HS2

Phase 2b Western Leg Information Paper

D13: Tunnels

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

It will be of particular interest to those potentially affected by the Government's proposals for high speed rail.

This paper was prepared in relation to the promotion of the High Speed Rail (Crewe - Manchester) Bill. Content will be maintained and updated as considered appropriate during the passage of the Bill.

If you have any queries about this paper or about how it might apply to you, please contact the HS2 Helpdesk in the first instance.

The Helpdesk can be contacted:

by email: HS2enquiries@hs2.org.uk

by phone (24hrs): 08081 434 434
08081 456 472 (minicom)

or by post: High Speed Two (HS2) Limited
2 Snowhill, Queensway
Birmingham
B4 6GA

Version 3
Last updated: 3 July 2023

1 Introduction

1.1 High Speed Two (HS2) is the Government's scheme for a new, high speed north-south railway, which is being taken forward in a number of phases. Phase One will connect London with Birmingham and the West Midlands. Phase 2a will extend the route from the West Midlands to Crewe. The Phase 2b Western Leg will connect Crewe to Manchester. As set out in the Integrated Rail Plan, published in November 2021, HS2 East is proposed to deliver a new high speed line from the West Midlands to East Midlands Parkway.

1.2 HS2 Ltd is the non-departmental public body responsible for developing and promoting these proposals. The company works under the terms of a Development Agreement entered into with the Secretary of State for Transport.

1.3 The construction and operation of Phase One of HS2 is authorised by the High Speed Rail (London – West Midlands) Act 2017 and Phase 2a by the High Speed Rail (West Midlands – Crewe) Act 2021.

1.4 In January 2022, the Government introduced a hybrid Bill to Parliament (hereafter referred to as 'the Bill'), to seek powers for the construction and operation of the Phase 2b Western Leg (the Proposed Scheme), which is called the High Speed Rail (Crewe – Manchester) Bill. The Proposed Scheme comprises the Phase 2b Western Leg from Crewe to Manchester and several off-route works. It also facilitates the delivery of Northern Powerhouse Rail by providing the Crewe Northern Connection and junctions and other infrastructure to be used in future schemes.

1.5 The work to produce the Bill includes an Equalities Impact Assessment and an Environmental Impact Assessment (EIA), the results of which are reported in an Environmental Statement (ES) submitted alongside the Bill. The Secretary of State has also published draft Environmental Minimum Requirements (EMRs), which set out the environmental and sustainability commitments that will be observed in the construction of the Proposed

Scheme. For more information on the EMRs please see Information Paper E1: Control of environmental impacts.

1.6 The Secretary of State for Transport is the Promoter of the Bill through Parliament. The Promoter will also appoint a body responsible for delivering the Proposed Scheme under the powers granted by the Bill. This body is known as the 'nominated undertaker'. There may 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 EMRs and any commitments provided in the information papers.

1.7 These information papers have been produced to explain the commitments made in the Bill and the EMRs and how they will be applied to the design and construction of the Proposed Scheme. They also provide information about the Proposed Scheme itself, the powers contained in the Bill and how particular decisions about the Proposed Scheme have been reached.

2 Overview

2.1 This information paper provides an overview of the range of proposed tunnelling methods to be employed on the Proposed Scheme, the factors that influence the choice of method, and the means of mitigating the construction and operational impacts associated with tunnelling.

2.2 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.

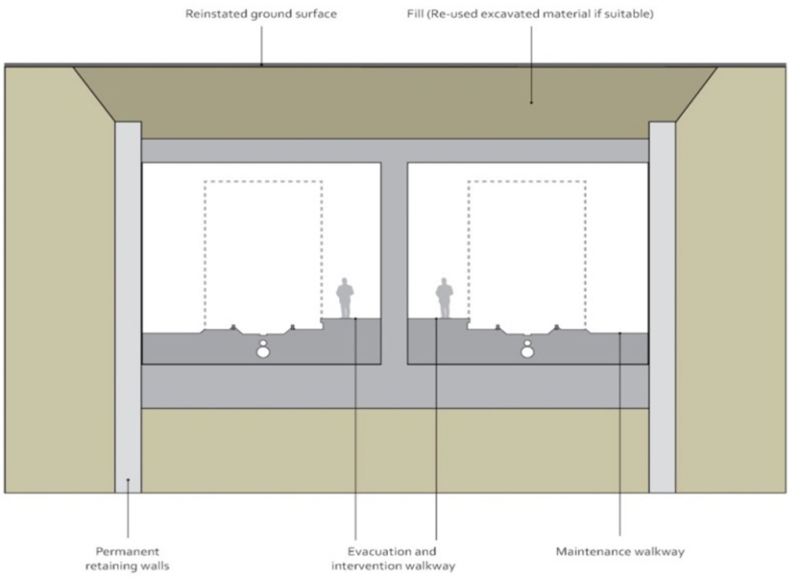
2.3 Tunnels have also been introduced into the Proposed Scheme for environmental reasons, for example, to pass beneath built-up areas where disruption at the surface would be severe.

3 Tunnels on the Proposed Scheme

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

- **cut-and-cover tunnel** (also referred to as green 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

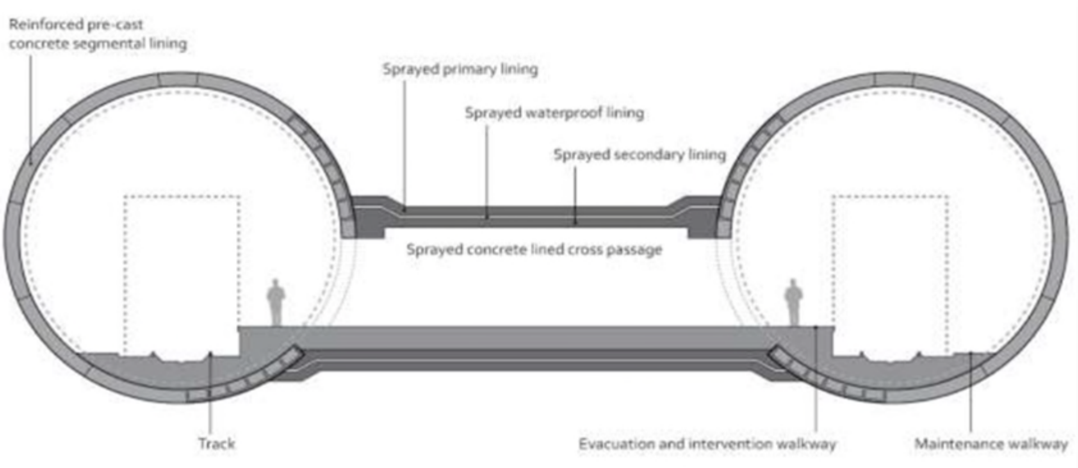


- **bored tunnels** – where two parallel tunnels, each containing a single rail track, are constructed. This can be done by either using tunnel boring machines (TBMs) or by excavation of a single-bore tunnel with mechanical plant. The Proposed Scheme includes approximately 19km of twin-bore tunnels (Crewe and Manchester Tunnels), see Figure 2. These are planned to have an internal diameter of 7.55m and 8.80m respectively. See section 5 below for further information on tunnel construction.

- **mined tunnels –** similar to bored tunnels above, however this does not make use of a TBM but uses more conventional tunnelling methods including roadheaders and excavators (see below) using an open faced sequential excavation method (SEM). This method is where modified excavators excavate the ground in a sequence progressively installing the lining using sprayed concrete. On the Western Leg, the tunnel cross passages on bored tunnels are likely to be mined (see below).

3.2 For safety reasons, when bored tunnels exceed 500m in length, they are required to have cross passages to connect the two/twin tunnel bores as well as escape routes 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 for a typical cross-section of a twin-bored tunnel with cross passage, (each tunnel contains one track; one for the upline track and one for the downline track).

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



3.3 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 Information Paper D14: Vent shafts and porous portals for further details.

4 Tunnel Construction Methods

Bored tunnels

4.1 Bored tunnels are constructed either by starting from one entrance and constructing the whole tunnel or by starting at both entrances and meeting in the middle, where a shaft is located. The construction strategy will 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 that 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 rail;
- impact on overall construction programme; and
- economic use of plant and machinery.

4.2 The main tunnel worksites are required for the removal of excavated material from the tunnel. They also form the main logistics area to take 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.

Cut-and-cover tunnels

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

4.4 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.

4.5 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.

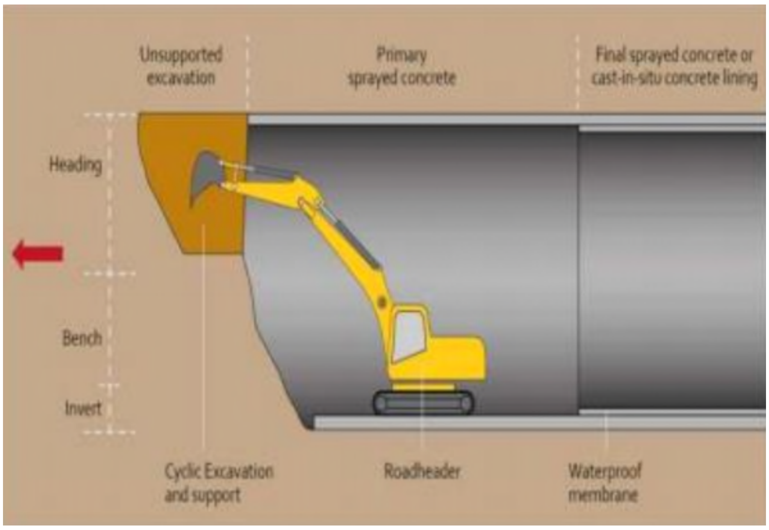
Mined tunnels

4.6 For the emergency evacuation 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.

4.7 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 a sequential excavation method (SEM) and lining to form the required tunnel geometry.

4.8 In the case of emergency evacuation cross-passages and connections between the rail tunnels and vent shafts, excavated materials would be removed using the TBM conveyor belt, narrow-gauge temporary railway or a tyred Multi Service Vehicle (MSV).

Figure 3: Mined excavation by conventional methods



5 Tunnel boring machines

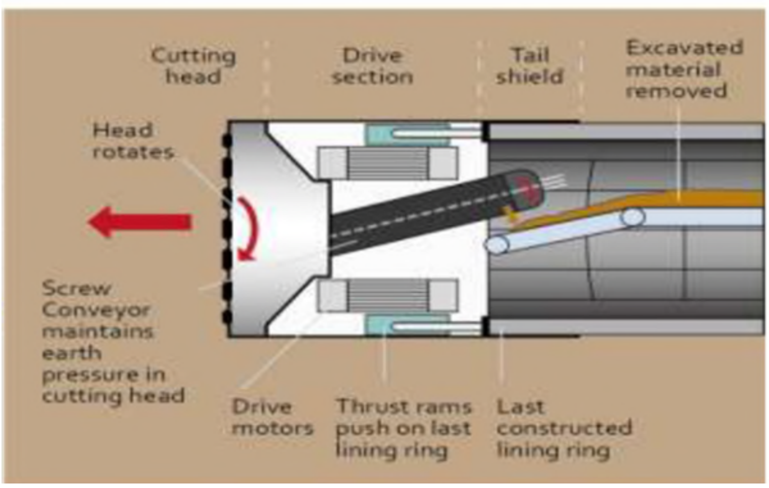
5.1 The TBMs used to construct HS2 will be purpose-built machines, using proven state-of-the-art technology and will operate 24 hours a day, seven days a week. They will be designed specifically for the project to ensure their reliability of performance, settlement control and to cope with the range of ground conditions expected along the Proposed Scheme.

5.2 The success of constructing tunnels on Jubilee Line extension, HS1 and Crossrail projects demonstrates the ability of modern construction techniques to successfully tunnel through the range of ground conditions identified by the site investigations.

5.3 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.

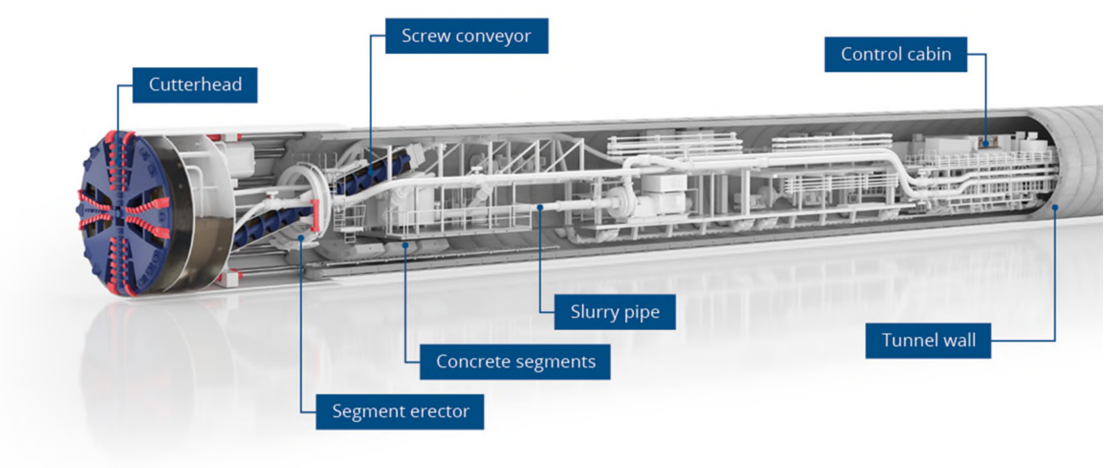
The TBMs most likely to be used on tunnels for the Proposed Scheme are Earth Pressure Balance Machines (EPB). Figure 4 shows the key components of an EPB TBM.

Figure 4: Earth Pressure Balance TBM



5.4 Some of the HS2 Phase 1 Tunnels utilised Variable Density TBM's which are state of the art TBM's which can deal with variable and changing ground conditions. An example of a Variable Density TBM is in Figure 5 below. The TBM arrangement shown would be tailored to suit the ground conditions and specific logistics and location of the tunnel. A Variable Density TBM is a slurry type of TBM where the excavated spoil is pumped out to surface in a bentonite suspension.

Figure 5: Variable Density TBM



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

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

5.6 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.

5.7 The decision on the type of tunnelling technique(s) to be used will be made, taking account of the ground conditions and the Contractor's preferred method of construction and could include, mined tunnel, shielded tunnel or a type of TBM illustrated in figures 4 and 5 above.

6 TBM operation

6.1 The TBMs will weigh around 1,500 tonnes when fully operational. They will be delivered in smaller components and assembled near the tunnel entrance.

6.2 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.

6.3 Where necessary, ground treatment will be carried out around the TBM launch chamber structure to allow the TBM to be driven into the ground at the start of tunnelling before the full stabilising effects of the TBM can be brought into operation. The TBM will offer a constant and variable pressure onto the face as it is excavated and advanced in order to mitigate against surface settlement

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

- excavation will be undertaken one tunnel lining ring at a time. First the TBM will excavate a short section of tunnel sufficient to allow a ring to be installed. 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 next short section of tunnel will be excavated, with the TBM propelled forwards by hydraulic jacks shoving off the previously erected tunnel lining ring;

- grouting of the tunnel lining rings will be undertaken as a continuous process through the tail-skin of the TBM to fill the voids between the tunnel lining rings and the excavated surface of the ground as the ring emerges from the tail skin;
- materials (such as tunnel lining rings and grouts) will be delivered to the TBMs by a narrow-gauge construction railway 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.

6.5 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. These checks will be performed by drilling through the tunnel lining crown zone with any voids filled with grout.

6.6 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 Noise and vibration due to tunnel boring during construction have been 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.

7.2 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.

7.3 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. Full details of this process are set out in Information Paper C14: Ground settlement.

7.4 The environmental impacts of tunnelling are considered within the ES.

8 Tunnelling Operational Phase Impacts

8.1 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);
- Floating track slab where track is part supported on hard rubber; and
- better suspension on the trains (which improves passenger comfort, as well as reducing the impact forces on the track).

8.2 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.

8.3 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.

8.4 Further information on noise and vibration control, and mitigation is available in Information Paper E10: Control of ground-borne noise and vibration from the operation of temporary and permanent railways; Information Paper E11: Control of noise from the operation of stationary systems; and Information Paper E13: Control of construction noise and vibration.

9 Tunnel lining design

9.1 Tunnel linings are required to:

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

9.2 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.

9.3 The linings will be designed to withstand all foreseeable loading, including construction loads and those from the surrounding ground and groundwater. They will also meet fire resistance and durability requirements.

9.4 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.

9.5 The majority of the bored tunnels will 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 will be constructed and the openings for these formed using spheroidal graphite iron linings or steel frames encased in concrete or reinforced concrete segments with shear dowels. The linings are made up of a number of tunnel segments which are joined to form a ring.

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

9.7 The lining of cut-and-cover tunnels will be conventional reinforced concrete.

10 Fit-Out of Tunnels

10.1 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 over head catenary;
- installation of mechanical and electrical systems; and
- testing and commissioning.

11 More information

11.1 More detail on the Bill and related documents can be found at www.gov.uk/hs2-phase2b-crewe-manchester.