Cut-and-cover tunnels

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Introduction

Mention the CTRL and people are unlikely to think of cut-and-cover tunnels. Nonetheless, there are 17 such structures along the route, totalling 3.4km, and they represent major civil engineering feats in their own right. Section 1 has 12, and the remaining five in Section 2 are at various stages of construction with civil engineering works not due for completion until early 2005.

The cut-and-cover tunnels on the CTRL can be categorized as:

1 approach structures to bored tunnels

2 tunnels to overcome urban constraints, like roads, railways, and adjacent structures

3 tunnels to overcome environmental constraints

4 station boxes.

The categories and general details for each tunnel are summarized in Table 1.

The CTRL project defines a tunnel as 'a roofed structure more than 50m long', and the railway safety case goes on to differentiate between those up to 1500m long ('short tunnels') and those longer than 1500m ('long tunnels').

The safety issues with longer tunnels demand the consideration of forced ventilation for smoke management in the event of fire, emergency lighting, public address system, wider evacuation walkways, etc. As a result of this, the cut-and-cover tunnel approaches to the London Tunnels and Thames Tunnels are designed differently from the rest of the cut-and-cover tunnels, because they are considered part of a 'long tunnel'.

As this edition of *The Arup Journal* makes clear, the CTRL is a unique enterprise for modern Britain, and the following particular characteristics of it are of special relevance to cut-and-cover tunnels:

- The end product is the railway and not just a tunnel.
- These are the first high-speed rail tunnels in the UK.
- The trains will travel at up to 300km/h (5km/min; 80m/s).
- There was a general lack of familiarity with them in the UK railway industry.
- The civil engineering design is largely complete before the system-wide design commences, eg trackwork, electrification, signalling.

Table 1

Name of structure	Category of tunnel	Length of tunnel	Type of construction	Line speed	Tunnel nominal internal dimensions: Width	Height[1]	Free cross-sectional area
[Section 2]							
Thameslink box (St Pancras)	4	380m	Contiguous piles	<100km/hr	22m	6.6m & 4.6m (min)	145m^2
London Tunnels approach (Ripple Lane)	1	175m	In situ box	230km/hr	7.3m	6.6m (varies slightly)	47m^2/tunnel
Thames Tunnel northern approaches	1	300m	Diaphragm wall	230km/hr	15m to 29m	6.7m	47m^2/tunnel
Thames Tunnel southern approaches	1	300m	Diaphragm wall	230km/hr	25m to 29m	6.7m	47m^2/tunnel
Pepper Hill Tunnel (A2 crossing)	2	300m	Contiguous piles	230km/hr	11.1m	6.4m	71m^2/tunnel
[Section 1]							
Southfleet Tunnel	2	85m	In situ box	230km/hr	10.4m	6.4m	67m^2
Halfpence Lane Tunnel	2	170m	In situ box	300km/hr	10.7m	6.3m	68m^2
Brewers Lane Tunnel	2	55m	Contiguous piles	300km/hr	11.3m	6.5m	74m^2
Boxley Tunnel	3	325m	Contiguous piles and in situ box	300km/hr	12.3m	7.1m	86m^2
Eyhorne Tunnel	3	360m	Precast arch	300km/hr	13.3m	8.4m at crown	107m^2
Harrietsham Tunnel	3	150m	Contiguous piles	300km/hr	11.2m	6.3m	68m^2
Sandway Tunnel	3	170m	Precast arch	300km/hr	13.3m	8.4m at crown	107m^2
Westwell Leacon Tunnel	3	120m	In situ box	270km/hr	11.7m	7.7m	86m^2
Ashford four-track tunnel	2	570m	Contiguous piles	160km chord 270km main	27.8m	6.5m to 11.1m	164m^2 to 237m^2
Ashford two-track tunnel	2	422m	Contiguous piles	160km chord 270km main	12.1m	7.3m to 6.3m	76m^2 to 85m^2
Mersham Tunnel	3	160m	Contiguous piles In situ box	300km/hr	13.3m to 15.2m	6.2m	69m^2 to 93m^2
Sandling Tunnel	3	92m	Contiguous piles	300km/hr	11.3m to 11.5m	6.2m	72m^2 to 76m^2

Note 1: The height given is the height above Vertical Control Level, ie similar to rail level (to within +/-100mm). The overall height of the tunnel between base slab and roof is typically about an extra 1.2m.

Some of the cut-and-cover tunnelling works for Section 2 are illustrated on this page.

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1. above and 2. below:
London Tunnel approaches (Ripple Lane).

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3. above, 4. and 5. below:
Thames Tunnel southern approaches.

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Establishing the design brief

The design of the 17 cut-and-cover tunnels involved the production of some 2000 drawings and related specifications.

The structural and geotechnical design work required to produce these drawings was an enormous task.

The overall key to the successful production of the construction drawings, however, was the early establishment of the design brief, and the tight control of any subsequent changes to it.

The four key steps in establishing the design brief were:

1. defining the basic geometry for the railway tunnel, eg minimum rail safety clearances for the design line speed

2. defining the constraints as follows:

- design life
- ground conditions
- existing utilities
- existing roads and railways (possessions)
- third parties
- environmental
- cost and programme.

3. establishing the best method of construction to be assumed for the design

4. finalizing the geometry based on the first three key steps 1, 2, and 3 above.

Details of the considerations for each step are summarized in Table 2 on the facing page.

Table 2

Step	Issue	Criteria to be considered
1. Basic geometry	Track alignment	Track separation Vertical alignment Horizontal alignment Cant (superelevation) Gauge (UIC GC) Multiple tracks; tracks at different levels
	Rail safety (HMRI Railway Safety Principles)	Clearances to tunnel structure (ie structure gauge) Evacuation strategy (walkways, ventilation, lighting, communications, and fire resistance of structure) Access strategy (inspection and maintenance) Collision/impact resistance Derailment containment
	Aerodynamics	Limits on maximum air pressure change experienced by train passengers' ears (transient pressures) Minimum free cross-sectional area to meet transient pressure limits
	Drainage	Catchment area of tunnel drainage Potential for carrier drains beneath tunnel base slab Drainage design unlikely to be complete before tunnel design The drain can form part of the walkway Drain inspection and maintenance
	Systemwide requirements	Minimum ballast depth Maximum ballast depth Clearance for ballast cleaning machine Special requirements at track crossovers and scissors: Extra space for point motors, replacement of track, etc Extra vertical clearance for catenary Allowance for future track shift and lift Electrical clearance around the catenary system Signs to be mounted in the tunnel
2. Constraints	Ground conditions	Soil profile and properties Contaminated land Groundwater conditions Groundwater protection zones
	Design life of the CTRL	120 years; high reliability, low maintenance
	Utilities	Existing – long lead time for diversions Future provision
	Roads	What interference with the road is allowed during construction?
	Railways	What interference with the railway is allowed during construction? Need for possessions and temporary speed restrictions Long lead time for possessions
	Environmental	Noise and ground vibration (both during construction and permanently) Light pollution; dust; pollution by the trains Archaeology (Scheduled Ancient Monument Sites) Fauna, flora and wildlife (eg Sites of Special Scientific Interest) Temporary and permanent dewatering Surface water discharge Use/disposal of tunnel spoil
	Tolerances and deflections	Construction tolerances; wall and slab deflections during construction and in the long term
3. Method of construction	Conventional cast in situ concrete construction within an open cut	Southfleet Tunnel (space available for an open excavation) Halfpence Lane Tunnel (space available for an open excavation) Westwell Leacon Tunnel (space available for an open excavation) London end of Ashford four-track tunnel (space available for an open excavation)
	Proprietary precast concrete arch tunnel within an open cut	Sandway Tunnel (space available for an open excavation: precast arch more cost-effective) Eyhorne Tunnel (space available for an open excavation; precast arch more cost-effective)
	Tunnel with diaphragm walls or contiguous pile walls and built bottom-up	Country end approach (Ripple Lane) to the bored London Tunnels (adjacent railway lines; groundwater cutoff required) Northern and southern approaches to the bored Thames Tunnel (walls needed to form partial groundwater cut-off) Ashford two-track tunnel (adjacent railway tracks and structures)
	Tunnel with diaphragm walls or contiguous pile walls and built top-down	Thameslink Box (need to minimize construction works during the railway blockade) Tunnel under the A2 trunk road (to be kept open at all times with minimum traffic management) Brewers Lane Tunnel (road to be kept open at all times) Boxley Tunnel (presence of an ancient woodland precluded open excavation)
4. Complete design	i Finalize geometry	Collate all information derived from Steps 1, 2 and 3
	ii Approval of design statement	Produce a design statement (approval-in-principle document) and get sign off from all RLE disciplines and client
	iii Undertake structural analysis	
	iv Produce construction drawings and specifications	

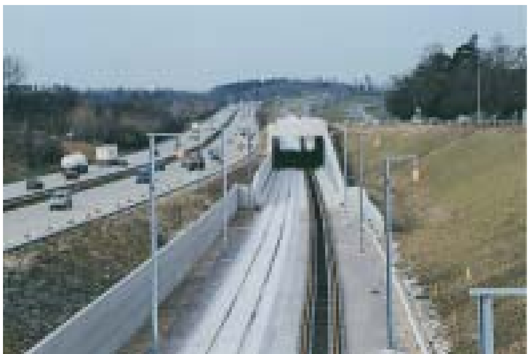
Some of the cut-and-cover tunnelling works for Section 1 are illustrated on this page.

6. Eyhorne Tunnel mitigates the railway's impact close to residences.

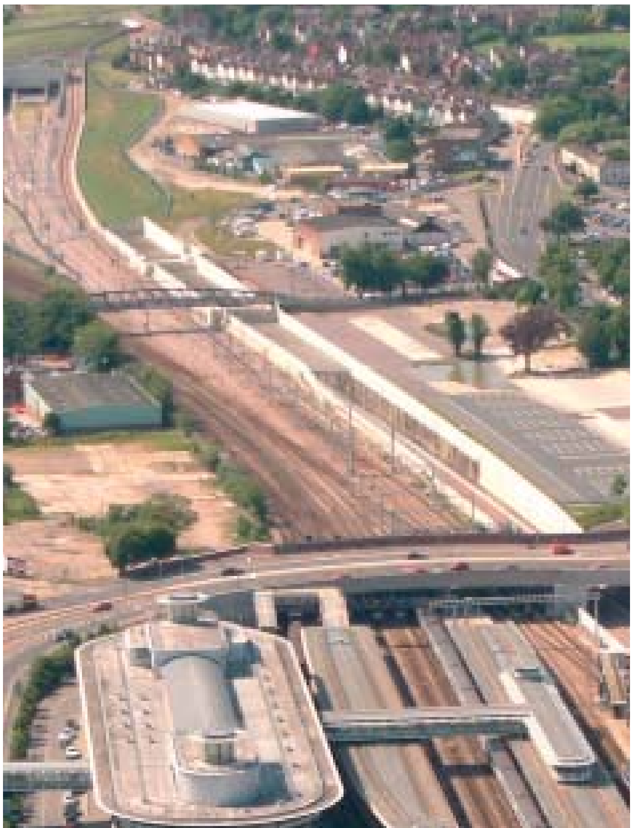
7. Eyhorne Tunnel arch being built.

8. Boxley Tunnel, which passes through an area of ancient woodland that had to be conserved.

10. Sandway Tunnel precast arch.



9. Harrietsham Tunnel.



11. The two-track tunnel at Ashford International Station.