WORLD TUNNELLING

CTRL Enters Second Phase

The August issue of *World Tunnelling* covered, in the Panorama Section, the inauguration on 2nd July 2001 of the start of Section 2 of the Channel Tunnel Rail Link (CTRL). The Transport Minister, Mr John Spellar, MP, gave the signal for machinery to start work on the International Station at Stratford. This overview marks this milestone and is also a backdrop to the Underground Construction 2001 Conference and Exhibition, from 18th to 20th September. The CTRL is the largest tunnelling project in the UK since the Jubilee Line Extension and the Channel Tunnel. The following article looks only at the extensive underground works involved.

Section 1 of the CTRL, consisting of 74km of new alignment in Kent from Cheriton to Southfleet Junction and the Waterloo connection to Fawkham Junction, is now over 70% completed and is scheduled to become operational in 2003. Section 1 will save 20 minutes on the rail journey time through Kent.

Section 2 of the CTRL, 38.5km in length, takes the alignment from Southfleet Junction, north across the River Thames and, after a section of elevated construction to Ripple Lane, in tunnel to the St Pancras International Terminal. There will be two new stations at Ebbsfleet, in North Kent, and at Stratford in East London.

Section 2 is planned to be opened at the end of 2006 when a further 15 minutes will be saved on the journey time to the Channel Tunnel giving a total journey time from St Pancras to Paris of 2 hours 20 minutes and to Brussels of 2 hours.

London & Continental Railways (LCR) won the franchise in 1996 to design, build, operate and finance the CTRL. However, following a re-negotiation of the contract in 1998 a deal was agreed between LCR and Railtrack to build the CTRL in two sections. Railtrack would purchase Section 1 on completion and had the option to purchase Section 2. However, in April 2001 Railtrack, in view of its worsening financial position, withdrew from its option on Section 2. Railtrack will, however, operate the entire CTRL on completion.

On behalf of LCR, Union Railways (South) Ltd, a subsidiary of LCR but controlled by Railtrack, is responsible for the overall provision for Section 1. Union Railways (North) Ltd, also a subsidiary of LCR, is responsible for the overall provision of Section 2.

Rail Link Engineering (RLE), a consortium of Bechtel, Ove Arup & Partners, Halcrow Group and Systra, a subsidiary of the French Railways, SNCF, is responsible for the design and the project management of both sections of the link.

North Downs tunnel, recently completed and ready for track laying.

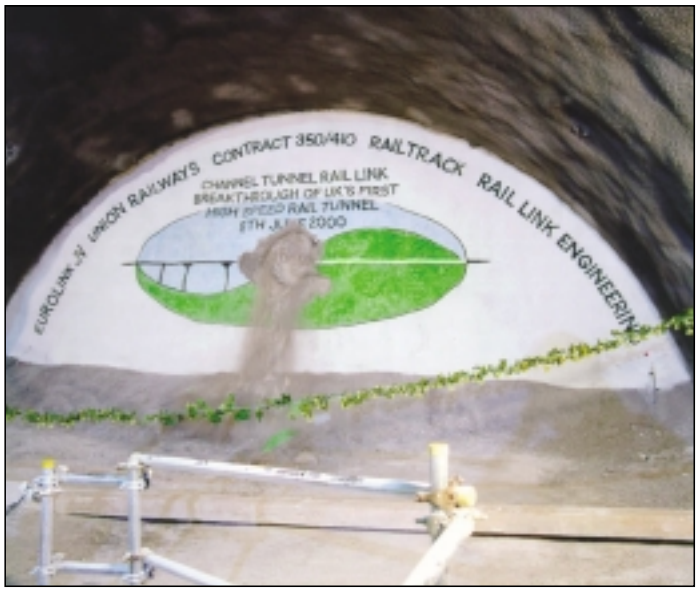
Underground Contracts

There are five underground works contracts in Section 2. In Section 1 there is one bored tunnel contract, the North Downs Tunnel, a substantial length of cut and cover tunnel at Ashford and a number of short cut and cover tunnels in four of the other contracts. The table gives details of the underground works contracts, the contract number, location, the contractor's JV, the length of the contract and the length of underground works and the target price.

Form of Contracts

All the civil engineering contracts for the CTRL are under a modified New Engineering Contract, (NEC), Option C, Target Contract. There is a large incentive for the contractor to achieve an outturn cost lower than the target cost through detailed value engineering within the project team. 25% of the saving will be given to the contractor. If the outturn cost should be lower than 90% of the target

CONTRACT	LOCATION	CONTRACTOR JV	LENGTH	TARGET PRICE
Section 2				
220	Gifford Street Portal to Stratford	Nishimatsu/ Cementation/Skanska	7.5km bored tunnel, 45m of cut and cover at portal	£145m
230	Stratford Box	Skanska	1070m cut and cover box	£105m
240	Stratford to Barrington Road	Costain/Skanska/ Bachy Soletanche	4.68km bored tunnel	£120m
250	Barrington Road to Ripple Lane Portal	Nuttall/Wayss & Freytag/Kier	5.25km bored tunnel, 150m cut and cover tunnel	£115m
320	Thames Tunnel Thurrock to Swanscombe	Hochtief/Murphy	2.5km bored tunnel, 1040m of cut and cover tunnel	£128m
342	Thames Tunnel to Southfleet	To be awarded in January 2002	3.5km, 305m of cut and cover at Pepper Hill	NA
Section 1				
330	East Thames, Waterloo Connection to Medway Valley	Alfred McAlpine Construction/Amec Civil Engineering	16km, 55m cut and cover at Brewers Road	£80m
410	North Downs Tunnel	Miller Civil Engineering/Dumez-GTM/Beton und Monierbau	3.2km bored tunnel	£80m
420	Mid Kent, Boxley to Lenham Heath	Hochtief/Norwest Holst	20km, 1005m in four cut and cover tunnels	£85m
430	Ashford	Skanska (Kvaerner)	14.4km, 1112m in three cut and cover tunnels	£150m
440	East Kent, Ashford to Cheriton	Balfour Beatty Major Projects	16km, 252m in two cut and cover tunnels	£75m



North Downs tunnel – initial roadheader breakthrough in June 2000.

cost the contractor will receive 50% of any saving below the 90% level.

However, if the outturn costs are higher the contractor will be penalised and will have to pay 25% of the overrun, which will include the loss of the Contractor's fee, up to 120% of the target cost and 10% of any excess above that figure.

This target system has meant that the initial negotiations and the agreement of the target cost have been crucial to the success of each contract. It has meant that all parties have worked together in a partnership for the success of the contract and that there has been complete openness between the parties. On site all parties share offices, technical and financial information.

On Section 1, the re-negotiation of the franchise meant that it was not possible to have a long period between the appointment of the contractors and the commencement on site. For Section 2 the contractors' teams for each contract have worked together with the RLE team in detailed preliminary design, planning and value engineering for up to six months before starting work on site. This has also led to cooperation between all contracts, the purchasing of system wide materials jointly, such as cast iron linings for the cross passages and other tunnel materials.

Tunnel Linings

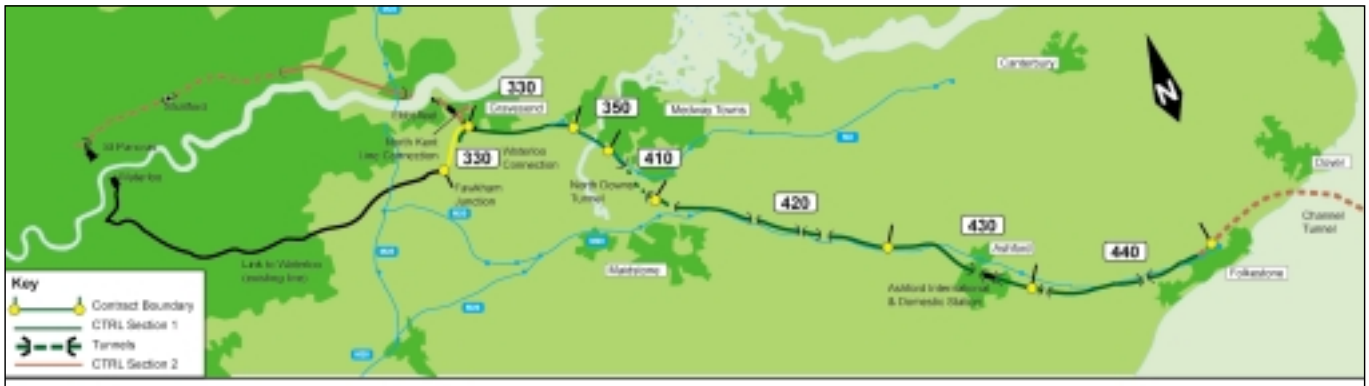
The internal diameter for single track tunnels on the UK railway system is generally of the order of 5.6 to 5.7m. However, for the CTRL, with speeds for Section 2, up to 230km/h in the tunnels, the aerodynamic effects and ventilation require a considerably larger diameter. Following modelling of these effects the RLE design team chose an internal diameter for the whole of Section 2 of 7.15m.

The design of the tunnel linings, for all four contracts, was developed during the pre-tender period. Tests were carried out at the Building Research Establishment, using half segments with both plane joints and with 3000mm radius convex/convex joints reinforced with steel fibre. In addition birdsmouthing at the joints of 1.6 degrees was tested.

Fire tests were carried out at Delft University, in the Netherlands, using panels cast in limestone, granite, and 'Lytag' lightweight aggregate together with different types and weights of steel fibre and polypropylene fibres.

Following a detailed analysis, review and value engineering carried out by the RLE Team a tapered ring, 1.5m long, of 9 segments and a key, a thickness of 350mm with a concrete strength of 40Mpa and 30kg of 40mm long steel fibres reinforcement with 1kg of polypropylene fibres was chosen for the Tender design. The design life of the rings is 120 years. The waterproofing is provided with EPDM gaskets at the back of the joints and an hydrophilic seal at the front of the joint. The connections between segments are inclined spear bolts connecting into cast nuts in the adjacent segment

The successful Joint Ventures for the tunnelling contracts for the London Tunnels and for the Thames Crossing have each reviewed the design of the tunnel linings with their consultants and have accepted the RLE design with only minor changes. The taper of the ring for the Thames Tunnel is 35mm and 15mm for the other contracts.



Main Civil Contract Packages - Section 1 (Fawkham Junction, North Kent - Channel Tunnel)

Contract 330 - East Thames - Medway Valley & Waterloo Connection
JV Name: Alfred McAlpine / AMEC JV
Members: Alfred McAlpine Construction Ltd / Amec Civil Engineering Ltd

Contract 350 - Medway Crossing
JV Name: Eurolink JV
Members: Miller Civil Engineering / Dumez-GTM / Beton und Monierbau GMBH

Contract 410 - North Downs Tunnel
JV Name: Eurolink JV
Members: Miller Civil Engineering / Dumez-GTM / Beton und Monierbau GMBH

Contract 420 - Mid Kent - Boxley to Lenham Heath
Contractor: Hochtief / Norwest Holst JV

Contract 430 - Ashfordt - Lenham Heath to Ashford (Sevington)
Contractor: Skanska Construction UK Ltd

Contract 440 - East Kent - Ashford (Sevington) to Cheriton
Contractor: Balfour Beatty Major Projects

Skanska, following its purchase of Kvaerner, is now part of the joint venture consortium for Contracts 220, 230 and 240. This has enabled an unique cooperation agreement, Team 200, to be reached between the three contractor groups. The tunnel linings for Contracts 220 and 240, a total length of tunnel linings of approximately 24km, will be manufactured on the site at the Stratford Box. The segments will be cast on four carousels with steam curing. Limestone aggregate will be used with a cement blend of OPC, pfa and ggbs. Malling Precast, an O'Rourke company, in joint venture with Holtzmann will manufacture the segments. Some of the staff are from the former Taylor Woodrow segment precasting yard.

The segments for Contract 250 will be cast at the Ripple Lane site. The choice of aggregates, granite or limestone has yet to be decided. The segments for Contract 320 will be cast on the Swanscombe site using granite aggregate with Brett Concrete as the manufacturer.

The cast iron linings for cross passages and sumps are being ordered jointly for all four contracts, but the manufacturer has not yet been appointed.

Tunnel Boring Machines

The RLE team prepared a very detailed TBM specification, following in-depth studies of successes and problems on other UK and overseas projects. The type of TBM was specified for each contract, but it was left to the successful JV to choose the manufacturer and to convince the project team, on past experience, for any changes to be approved. All TBMs had to have, *inter alia*, facilities for forward probing, for array grouting, for wear detection of the picks and cutters, for replacement of tools from the rear, an interlocking system to prevent the forward movement of the TBM without grouting through the tail, and two airlocks with equipment for oxygen assisted decompression to the proposed new CEN standards.

CONTRACT	MANUFACTURER	TYPE	NUMBER	GROUND CONDITIONS
220	Kawasaki	EPB	2	London Clay, Woolwich & Reading Beds, Thanet Sands, Harwich Formation and skirting the Bullhead beds above the Upper Chalk
240	Wirth	EPB	2	Thanet Sands with possible mixed face with the Upper Chalk
250	Lovat	EPB	2	Superficial Deposits, London Clay, Harwich Formation, Woolwich & Reading Beds and Thanet Sands
320	Herrenkneckt	Slurry	2, but with only one backup	Upper Chalk with flint bands

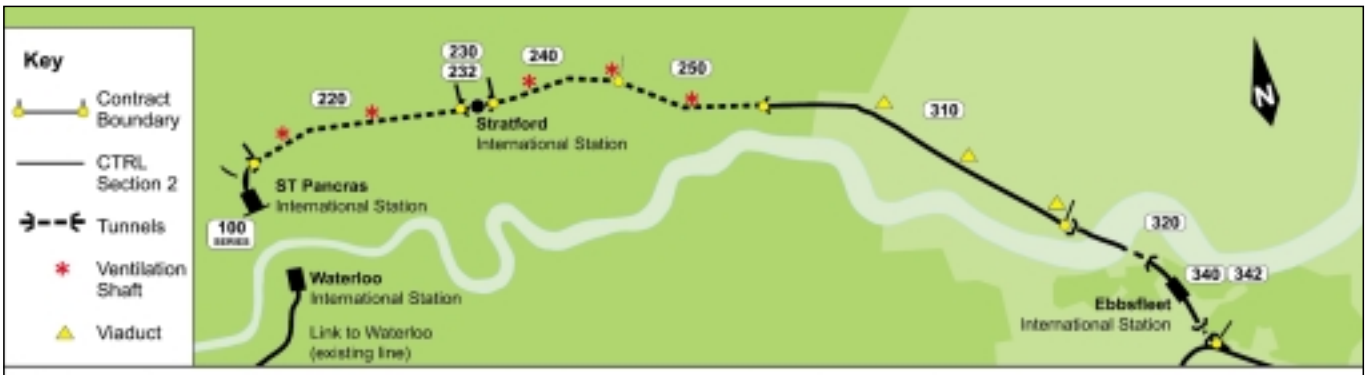
The table (above) shows the TBMs to be used and the ground conditions in the four bored tunnelling contracts. The weight of each of the TBMs is approximately 650t with backup equipment of a further 350t. The design of the TBMs is at different stages on the four contracts.

TBM Details

The two TBMs for Contract 220 were specified to be 'convertible EPB machines' with a screw conveyor in the invert, for the closed mode, and a belt conveyor in the upper part for the open mode. The transition from the open mode to the closed mode had to be minimised. The Nishimatsu/Cementation/Skanska JV chose 'dual mode' TBMs with a single screw conveyor which can be moved forward quickly to be in the closed mode and have hydraulically extending hoppers to aid spoil removal in the open mode.

The specification asked for a 900mm screw conveyor, but the JV has increased the diameter to 1100mm to meet the overall 'convertible machine' specification. Six similar Kawasaki TBMs have been used on the Bangkok metro. The picks and discs have an hydraulic wear detection system. Inspections of the face should not be a problem as the maximum water pressure along the drive is less than one bar.

The shield is in two parts with a floating tail. A gripper in the tail allows the front section and head to be retracted. The cutter head will have two speeds. The spoil will be removed down the tunnel by conveyor to the Stratford Box and after treatment will be placed on the site as part of a regeneration scheme to raise the level of the area by some 6m. The segments will be erected with a vacuum suction grip erector. A thixotropic gel grout, as used by Nishimatsu on the Docklands Light Rail to Lewisham, will be injected through two of the eight injection pipes in the tail as the TBM is shoved forward.



Main Civil Contract Packages - Section 2 (St Pancras - Southfleet Junction)

St Pancras
103 - King's Cross Lands Civil Works
Contractor: Kier Construction Ltd/ Edmund Nuttall Ltd JV
104 - Railway Staging & Interface Works
105 - Deck Extension & Thameslink
108/109/139 - St Pancras Station Refurbishment, Fit-out & M&E
135 - St Pancras Highway & Utility Diversions
Contractor: Edmund Nuttall Ltd

London Tunnels & Stratford
220 - London Portal (edge of King's Cross Railway Lands) **to Stratford Box**
Contractor: Nishimatsu-Cementation Skanska JV
232 - Stratford Station
240 - Stratford to Barrington Rd (Little Ilford, Newham)
Contractor: Costain Ltd/Skanska UK Ltd/ Bachy Soletanche Ltd JV
250 - Barrington Rd to Ripple Lane (Dagenham)
Contractor: Edmund Nuttall Ltd/Wayss & Freytag/Kier Construction Ltd

Thames and Ebbsfleet
310 - West Thames: Ripple Lane to River Thames
320 - Thames Tunnel & Approaches
Contractor: Hochtief/J Murphy & Sons Ltd JV
340 - Ebbsfleet Station
342 - Ebbsfleet Station Access Roads & Bridges

The TBMs are being designed in Japan but the fabrication of the shield, machinery and cutterhead will be carried out at the Kvaerner works at Sheffield. This is the works where the Markham manufacturing machinery was transferred to when the Chesterfield works closed. The assembly of the TBM will be by Qualter Hall at its offshore fabrication yard at Middlesbrough. The back up is being designed by Bennett Associates. The first TBM will be delivered to site in April 2002 and the second in May 2002.

The two TBMs for Contract 240 will be EPB machines with no major changes from the specified machine. The success of the JLE Canary Wharf to Greenwich ground water lowering scheme led to the decision to have a global dewatering system at the Stratford Box and along the tunnel route. This will reduce the working water pressure necessary for the machines and will allow easier excavation of the cross passages. The maximum water pressure would reach 3.2 bar at the deepest section without the influence of the dewatering.

The variable speed cutterheads for the two machines will be very robust with only pick cutters. Provision will be made, however, for the installation of disc cutters if the need should arise. The wear detection system is electrical. The shield will be doubly articulated with active articulation at the head and passive articulation at the tail thus minimising the TBM overcut and mitigating the settlement risks.

The excavated spoil will again be removed from the tunnel to the Stratford Box site by conveyor. A cement grout will be used with tail injection. The first TBM will be manufactured at the Wirth works in Germany, but the location for the manufacture of the second machine has not been finalised. The backup equipment is being designed and fabricated by Rowa of Switzerland. The first TBM will be delivered to site in July 2002 and the second TBM in August 2002.

The two Lovat TBMs for Contract 250 are convertible screw or belt machines as specified and both conveyors are hydraulically retractable/extendible into the cutter head chamber. Operation will start in closed mode through the Superficial Deposits and then change into open belt mode for the London Clay section. The tunnel drives will benefit from the planned global dewatering system as they approach the deeper section at Barrington Road and work in EPB mode through the Thanet Sands.

The articulated cutterheads will have picks, but if necessary discs can be fitted. The wear detection system is hydraulic. The tail is floating with a mechanical spring/bolt connection to the main shield. The Lovat backup equipment will run on rails. A special feature is a ring main to inject foam around the machine body to prevent grout or other material sticking to the skin and to mitigate settlement. The machines and backup will be manufactured in Canada.

All the spoil will be removed by conveyor to the Ripple Lane portal and after any treatment removed to a land raise site 600m from the Ripple Lane Site.

Two Herrenknecht TBMs will be manufactured for Contract 320, but the programme allows for the backup for the first drive to be removed and reused for the second drive. The first machine will be fabricated at the Strassbourg works in France and assembled at the Herrenknecht plant at Schwanau in Germany. The TBMs will have hydraulic passive articulation at the tail and the cutterhead can be moved forward and backwards to aid tool changes and tunnel face access. There is a crusher and grill in the invert to crush the large flints. The wear on the picks and twin cutters will be monitored electrically.

The maximum water pressure will be 4.2 bar. Glands are provided for angular ground treatment ahead of the face and a large dewatering facility through the slurry discharge pipes is provided. The backup has been designed by H S Engineering of Switzerland. The first TBM will be on site in June 2002.

The slurry will be treated in a plant at the surface with vibrating screens, hydro cyclones and centrifuges. The treated material will be placed in a nearby Blue Circle Quarry. The treatment plant has been transferred from a Hochtief site in Berlin, Germany.

Shafts

There are six intervention and ventilation shafts along the bored tunnel alignment in Section 2. Details of the shafts are given in the table below.

Shaft Details

The Corsica Street shaft was originally designed as a 18m diameter segmental lined shaft. The shaft will be sunk through the London Clay and into the Woolwich and Reading Beds. During the value engineering process the lining has been changed to sprayed concrete ground support with a cast *in situ* secondary lining. The shaft is on the alignment of the down line and adits will be constructed under the North London Line to the up line.

The Graham Street shaft will be the deepest diaphragm wall shaft in the UK with excavation to 45.3m and diaphragm walls to a depth of 54m. The shaft is adjacent to an existing live railway line. The wall panels are 1.2m wide and will key into the Thanet Sands. Dewatering will be required to secure the base of the wall. The shaft must be completed before the Kawasaki TBMs arrive as this will be the first location when a thorough inspection of the cutter heads can be made.

The Woodgrange shaft site is very restricted behind a parade of shops at the end of a narrow street. The upper part of the walls will be excavated by grab and the lower part by hydrofraise. The shaft will be the first location that a thorough inspection of the Wirth TBM cutterheads can be made.

The Barrington Road shaft is in a field adjacent to an existing railway embankment. The up line lies beneath the District Line and the London Tilbury & Southend Railway with an adit to the shaft. The shaft will be the reception shaft for both Contract 240 and for Contract 250. Consideration is being given to the construction of a second shaft at Barrington Road as part of the value engineering.

The Wayside shaft is adjacent to the A13. The RLE design was a rectangular diaphragm wall shaft, but the contractor has chosen an oval shaped shaft with secant piles. The shaft bottoms out in the London Clay. Adits will be excavated under the London Tilbury & Southend Railway.

Cross Passages and Sumps

The cross passages will be used for emergency evacuation of the passengers in the case of an incident. Passengers will be transferred to a train in the adjacent tunnel. The spacing of the cross passages is based upon the length of the Eurostar trains and is an average of 560m, but with a minimum spacing of 350m and a maximum spacing of 750m. Close to the intervention shafts there will be cross passage at 50m and 425m on one side of the shaft and one at 375m on the opposite side of the shaft. The cross passages will also house systemwide electrical and mechanical equipment.

CONTRACT	SHAFT	SIZE	FORM OF CONSTRCUTION	SUB-CONTRACTOR
220	Corsica Street	18m diameter, 24m deep	Sprayed concrete primary lining with cast *in situ* concrete secondary lining Diaphragm walls 54m deep	JV Cementation Skanska Foundations/Bachy Soletanche
	Graham Road	28m by 13m, 45m deep		
240	Woodgrange Road	28m by 12m, 29m deep	Diaphragm walls 35m deep	Bachy Soletanche
	Barrington Road	6.5m by 21.65m, 35m deep	Diaphragm walls 42 deep	Bachy Soletanche
250	Wayside	12m by 18m oval shaft, 22m deep	Secant piled walls 25m deep	JV Nuttall/Wayss & Freytag/Kier

The cross passages will be lined in cast iron segments except for cross passages in London Clay which will have sprayed concrete linings. The rings in the two running tunnels at cross passages will have preformed openings which can be removed without the need for propping the tunnels.

The methods of construction of the cross passages have yet to be decided, but the location of each will be studied individually. Probing and grouting, dewatering and in an extreme case ground freezing will be used.

There are four sumps along the bored tunnel alignment, three in the London tunnels and one under the River Thames. The sumps have a capacity of 12m^3 and will be lined in cast iron rings. Similar methods of construction as the cross passages will be required.

Cut and Cover Tunnels

In Section 2 the main cut and cover is for Stratford Station and this is described separately. There will be cut and cover tunnels at the two ends of the London tunnels and at the ends of the Thames tunnel. The cut and cover works at Pepper Hill will incorporate the widening of the A2 for the Highways Agency. The structure has to be constructed with two lanes open at all times. The top down method of construction will be used.

In Section 1 the main cut and cover works are at Ashford and these are discussed in a separate section. The other cut and cover structures are at road or other crossings or where the alignment had been put below ground level for environmental reason. At Mersham for example the cut and cover will reunite the village and will be covered with a meadow.

The forms of construction of the cut and cover tunnels are conventional cast *in situ* cut and cover, contiguous bored piles with top down or bottom up construction or precast arches. This latter form of construction was part of the value engineering on Contract 420. This form of construction had been used by one of the JV partners on the continent.

DETAILS ALONG THE ROUTE

Contract 220 – Gifford Street to Stratford

The tunnelling will be carried out from the west end of the Stratford Box towards the Gifford Street portal. Tunnelling will commence with the up line in June 2002 with the down line 4 to 6 weeks later. The machines will start with a decline drive into the Thanet Sands and the upper chalk. The dewatering for the Stratford Box will assist in reducing the water pressure. Much of the route lies below Railtrack property, but there are some 900 properties in the zone of influence along the route.

The TBMs will stop, after 3.2km, at the Graham Road shaft in the summer of 2003

CONTRACT	LOCATION	TYPE OF CONSTRUCTION	LENGTH, WIDTH, DEPTH/HEIGHT
Section 2			
220	Gifford Street Portal	Bored piles and *in situ* concrete	45m by 22m by 10m deep
230	Stratford Box	Diaphragm walls over 1m wide and up to 30m deep, bored piles with steel columns	1,070m by 50m by 16 to 22m deep
250	Ripple Lane	Combined steel sheet piles and *in situ* concrete	178m by 23m by 14m deep
320	North of Thames Tunnel	Diaphragm walls and *in situ* concrete	140m by 24m by up to 15m deep
	South of Thames Tunnel	Diaphragm walls and *in situ* concrete	590m by 30m by 20m deep
342	Pepper Hill	Bored piles, top down	305m by 11m by 15m deep
Section 1			
330	Brewers Road	Contiguous bored piles	55m by 12m by 9m deep
420	Boxley	Contiguous bored piles and *in situ* concrete	325m by 12m by 7m high
	Eyhorne Street	Precast arches	360m by 14m by 9m high
	Harrietsham	Contiguous bored piles	150m by 11.5m by 6.5m high
	Sandway Tip	Precast arches	170m by 13.3m by 8.5m high
430	Westwell Leacon	*In situ* concrete	120m by 11.7m by 7.8m high
	Ashford West	Contiguous bored piles	570m by up to 28m by 11m deep
	Ashford East	Contiguous bored piles	422m by up to 12.1m by 7.3m high
440	Mersham	Contiguous bored piles and *in situ* concrete	160m by up to 15.2m by 6.2m high
	Sandling	Contiguous bored piles	92m by 11.5m by 6.2m high

Digging the diaphragm well for the Stratford Box.

when the cutterheads will be inspected and any necessary maintenance carried out. The second schedule maintenance stop will be at the Corsica Street shaft, 2km further along the drive. The final section of the drive passes under the Highbury and Islington Victoria Line and Northern City Line stations and then, with a low cover of half a diameter, under Caledonian Road. This section was originally in cut and cover, but during the House of Lords Parliamentary stage, following objections about the part closure of the road for up to two years, it was placed in bored tunnel. Along Caledonian Road above the tunnel are the 1,650mm by 750mm brick lined Fleet Sewer and, 750mm and 900mm high pressure cast iron water mains.

It is planned that these services will be replaced and supported during the tunnelling operation. A planning application has recently been submitted for these works, but there is some concern by the shop owners along Caledonian Road that the works will cause disruption for a very long period.

Contract 230 – Stratford Box

The Stratford box will be 1,070m long, up to 50m wide and between 16 and 22m deep and will have two international platforms and two domestic platforms and a crossover. The two ends of the box will be constructed first and handed over to Contracts 220 and 240 by May 2002 in time for the delivery of the TBMs on the two contracts and the commencement of tunnelling. Installation of the Diaphragm walls, 1m wide and up to 30m deep, commenced at the beginning of July. The maximum depth of diaphragm wall is 30m with an average depth of 27m.

The west end section will have permanent props at 10m centres at the 5m level supported on two steel intermediate piled columns and one or more temporary props. At the east end there will be two permanent props. The central part of the box will have no permanent props. The base slab, will be cast in two phases; first the central section followed by the two outside sections.

A permanent dewatering system, to reduce the uplift on the structure, is being installed for the 120 year life of the structure. A trial test programme with five wells installed by Thames Utilities Ltd. which produced 12l/sec per well. A total of 30 wells will be installed around the box. Permanent pumps will be installed following completion of the construction.

Contract 240 – Stratford to Barrington Road

The two TBMs, to be delivered in July and August 2002, will drive eastwards to the Barrington Road shaft. The majority of the drive will be in the Thanet Sands. The Thanet Sands are under artesian water pressure and have caused many tunnelling problems in the past. A temporary dewatering system will be installed, along much of the tunnel alignment, to reduce the water pressure and to improve the stability of the sands. 15 wells will be installed to reduce the water pressure from about 30m above the tunnel invert to 5m.

The two drives pass under the two London Underground Central Line tunnels about 35m from the Stratford Box with a clearance under the nearest tunnel of about 4m. Particular care will be needed at this early stage of the drive.

Contract 250 – Barrington Road to Ripple Lane

Two thirds of the tunnel drives on this contract will be in the London Clay and virtually all the tunnelling will be beneath Railtrack property. The drives will commence at the Ripple Lane site from a steel sheet piled cofferdam. The piles will be vibrated down most of their depth and then driven down to the their final level by hammer. The two TBMs will be delivered to site in April and June 2002.

The former Freightliner Terminal at Ripple Lane lies above the tunnel alignment. The terminal is founded on reinforced concrete piled. Those piles along the tunnel alignment will be removed in advance of the tunnelling. Near the Wayside Shaft the tunnel alignment passes under the A13 Alfred's Way railway bridge and 8 piles are expected to obstruct the tunnel alignment. Accommodation works are being planned to install new bridge foundations, in tunnel, above the CTRL alignment.

Contract 320 – Thames Tunnel

This 3.55km long alignment has a 140m long cut and cover and 160m long retained wall at the north end and a 590m long cut and cover and 150m long retained wall at the south end. The remaining 2.5km is in bored tunnel under the Thames. These diaphragm walled and piled structures represent two thirds of the target price. Amec/Spie Batignolles have been awarded the diaphragm wall and piling sub-contract.

On the north side there is a SSSI site and potential dewatering problems. Site trials are planned for a 10l/sec water recharge system. On the south side the Swanscombe Marshes are being stabilised for the piling platform and delivery of TBMs. This work is being carried out by Keller.

The two drives will be in the Upper Chalk which has between 15% and 25% of flints. The abrasiveness of the flints is being investigated by a task force. The first TBM is planned to start driving in June 2002. The first tunnel has to be handed over to the track laying contractor by 27th June 2003 and the second tunnel by 15th August 2004.

Contract 410 – North Downs Tunnel

Contract 410, the North Downs tunnel, was described in the September 2000 issue of *World Tunnelling*. This contract has been one of the great successes of Section 1 of the CTRL. Good planning, coordination and value engineering has achieved a completion 5 months ahead of programme with an outturn cost some 10% below the target price. The tunnel was officially handed over at the end of July 2001.

The excavation was carried out in three stages – top heading, bench and invert – using a Paurat E242 roadheader with the final trimming with a Liebherr excavator. The excavated material was removed with a Liebherr low loader and placed on a Burrows Brothers' 500 t/h conveyor for removal to the portal. The ground support was a combination of 4m long rockbolts, lattice girders and shotcrete. The best progress achieved was 14m a day and 81m a week for the top heading and 181m a week for the bench.

The invert excavation was carried out with a road planner which was followed by placing the 150mm blinding with a road paver. The best progress for the combined operation was 1,322m a week. The 600mm thick reinforced concrete invert was placed as a continuous operation in 500m lengths, over 8 days.

The 350mm thick *in situ* concrete secondary lining was cast using two 12m long shutters with a planned weekly progress of 108m a week. However, 10 pours a week, 120m, were regularly achieved. The

Construction in the North Downs tunnel.

Left: Boxley tunnel showing bored piles.

Right: Cladding placement at Eyhorne tunnel.

secondary lining was reinforced with polypropylene fibres for fire resistance. A 2mm thick waterproof membrane was placed between the shotcrete primary lining and the secondary lining over the arch.

There was one tragic accident in the tunnel when a miner was disabled by a small rockfall. This accident led to the RLE 'zero accident' policy. The joint contract 350/410, the Medway bridge and the North Downs tunnel, subsequently achieved an excellent safety record with one million hours without a reportable accident being recorded in the period leading up to November 2000.

Contract 430 – Ashford

The 15.2km long alignment between Lenham and Sevington in Kent includes a short, 120m long, cast insitu cut and cover tunnel at Westwell Leacon and a length of 1643m of underground earth retaining structures in Ashford of which 1021m are in cut and cover and 622m in retained cut. The length with contiguous piled walls is 1493m. In addition there are 193m of piled walls for the Up and Down Chords.

The project has been described in the recent June 2001 issue with particular reference to the geotechnical and hydrogeological issues and the design development of the piling, groundwater lowering and the choice of cast *in situ*, top down or bottom up forms of construction.

The contract is on the critical path for Section 1 with a completion date of May 2002. However, sectional handover dates are very critical for the tracklaying contract with the structures for the two main line fast tracks to be handed over on 1st December 2001 and the structures for the two tracks into and out of Ashford Station by 1st February 2002. At the time of the visit to the site about 85% of the contract had been completed, and despite one of the wettest winters on record the project was just ahead of programme.

The contract is the most complex contract on the CTRL, and has the highest target price, at £150m of which £18m is for service diversions. The value engineering, described in the June article, whilst showing some savings in cost, was really to mitigate risk and to improve the certainty of the schedule for the construction. The tender design showed all cut and cover tunnels being constructed top down. The value engineering concentrated on the areas where bottom up construction could be used to provide more flexibility in the programme. Approximately 75% of the length was changed to bottom up construction. The top down sections were under the Maidstone to Ashford railway and the Advanced Box which had to be constructed in advance of the adjacent section to carry utility and road diversions. The table illustrates the complexity of the underground works.

SECTION	LENGTH	NUMBER OF TRACKS	METHOD OF CONSTRUCTION
Retained cut	80m	Four	Cast *in situ*
West portal cut and cover	70m	Four	Cast *in situ*
Chart Road cut and cover	86m	Four	Bottom up
Chart Road, Advanced Box cut and cover	114m	Four	Top down
Chart Road – Maidstone Railway cut and cover	150m	Four	Bottom up
Maidstone Railway cut and cover	150m	Four	Top down
Greensand Way propped retained cut	48m	Two	Bottom up
Greensand Way – Gasworks Lane cut and cover	422m	Two	Bottom up
Gasworks Lane propped retained cut	186m	Two	Bottom up
Cattle Market Foot Bridge cut and cover	29m	Two	Bottom up
Cattle Market to Beaver Road propped retained cut	75m	Two	Bottom up
Cattle Market to Beaver Road retained cut	130m	Two	Bottom up
Beaver Road retained cut	103m	Two	Bottom up
Down Chord piled wall	120m	One	Bottom up
Up Chord pile wall	73m	One	Bottom up

Construction Works at Ashford

The observational method was used for monitoring with defined trigger zones to check and control the construction sequence. These trigger zones – green, yellow and red – were set for each construction stage of the excavation. The primary monitoring was wall movement, with inclinometers, and prop loads, with strain gauges. Construction Control Charts were produced and reviewed daily. Monitoring Review meetings were held weekly. Generally, wall movements were within the yellow zones. Red trigger zones were recorded on the two top down sections and one adjacent section. Secondary monitoring was water pressure and ground movements.

The contract has a major interface with Railtrack. When rail closures are necessary the project ensures there is 100% cover for all plant and labour to mitigate the risk of possession overruns and to ensure completion within the closure period. During Christmas 1999 a 27m long subway was jacked under the Ashford to Folkestone line in a 33 hour closure by Skanska Mining. On that occasion a 200% cover was provided for the hydraulic jacks and gantry cranes. However, all these additional provisions were small, and an insurance policy, compared to the £75,000 per hour charge for an overrun on the closure period for delays to Eurostar.

by Rodney Craig
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