CONSTRUCTING THE HINDHEAD TUNNEL

The second longest road tunnel in the UK was completed in July 2011. The £371 million project, which has relieved congestion around Hindhead in Surrey, had a wide range of engineering challenges to overcome. Ingenia asked Paul Arnold, Senior Project Manager at the Highways Agency and Paul Hoyland, a project director with Balfour Beatty, about how they came to satisfy the many stakeholders involved.

EARLY CONSIDERATIONS

In October 2002, the Highways Agency awarded an early design and build style contract to Balfour Beatty Major Projects, whose team included Mott MacDonald as their design partners. With Atkins being consultants to the Highways Agency, these organisations formed the A3 team that delivered the scheme to time and budget. The works started in January 2007 and the road was fully opened in July 2011.

TUNNELLING DECISIONS

Site investigation had shown that the ground along the proposed tunnel route was a mix of sandstone and sand, with more clayey sand (sand with clay) towards the southern end of the tunnel. The water table along the route was mostly lower than the bottom of the tunnel, meaning that the works would be almost wholly dry.

The challenge with tunnelling is how to excavate the tunnel without the face, roof or walls collapsing as the works progress. In this case, the method chosen was a variation of the method known as NATM (New Austrian Tunnelling Method). In NATM, as the tunnel is advanced, sprayed concrete is used to provide temporary support to the walls and roof prior to a structural lining being installed in the Hindhead tunnel, a variation of the technique known as Sprayed Concrete Lining (SCL) was used. This differs from NATM in that the lining is fully designed before work starts, and is applied based on a menu of pre-designed support solutions, which also provide the permanent structural lining of the tunnel.

These pre-designed support solutions included leaving a temporary bench in front of the face and (in more sandy ground) installing inclined perforated pipes into the roof of the tunnel (called canopy tubes) that can be filled with cement grout to form an arch protection over the tunnel roof (Figure 2). The horseshoe shape of the tunnel could be dug using a modified standard excavator instead of a tunnel boring machine. The horseshoe shape saved around 20% of the volume of soil dug.
WOOD WITHOUT WASTE

The construction team removed a total of 2.173 tonnes of wood, making efforts to ensure that none was wasted. Some was given for the Community Wood Recycling Scheme, which employs people who find it hard to get work elsewhere, for them to make objects that they could sell. Much of the land at the north end of the project was commercial woodland, owned by the Forestry Commission. Some of the felled trees became ship’s masts, and others came back to the site as fencing. Wood that could not be sold as timber was chipped and used for biofuel.

Once construction was complete, the team seeded all the banks and planted them with native trees and shrubs. The tunnel portals were then painted with yoghurt to encourage the growth of algae. Planting is also being done as part of the Community Wood Recycling Scheme, which employs workers who find it hard to get work elsewhere, for them to make objects that they could sell. Much of the land at the north end of the project was commercial woodland, owned by the Forestry Commission. Some of the felled trees became ship’s masts, and others came back to the site as fencing. Wood that could not be sold as timber was chipped and used for biofuel.

Advance rates had to be consistent therefore with the concrete’s gain in strength with time. In addition, the lining material had to meet performance requirements of energy absorption, water penetration, drying shrinkage, as well as construction requirements for pumpability and retardation of set.

Figure 1 Plan of the A3 improvement at Hindhead

In the Hindhead tunnel, the initial sprayed lining is also the structural lining. This was made possible by developments both in excavation and in spray mixes. The rock that had to be removed and disposed of (land around £15 million in cost) compared to the circular tunnel that a boring machine would have made. The decisions about which support method should be used in the different ground conditions being encountered during the tunnel construction were taken at daily review meetings, at which data from observations and measurements were examined. The data included tunnel settlements and internal convergence (the inward movement of the tunnel wall), surface settlements, geological face logs, records from probing ahead of the tunnel face, sprayed concrete time and strength records, and quality, environmental and tunnel inspections. The review resulted in the issue of formal instructions for excavation and support, in effect a permit to dig. Additional but not reduced support measures could be provided if deemed necessary. A significant innovation was to use the sprayed concrete lining to carry the residual permanent ground load after the initial redistribution of stresses as the ground arched around the excavation – to become the primary lining. Traditionally, the original sprayed lining has been a temporary lining, and the secondary lining has provided the structural strength of the tunnel. In the Hindhead tunnel, the initial sprayed lining is also the structural lining. This was made possible by developments both in excavation and in spray mixes. For the primary lining to be structural, it needs a regular section, and to be at least 200 mm thick. Lasers were used to guide the excavation, make it more accurate, and to ensure that the thickness of the sprayed concrete was even. Advances in the additives that can be put in the sprayed concrete also made it far easier to control its application. The primary lining was reinforced with steel fibres.

Figure 2 Excavation and support: (a) in sandstone, (b) in sand. The excavation was carried out in four stages: first a headering was created; this was enlarged to create the top half of the tunnel, the lower quarters or benches were then excavated.

Concrete was sprayed to form the primary lining (top) with a 12 m long shutter (bottom) used to form the secondary lining (above). Protection (metal mesh) for primary and permanent primary shotcrete, and fire protection (metal mesh) for the secondary lining. The secondary lining is 200 mm thick. Lasers were used to guide the excavation, make it more accurate, and to ensure that the thickness of the sprayed concrete was even. Advances in the additives that can be put in the sprayed concrete also made it far easier to control its application. The primary lining was reinforced with steel fibres.

FIRE PROTECTION

Fire is a hazard in tunnels that must be taken into account because the impact of vehicle fires – which are a constant risk on any section of road – are particularly pronounced when they occur in tunnels. It is of concern in terms both of safety and of structural damage and is a very serious problem in the confined space of a tunnel. Planned and tested evacuation
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the secondary lining, the included water shatters the concrete. In pores. With nowhere to go, the expansion of water within its concrete mix. The main cause of damage to concrete by fire is microfine polypropylene fibres in the concrete. The right mix of fibres, but also the correct aggregate. Aggregate limestone and granite offer the best performance universally in concrete, so it was essential that they were specified correctly. Limestone and granite offer the best performance universally in concrete, so it was essential that they were specified correctly. Limestone aggregates are used commonly but not universally in concrete, so it was essential that they were specified in this instance. Fire tests at Balfour Beatty showed that sample lining panels performed well. In contrast, a comparison panel with no added fibres shattered so violently that it damaged the test rig.

ACTIVE LIGHTING
One way to save energy in use and make the tunnels safer is by ‘active lighting’. This is lighting that responds to the outside conditions rather than being at a constant level. On a sunny day, therefore, the lighting at the tunnel entrances will be very bright to match the external conditions, but will decrease in intensity towards the centre of the tunnel, and brighten again towards the exit. In contrast, at night, lighting levels will be fairly low at the entrances and brighter towards the centre. The main aim is to allow drivers’ eyes to adjust, and minimise the risk of accidents, but by varying the intensity of the lighting, energy will also be saved.

EARTHWORKS AND CONSTRUCTION SPOIL
The environmental targets of the design included minimising both the amount of land-take and the amount of spoil to be taken off site as unwanted. For the first of these, both embankments and cuttings were designed at steep slopes – at 60° to the horizontal and up to 20° high. This also helped to conceal the line of the road. In order to achieve the required long-term stability, some 10,000 soil nails were used to reinforce the ground by drilling in and grouting 6m long rods into the slopes at spacings of 1 to 2m. Despite the surrounding hilly terrain, the vertical alignment of the tunnels was designed to a gradient of no more than 2.5%, avoiding steeper inclines that would cause heavy vehicles to slow down, and helping to ensure that the two lane dual carriageway could keep traffic flowing at 70 mph. There were a number of environmental issues that were requirements of the project and which could have seriously interfered with progress. Two examples are outlined here: first, the care for wildlife (see Wood without waste) and second, dealing with the amount of timber to be felled (see Considering the Wildlife).