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A subterranean Jigsaw

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The trains will have been a very long time coming. London's massive Crossrail project was discussed 100 years ago, and first seriously proposed in the 1980s, but saw many false starts as governments baulked at the cost.

// **Mark Smulian**

London's relentless growth and the pressures on its public transport system finally led the £14.8 billion project to start in 2007. Crossrail is due to open in 2018, linking railway lines that at present terminate on the edges of central London to provide a through service under the UK capital's heart. Trains will run from Reading to Shenfield or Abbey Wood, linking Heathrow airport and the skyscrapers of Canary Wharf. Alpine BeMo is working on two stations here as part of BBMV – a long-established partnership with Balfour Beatty, Morgan Sindall and Vinci: the excavation of stations at Liverpool Street, in the City of London, and at Whitechapel in the historic East End. The former is in the main financial district, but Whitechapel, though barely 20 minutes' walk away, is quite different. This is the old East End, where outsiders' images persist of cheerful Cockneys talking in rhyming slang while dressed in pearly costumes; a place once associated with the notorious Jack The Ripper and the Kray twins, and with popular television shows from Till Death Us Do Part to Eastenders.

It is changing fast. Whitechapel has been home to successive waves of immigration, most recently from Bangladesh, and colourful market stalls of Asian clothes and fresh produce and the extended Royal London Hospital impart an air of busy activity. Whitechapel station is already served by London's Underground and Overground lines, and Crossrail will turn it into an important interchange, making the area much more attractive for investment.



Good for business

As Mujahid Ali, owner of a menswear market stall says: "I think Crossrail

will be good for business. "There will be a lot more people coming into the area. It's already changed a lot with the new Royal London hospital and it will get even busier with Crossrail." On a very constricted site near Whitechapel market, engineers are at work on the Crossrail station, which will be built beneath the existing one. They started in January 2011 and are due to finish in 2015. They are excavating the station tunnels and its associated internal passages, escalator shafts and concourses using sprayed concrete lining, ultimately to a 300-400mm thickness to hold them place. Martin Fischer, Alpine BeMo's sprayed concrete lining coordination manager, explains that this technique is better suited to the multiple sizes and shapes needed in stations than is the TBM boring used for the running tunnels. He says: "Stations are quite complex structures, not straightforward ones like the running tunnels. In stations, you go around corners, up and down slopes of 30 degrees and there are tunnels everywhere, "It's like a Swiss cheese, with concourses and passages of different sizes, so you use sprayed concrete lining for these applications." Geologically, this is straightforward as both stations are being built into easily-worked London clay. Mr Fischer says: "We use standard application Sprayed Concrete Lining Method and as London clay is soft ground, we have an excavator like those you see on the surface, but with special applications. "After we have excavated one metre we then support it by spraying shotcrete, then do the next, always one metre at a time."

Guiding the geometry

A specially developed surveying system monitors the work in real time guiding the engineers to the correct tunnel geometry. The stations must connect to the running tunnels and the surface entrances, both of which are being built by other contractors. When station excavations are complete, the tunnel boring machines will pass through and resume their work on the far side, so all tasks must be completed to rigid timetables to ensure smooth workflow without delays. Tunnelling creates settlement during which the buildings above could be damaged, "so we have borehole arrays installed below sensitive buildings from which we do compensation grouting and if something moves we inject grout, stabilise it and bring it back up where it was before," Mr Fischer says. Constant remote measurements are carried out to detect any unacceptable movement, with one monitoring station even situated atop a nearby bank. Alpine BeMo's chief geotechnical engineer Alfred Stärk says London clay "is pretty much perfectly well formed for tunnelling, it has no water and is easy to excavate". But there is something less helpful beneath it – the Lambeth Group. This can contain sand structures a couple of metres thick and up to 20m of confined water at high pressure. Excavating the 'invert' (the lowest part of the tunnel) can disturb the Lambeth Group, risking water entering the tunnel. "We survey ahead to see if Lambeth Group is rising and if we encounter sand with high water pressure then we drill vertically into it and depressurise the water," he explains. These problems have not yet appeared here. "We have a good idea about most of the area, but the sand layers are not consistent, they are distributed randomly so we need to drill ahead of the excavation to see exactly what is there".

Missing records

Also not fully known is what structures the tunnellers may encounter. As Dr Stärk explains: "London was the first city that built an underground railway, and in the 1860s nobody paid attention to making records of where these underground structures are. "At one stage nearly every building had a well. Those days are gone but the wells haven't, and not all of them are recorded. At Liverpool Street we were tunnelling and suddenly there was a well that was not on any drawing." That well was easily made safe, but the work at Liverpool Street (which links to nearby Moorgate station) is highly complex because the site is crossed by London Underground's Hammersmith & City and Northern lines, by the Post Office's disused rail line – now used for telecommunications cables – and by the long-abandoned Queen Victoria tunnel. "The Post Office line is two metres from our access shaft at Liverpool Street, we are building a station below the Northern line, but an escalator tunnel that goes above it, so there is a massive monitoring regime to control any movement in the tunnel," Dr Stärk says. "We have triggers for movements permitted, and they are quite rigid and small; there is great deal of complicated geometry." One further complex piece of work will be the Vallance Road crossover, to enable trains to change from the westbound to eastbound track at Whitechapel. With up to a 20m span it will, Dr Stärk says, probably be one of the largest structures ever built in London clay.

Long experience

It is essential that everything is built to last – Crossrail structures have a 120 years design life – so two of Alpine BeMo's most experienced quality inspectors have been called in. Hermann Dettelbacher and Karl Fender have 70 years' experience between them. Mr Dettelbacher says: "It is important to see if people are doing things right and safely, and if something comes up that could be done better or more efficiently then to talk about it." Liverpool Street is more complicated than Whitechapel, as it has four tunnels leading off the access shaft and organising materials delivery is critical or, "you get a traffic jam in the middle, that is the challenging part". But after decades of experience all over the world of tough geological conditions, Mr Dettelbacher says: "I like London clay! It is like a cheese, you just cut through it." Crossrail is already boosting the East End's economy. John Bryson, employment and inclusion manager at East Thames, one of the largest local providers of affordable homes, says: "The main thing Crossrail has done is make it easier for us to place apprentices as there has been a large volume of opportunities for them and there have also been many entry level jobs, so it's been a real opportunity for local people. "Crossrail will attract more businesses to invest here; it will create local jobs for people, which will be great." First though, the tunnel engineers must complete one of the most complex underground 'jigsaws' they are ever likely to be asked to solve.



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