground settlements, occasionally an incident occurs that results in higher localised ground settlements or subsidence.

7.1.3 The impact of ground movements on buildings will be assessed through a well-established three-stage process to determine whether there is a risk of potential building damage. This process has been used successfully on both HS1 and Crossrail.

7.1.4 The environmental impacts of tunnelling will be reported in the formal ES.

8 Tunnelling Operational Phase Impacts

8.1.1 Modern tunnelling methods mean the impact of ground-borne noise and vibration from railway operations are relatively low and may be effectively controlled. The main reasons for this are:

- better quality track;
- straighter track alignments;
- smoother running surfaces on the rails;
- fewer rail joints and the use of continuously welded track (reducing the dynamic loads and consequently the wear and tear on the rolling stock); and
- better suspension on the trains (which improves passenger comfort, as well as reducing the impact forces on the track).

8.1.2 For high speed trains, the need for better performance requires that the track is maintained to a very high standard. The process of calculating noise and vibration from rail tunnels is well understood and the effects can be accurately predicted. Where noise and vibration levels are considered to be an issue, well-tried mitigation measures are available.

8.1.3 Recent projects, such as the Jubilee Line Extension and HS1 tunnels under London, have shown that modern railways can run in tunnels under large residential areas without noise and vibration affecting the people who live there or disturbing other highly sensitive non-residential uses.

8.1.4 Further information on noise and vibration control, and mitigation is available in Phase 2b Western Leg Factsheets: Control of ground-borne noise and vibration from the operation of temporary and permanent railways; Control of noise from the operation of stationary systems and Control of construction noise and vibration.

9 Tunnel lining design

9.1.1 Tunnel linings are required to;

- structurally retain the earth and groundwater pressure; and
- provide an internal space appropriate to the function of the operational railway.

9.1.2 Tunnel linings will be designed in accordance with the relevant regulatory standards, guidelines and current practice. These are based on proven design and construction technology that has been used successfully worldwide.

9.1.3 It is expected that the linings would be designed to withstand all foreseeable loading, including construction loads and those from the surrounding ground and groundwater. They would also meet fire resistance, durability and waterproofing requirements.

9.1.4 As well as the train itself, the internal diameters of the tunnels have been sized to accommodate the swaying movement of trains, the overhead power supply, evacuation and access walkways, track slab, cables and associated furniture, and construction tolerances. Their sizing also takes account of the aerodynamic requirements of high speed trains.

9.1.5 The majority of the bored tunnels would be lined with pre-cast concrete tunnel lining segments, reinforced with steel fibres and polypropylene fibres. To enable connection between the twin bored tunnels, at intervals along the length of the route, cross-passages would be constructed and the openings for these formed using round graphite iron linings or steel frames encased in concrete alongside precast concrete tunnel linings. The linings are made up of a number of tunnel segments which are joined to form a ring.

9.1.6 The mined cross passage tunnels, which are lined with sprayed concrete, would have a primary sprayed lining of fibre-reinforced concrete with a waterproof layer. A secondary lining of fibre-reinforced concrete would be either sprayed or cast in place. These construction techniques have been used successfully on the Crossrail project.

9.1.7 The lining of cut-and-cover tunnels would be conventional reinforced concrete.

10 Fit-Out of Tunnels

10.1.1 Once tunnels are excavated, lined and cleaned out, the following activities take place:

- construction of walkways and drainage;
- installation of rail track and formation;
- installation of mechanical and electrical systems; and
- testing and commissioning.

11 More information

11.1.1 Further factsheets and details on the Proposed Scheme can be found at: www.hs2.org.uk/phase2b