The Holmesdale Tunnel

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Introduction

THE M25, London Orbital Road, a dual carriageway motorway which when complete around the year 1986 will be about 190km long completely encircling the metropolis, may claim to be unique in many ways. Out of this total length the 3km section running eastwards from the A10 Cambridge Road past Waltham Cross to the west bank of the River Lea Navigation has the distinction of being the most expensive section of road in Britain.

This section is currently under construction by Tarmac National Construction Ltd. for the Department of Transport, Eastern Road Construction Unit, under a £28.6 million contract. Work commenced in 1980 and completion is due in 1983.

The line of this section runs through the heart of an existing residential area, where, for environmental reasons, the motorway is to be run underground through the biggest cut-and-cover tunnel currently under construction in this country (Fig. 1). This super-underpass, 670m long, will be known as the Holmesdale Tunnel.

Design

Geologically, the site lies at the edge of the London Basin and the general strata comprises a thin band of alluvial clay about 1m thick overlying a layer of terrace gravel some 4m thick. Beneath this are found the basement beds of the London Clay some 3m thick merging into the Woolwich and Reading Beds which are of considerable depth. The tunnel accommodates the full motorway width of 3-lane dual carriageways plus hard shoulders and has an overall width between side walls of 39.2m. There are also raised walkways along both sides of each carriageway under which are accommodated the tunnel services and motorway communication cables. A continuous wall along the centre-line separates the two carriageways.

The outer walls of the tunnel are propped cantilevers, constructed of reinforced concrete 1.0m thick by the diaphragm wall technique, and penetrating to a maximum depth of 19m below existing ground level. The central wall is founded upon 1.05m dia. bored piles at 3.0m centres 14m long below formation level. These piles extend upwards as 600mm dia. columns to cill beams (Fig. 2) supporting the roof. The gaps between the columns are infilled with blockwork.

The tunnel roof is of prestressed composite construction using precast 'M' beams placed discretely, in composite action with an in-situ top slab. Beams (Fig. 3) are generally at 1.5m centres but are at 2.4m centres over a length at the west end and contiguous over a length at the east end. A total of 806 prestressed beams are used in the tunnel roof.

Construction of the tunnel was subject to a strict sequence of working to ensure that the roof slab acted as a prop to the outer walls before excavation to formation level was complete and the walls had taken up their full load.

Ventilation of the tunnel is by the longitudinal system using jet fans suspended from the roof. The permanent tunnel lighting will be to a high standard and induction loop arrays installed in the carriageways in the tunnel will monitor the flow of traffic.

The equipment for tunnel lighting, ventilation and drainage is housed in a central control structure located off the south side of the tunnel about midway along its length. This structure is 24.4m × 17.9m in plan area and extends to a depth of 21.7m below ground level, with one floor above ground and three below. The walls of the structure are 1.2m thick and also of diaphragm wall construction (Fig. 6); they are supported by permanent ring beams at each floor level which were constructed as excavation within the walls proceeded, floor by floor.

The control structure is divided into three cells by 600mm thick internal walls constructed by the diaphragm wall technique before excavation commenced.

The sump for collection of surface water from the motorway and ground water seepage from the sides of the approach cuttings is situated at the lowest level of the control chamber, together with a pump chamber housing four electrically driven pumps.

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Fig. 1. Construction work in progress for the cut-and-cover M25 Holmesdale tunnel at Waltham Cross. View shows the two diaphragm walls completed either side of the dual carriageways, and the excavation along the line of the central axis

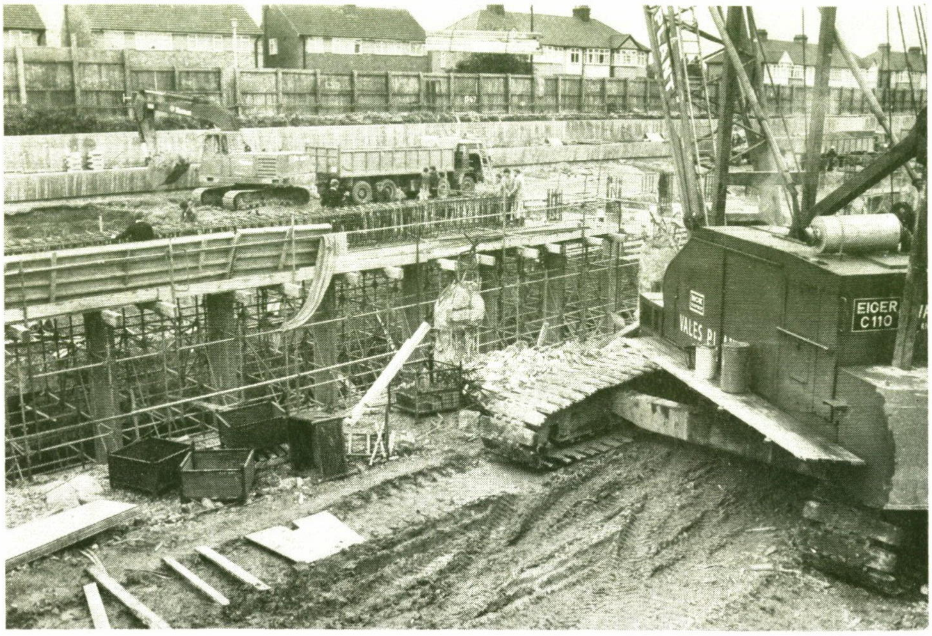

Fig. 2. Construction of the central cill beam on top of the 600mm dia. columns

The power supply for the tunnel will come through two 1 500kVA transformers at the control complex and two 1 000kVA transformers in a sub-station at the west end of the tunnel linked to two independent sources on the national grid. In addition a diesel-generator set will ensure the security of the power supply to the pumps in the event of a failure of the mains supply. A standby battery installation is provided for emergency lighting.

The eastern approach ramp to the tunnel is flanked by retaining walls 210m long and of thickness varying from 600mm to 1 200mm. These walls are designed as cantilevers propped at formation level and are also constructed by the diaphragm wall technique.

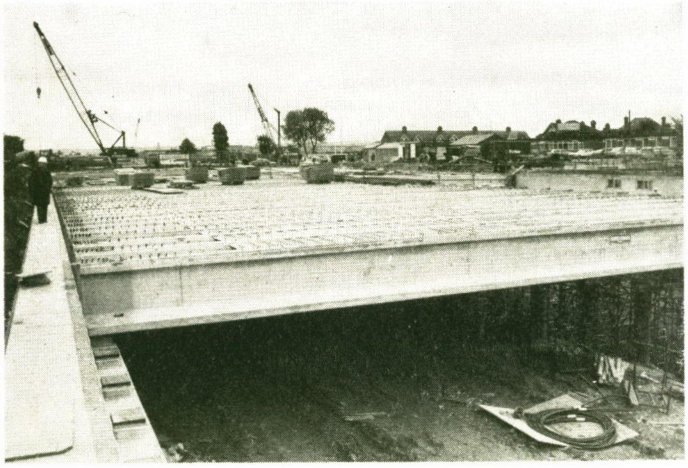

Fig. 3. Precast concrete beams spanning each carriageway of the tunnel between diaphragm walls and central piers

Construction of the diaphragm walls

Scope and organisation of the work

All the diaphragm wall work described above together with a cut-off wall across the eastern end of the tunnel excavation to exclude ground water seepage was entrusted to ICOS (Great Britain) Ltd. under a £4 million sub-contract to Tarmac National Construction. The sub-contract was awarded to ICOS in September 1980 and work thereunder was substantially completed by October 1981.

The side walls to the tunnel comprise 255 panels each 5.0m long and of average depth 14.7m. The walls are very heavily reinforced, each panel incorporating a prefabricated reinforcement cage of high yield steel weighing 17.1tonnes. Main bars were 50mm dia. The retaining walls to the eastern approach ramp comprise 63 panels varying in size from 6.0m long × 9.5m deep and 600mm thick to 6.0m long × 18.0m deep and 1 200mm thick. The reinforcement cages in this section weighed up to 14.6tonnes. The walls to the control structure comprise 29 panels, the largest being 4.5m long × 20.02m deep and 1 200mm thick, incorporating 20.9tonnes of reinforcement in a single cage.

Overall, the project comprised a total of 347 panels with 30 904m^3 of concrete to be placed and the fabrication of 5 385 tonnes of steel reinforcement into cages followed by their placing in the work. Some of these reinforcement cages required box-outs, the positioning of Macalloy bars and of ground-anchor sleeves.

For a project on this scale, with all diaphragm wall construction planned for completion within a period of 50 weeks including an initial 2 weeks for setting up, it was essential to mobilise a labour force with many skilled and experienced personnel. ICOS' Project Manager for the job was Mr. Federico DeBoni, who had earlier supervised the diaphragm wall construction at the Seaforth Dock.

The ICOS organisation, in conformity with its international standing, does not maintain a stock of all essential equipment in this country at all times but immediately the order was placed the necessary requisitions were implemented and during the following weeks there arrived on site clamshell grabs (Fig. 7) from Switzerland, desanders from France, stop-end material from Hong Kong, hydraulic extractors of up to 140tonnes capacity from Italy, etc. Much of this special equipment is of ICOS' own design and manufacture. By mid-November 1980 the site plant layout was

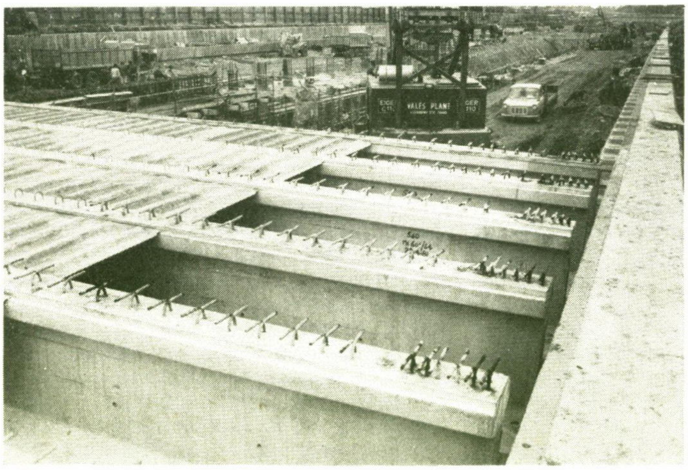

Fig. 4. Corrugated glass reinforced cement sheeting infill between beams supplied by Thyssen (GB) Ltd.

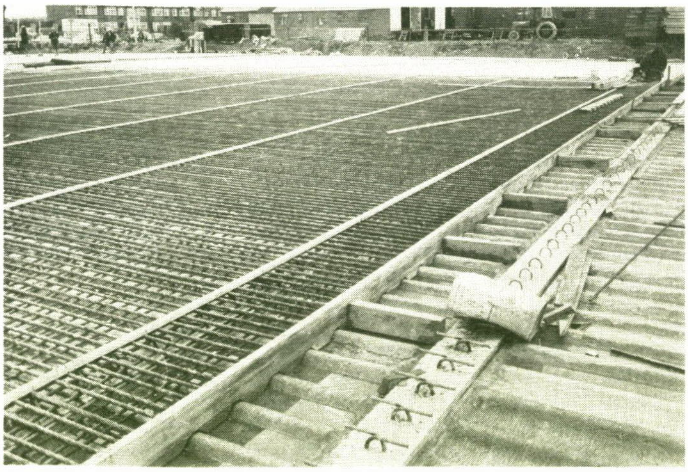

Fig. 5. Reinforcement installed ready for pouring the concrete decking slab

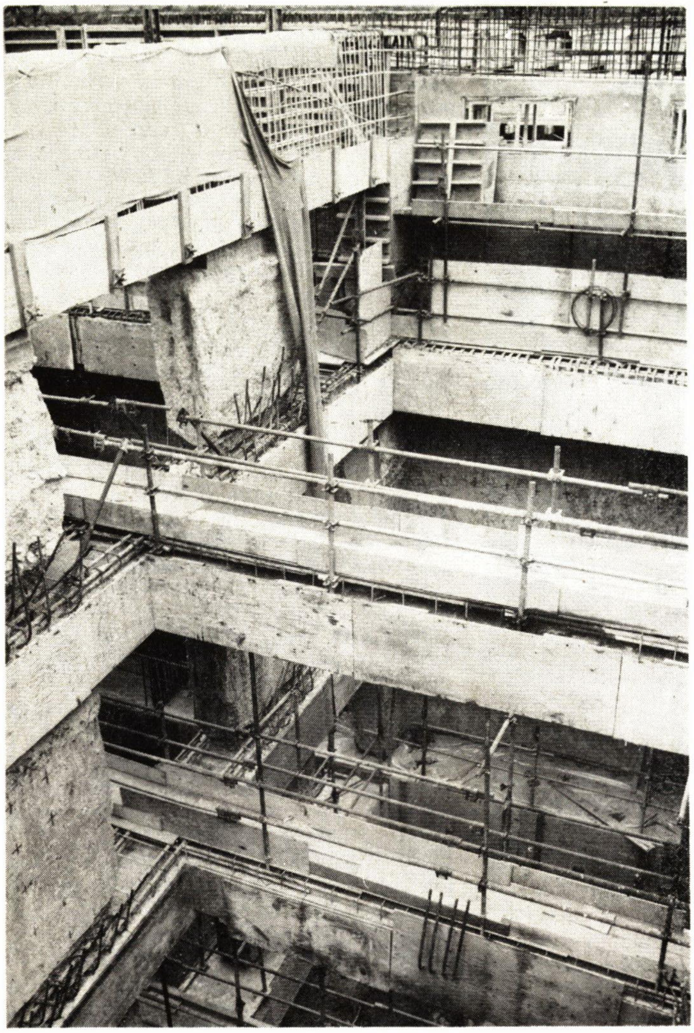

Fig. 6. The control room for the tunnel was formed between 1.2m thick diaphragm walls up to 21m deep, with 600mm thick inner partition walls also formed by diaphragm walling. Excavation was in stages with ring beams and struts cast in-situ at each stage

Fig. 7. Excavating for one of the last diaphragm wall panels (across the A1010 Hertford road)

operational and in the last week of that month the first panel was concreted.

Once work was firmly under way, strengthening and augmentation of the site installation arrangements proceeded in response to the dictates of progress requirements such as the laying of a 1km long water supply pipeline to the bentonite mixing plant and the substitution of a mains electricity supply from a point 0.8km distant for the portable generators initially used.

The labour force was comprised of 14 specialists in charge of the various operations such as excavation, bentonite mixing and distribution, stop-end insertion and extraction, placing of concrete and of reinforcing steel etc., when the establishment reached full strength. Each specialist normally had two or three unskilled operatives working with him. Most of this supporting labour force was without previous experience of diaphragm wall construction but by moving the men around between the specialists during the course of the work a well trained team was successfully formed.

Technical description of the construction method

Bentonite powder was delivered to the site in bulk and stored in a pair of 40ton capacity silos. The bentonite slurry was produced by mixing the powder with fresh water in the ratio of 50kg bentonite to 1 tonne of water in hydraulic mixers of ICOS' own design incorporating a Klein pump. Two such mixers were installed. After mixing the slurry was pumped into four 50m^3 capacity ageing tanks where it was retained for 24 hours for the bentonite to become thoroughly hydrated. From the ageing tanks the bentonite was circulated by 6in piston pumps through a 3in dia. closed circuit pipeline to the whole site, even to the extremity of the works 600m from the mixing station. Valved take-off points at suitable intervals were provided for the release of slurry into the trenches.

For excavation of the panels specially designed grabs mounted on standard crawler crane rigs are used. Six such rigs were used; on the main walls there were three NCK 605s, and two 38RBs, with one NCK 305 for the lighter work on the groundwater cut-off wall. The average rate of excavation through the contract was 4.5m^2 per hour but production rates of 6.0m^2 per hour were attained. All spoil was carted away by the main contractor for disposal to a landscape area provided by the client.

Immediately upon completion of the excavation of a panel a stop-end former was placed in position ready for concreting, but first of all the bentonite slurry required to be desanded. The slurry from the panel, contaminated with soil from the excavation process, was pumped by means of an air-lift through a cyclone desander to reduce the sand content to a maximum of 4%. This desanding of the bentonite after completion of the excavation and before concreting is essential to prevent the trapping of inclusions of soil-contaminated slurry amongst the reinforcement during concreting of any reinforced concrete diaphragm wall. The desander used was another piece of equipment designed and built by ICOS themselves.

The reinforcing steel, mostly in 50mm dia. bars, was supplied by Rom River Ltd. and prefabricated into cages on site under sub-contract by S. Arnold Ltd. An average work-force of eight steel-fixers produced 12 cages per week.

The handling and placing in position in the slurry filled trench of cages up to 20m long and weighing almost 21tonnes presents many problems even when they are fabricated within crane reach of the work. Each cage had to be hoisted from the horizontal position and turned through 180° whilst suspended. For this operation an Eiger 110 crawler crane equipped with a 100ft boom was used. The lifting capacity and reach of this rig enabled the movement of stop-ends, desander, etc. as well as the placing of reinforcement cages to be carried out as a slewing operation only. The cages were suspended by eight 22mm dia. wire rope slings arranged in pairs from 6in × 4in RSJs straddling the trench and supported by the guide walls. The normal arrangement whereby the weight of the cage is transferred to the slings by hanging stirrups incorporated in the prefabrication had to be abandoned on this project because of the exceptional weight of the cages.

The normal density of steel in diaphragm walling falls within the range 80–100kg/m^2 of wall but on this project the density was 232kg/m^2. Wire rope was substituted for the hanging stirrups and, additionally, to spread the load, eight 32mm bars were incorporated in the cage. None of this additional steel was recoverable for re-use. In spite of these exceptional measures it proved difficult to hold the cages at the correct level and within the tolerance of $\pm$5cm allowed. Because of this, some of the U-bars projecting from the top of the wall for bonding in to the cast in-situ capping beam had to be adjusted to the correct level after the concrete had set by cutting and welding.

After placing the cages, a 250 int. dia. tremie pipe assembly complete with gate and hopper was lowered into the centre of the panel. The contractor had to amend the reinforcement to permit the insertion of the 270mm overall diameter tremie pipe.

All concrete was obtained from the local plant of Ready Mix Concrete Ltd. at Waltham Cross whose truck mixers were delivering up to 1 300m^3 per week at the peak production period. RMC installed a Steelfields mobile batching plant in the depot to handle the extra demand from ICOS as the existing fixed plant was fully committed to producing concrete for the main contractor, Tarmac Construction. The mix used was to a 37.5N, SR & P2, 20mm max. aggregate size, specification with a slump of 175mm maximum.

As the concrete is poured the bentonite slurry rises in the trench and is progressively removed by pump for disposal or reuse (Fig. 8). The majority of the slurry on this contract was recycled by discharging into a 500m^3 capacity spent bentonite lagoon divided into three ponds. After a holding period in the first pond where most of the sand held in suspension settled out, followed by a further holding period in the second pond, the slurry from the third pond was passed through a Caviem desander. The cleaned slurry was then recirculated along with freshly mixed bentonite to the trenches.

The tremie is shortened as concrete placing progresses to avoid the build-up of an excessive head of concrete at the tremie outlet. This shortening was made in increments of 2.2m. Careful records have to be kept at all times as concreting proceeds to ensure that at least 2.0m of tremie pipe remains embedded in the rising concrete until the pour is complete.

The normal height of 'overpour' for a diaphragm wall of this depth is about 600mm, all of which is nominally classified as laitance or contaminated concrete which has to be broken out later. Except for the very top of this layer, the overpour on the M25 proved to be a hard concrete of acceptable quality and the height of overpour was reduced to 300mm during the course of the contract in order to minimise the amount of breaking-out required. This operation is carried out by the main contractor and is very time-consuming.

The disposal of waste bentonite slurry is another very costly operation, and the location of a suitable tip within easy reach of the site often presents a real problem. In this case, the reduction of the quantity of waste to no more than 15m^3 per panel by the installation of the recycling plant was an important factor in solving this problem.

Fig. 8. Panel concreting nearing completion, with bentonite slurry handling pump on the right

Fig. 9. Section of exposed diaphragm wall to the east of the Holmesdale tunnel, showing a trial panel of cladding material

Exposed wall surface finishes

Trimming of diaphragm walls

The specification required the exposed face of the diaphragm wall to be within 1% vertical tolerance and to have no protusions exceeding 10mm. At the time of writing, the main walls of the tunnel had not yet been fully exposed by excavation but it is anticipated that protuberances needing to be cut back will be found only in the upper zone where the walls penetrate the gravel stratum.

The results achieved in the control complex structure are rather more irregular. The layout dictated that all 29 panels of diaphragm wall comprising this structure were shorter than the 5m standard adopted for the main tunnel walls. This greatly increased the difficulty of maintaining accurate vertical alignment as excavation of the chamber to its full depth of 17m has revealed.

Facings

The main walls of the tunnel are to be faced with 6mm thick Glasal panelling manufactured by the Eternit Co. The panels, each about 5m^2 in area, will be mounted upon a framework of rolled aluminium sections secured to the face of the diaphragm wall with stainless steel fixings. The width of the space between the back of the Glasal panels and the theoretical plane of the face of the diaphragm wall is 13.5cm which is sufficient to accommodate all deviations of the wall face within the tolerances specified.

The walls within the control complex in areas such as the computer room, offices, etc. are faced either with blockwork which is plastered and painted or high quality facing brick. The sump chamber diaphragm walls, ring beams and floor are coated with Orsam waterproofing membrane.

Landscaping

The land occupied by the tunnel is not to be entirely given up to the motorway. By backfilling over the tunnel roof and surfacing with topsoil the area will be converted into playing fields for the use of the local community, a most pleasing finishing touch both aesthetically and economically.