Design of Farringdon Elizabeth line station

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Synopsis

Farringdon is one of eight new underground stations being built in central London for the Elizabeth line and will be one of the key interchange stations on the new line. Upon completion, over 140 trains per hour will pass through the Farringdon interchange, making it one of Britain's busiest stations. With Thameslink, Elizabeth line and London Underground services, it will be a key link in bringing passengers from outer London to the business hubs in the City and Canary Wharf. The station will also provide direct rail links to three of London's five airports.

Farringdon Elizabeth line station comprises two platform tunnels, each 245m long, between new ticket halls over 300m apart. Each ticket hall has been designed to accommodate future oversite developments.

This paper discusses the structural engineering challenges encountered during design and construction of the two ticket halls on constrained sites surrounded by existing transport infrastructure, utilities and historic buildings.

NOTATION

AOD	above ordnance datum
BIM	Building Information Modelling
CAD	computer-aided design
ETH	East Ticket Hall
LU	London Underground
mATD	meters above tunnel datum (AOD +100m)
OSD	oversite development
SCL	sprayed concrete lining
SH-W1	circular shaft (West Ticket Hall)
SH-W2	rectangular shaft (West Ticket Hall)
SH-W3	escalator shaft (West Ticket Hall)
SH-E3	trapezoidal shaft (East Ticket Hall)
TBM	tunnel boring machine
WTH	West Ticket Hall

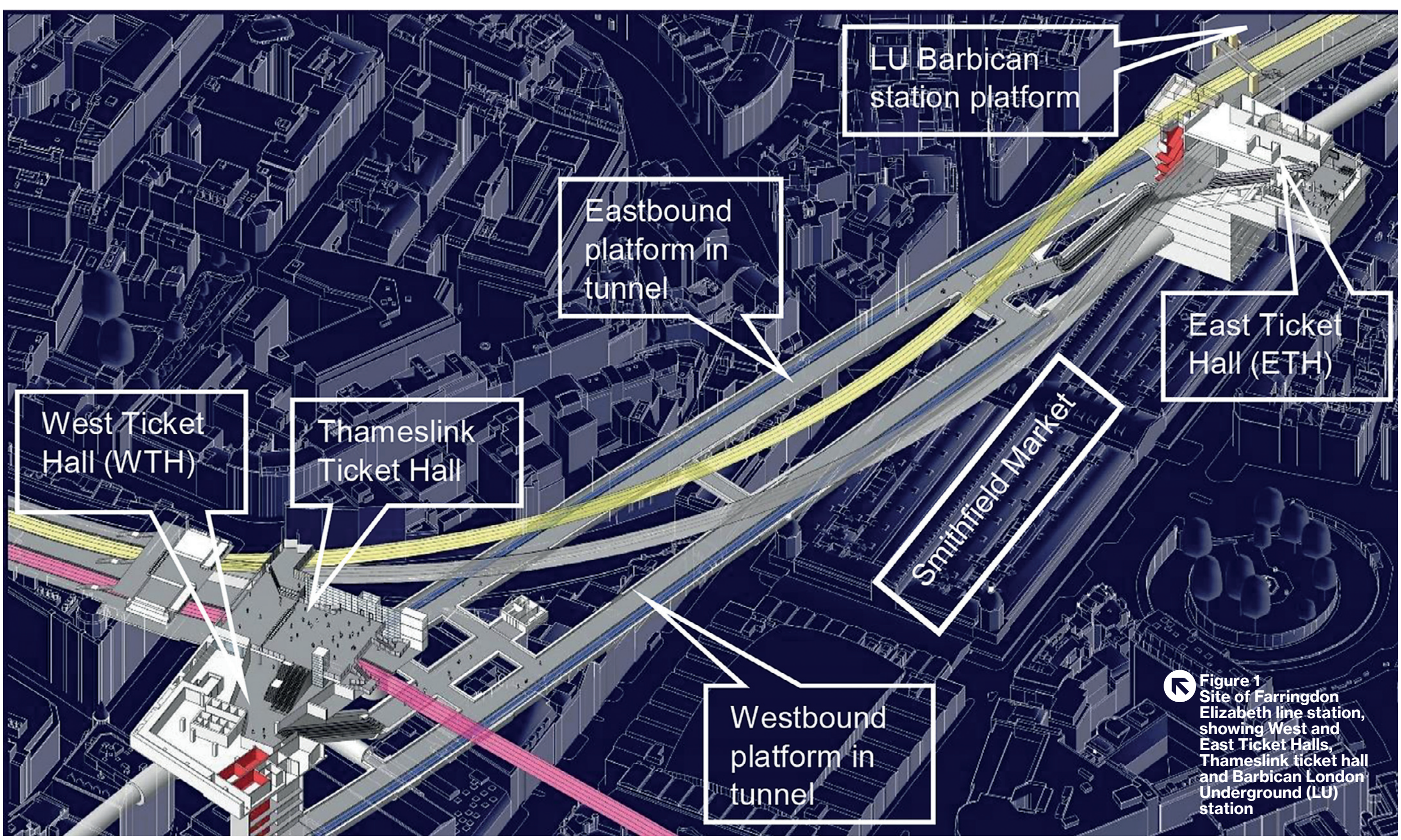


Figure 1 Site of Farringdon Elizabeth line station, showing West and East Ticket Halls, Thameslink ticket hall and Barbican London Underground (LU) station

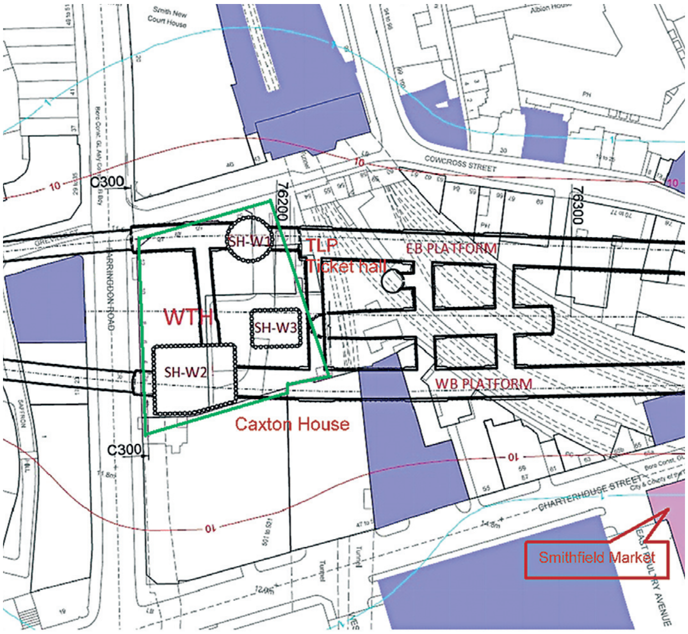


Figure 2
Existing structures and listed buildings around West Ticket Hall (WTH), including eastbound (EB) and westbound (WB) platform tunnels and Thameslink (TLP) ticket hall

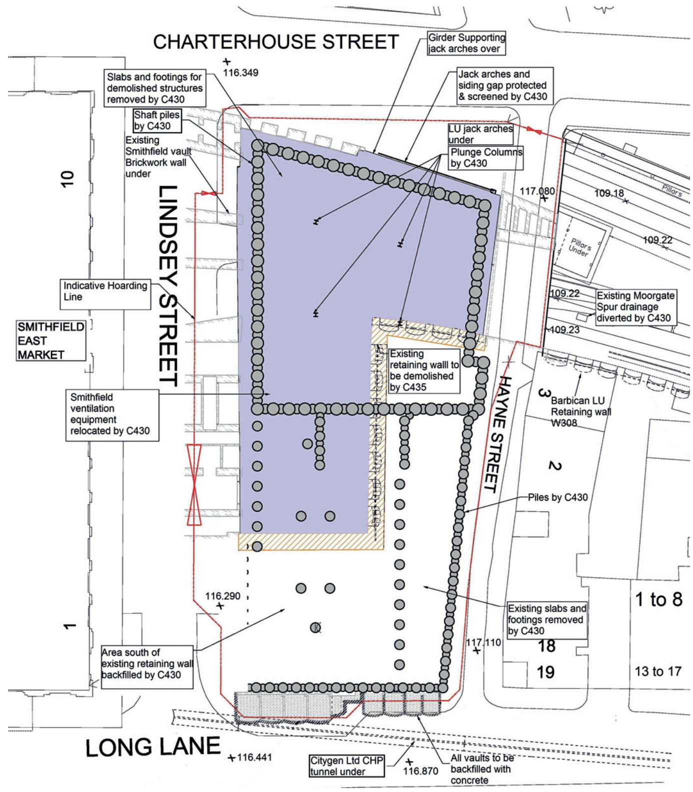


Figure 3
East Ticket Hall site at time of advanced works

Introduction

Farringdon Elizabeth line station is located in an area of London with a rich history. Former buildings on the site were demolished to allow construction of the ticket halls, shafts, etc. to take place. Both the East Ticket Hall and West Ticket Hall sites are surrounded by roads, railways and structures, with the original ground level typically 4–6m below the existing road level. These sites have a long history of railway-related activities, including railway maintenance workshops, goods yard operations, refuelling and storage of trains. The two sites are roughly rectangular and their overall dimensions are approx. 70m × 32m and 65m × 48m respectively.

The new station stretches the length of the neighbouring Grade II* listed Smithfield Market: from its West Ticket Hall immediately to the west of, and integrated with, the recently constructed Farringdon Thameslink ticket hall; to its East Ticket Hall adjacent to Barbican London Underground station (Figure 1).

During construction, Farringdon was also the termination point for four tunnel drives using four tunnel boring machines (TBMs): two commenced their journey from Limmo (near Canning Town station) in the east and two from Royal Oak just outside Paddington in the west. The design and construction phasing of the station, therefore, had to make provision to accommodate their arrival, decommissioning and removal/disposal.

Designing and constructing a new underground station in this highly constrained location presented significant challenges and opportunities. The final design has been driven by efficiency, physical constraints, buildability and construction phasing, as well as the need to provide a functional station appropriate to its location and historical setting. This paper presents an overview of the design and considers the constraints that influenced both the design and construction.

Existing infrastructure

West Ticket Hall

The West Ticket Hall occupies the site of the former 1960s Cardinal Tower and is located to the southwest of the existing Farringdon London Underground station. It is bounded by Cowcross Street to the north and Farringdon Road to the west. Demolition of Caxton House, which formed the southern boundary of the site, assisted construction activities. The new Farringdon Thameslink station ticket hall adjoins the eastern boundary.

A masonry retaining wall on the Farringdon Road boundary dates back to the development of the area as a goods depot in the late 19th century. To the north, the former Cowcross Street bridge structure had previously been infilled with mass concrete supported on piled foundations and fronted with a masonry skin. The former Caxton House building to the south, another 1960s development, has a basement at approximately the same level as the basement of the demolished Cardinal Tower building.

The River Fleet, which originally flowed near the site, now flows in a culvert directly beneath Farringdon Road. A culverted branch of the sewer (the St John's branch), which was diverted as part of the Thameslink Project, crosses the southeast corner of the site. Figure 2 shows the surrounding infrastructure and the listed buildings as per a register maintained by Historic England (previously known as English Heritage).

East Ticket Hall

The East Ticket Hall site is located at the west end of Barbican London Underground station. It is an island site bounded to the north by Charterhouse Street, to the east by Hayne Street, to the south by Long Lane and to the west by Lindsey Street. The London Underground's Metropolitan, Hammersmith and City, and Circle lines run east–west through the north of the site in a cut-and-cover tunnel approx. 10m below street level. The roof of this tunnel is formed of jack-arch construction. The recently decommissioned Thameslink lines to Moorgate (the Moorgate spur) run just to the south in the same cutting and were partially covered by a steelwork deck at general street level.

Masonry arch bridges carry Hayne Street and Lindsey Street over the London Underground and Moorgate spur lines.

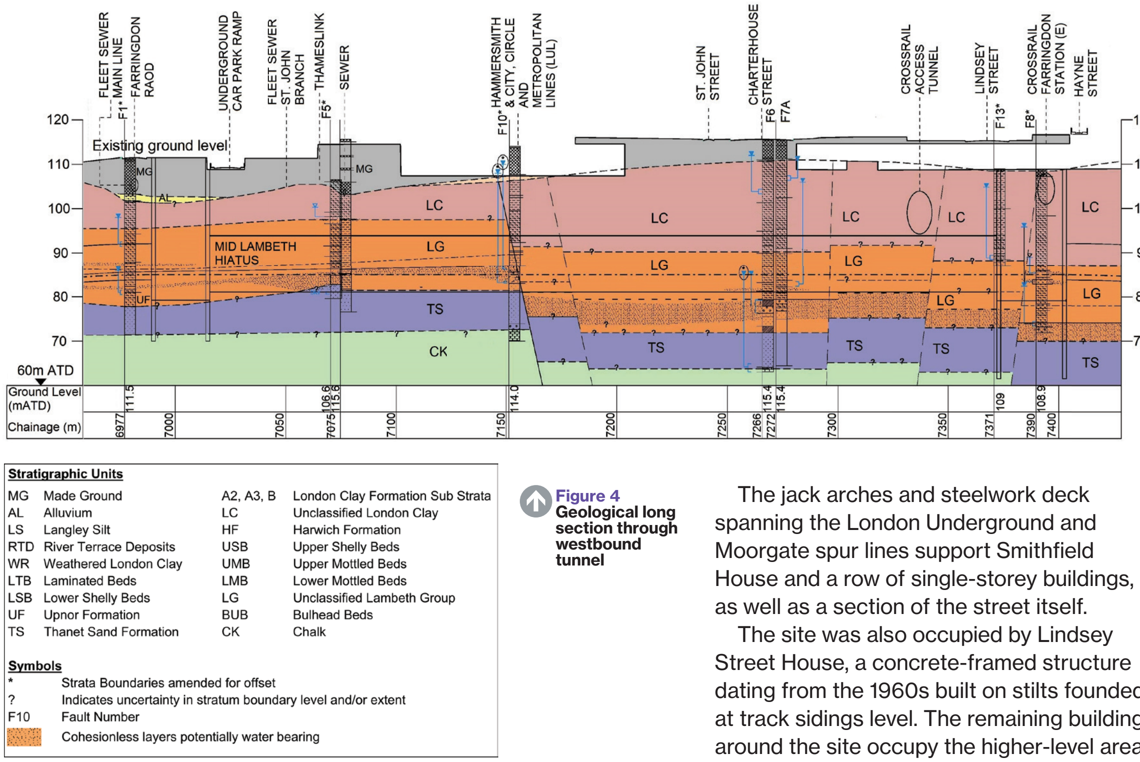


Figure 4 Geological long section through westbound tunnel

Sidings originally used by Smithfield Market extend under Lindsey Street and occupied part of the East Ticket Hall site to the south of the Moorgate spur tracks. A large masonry retaining wall previously cut through the site, forming the change in level between the track/sidings and street level.

The jack arches and steelwork deck spanning the London Underground and Moorgate spur lines support Smithfield House and a row of single-storey buildings, as well as a section of the street itself.

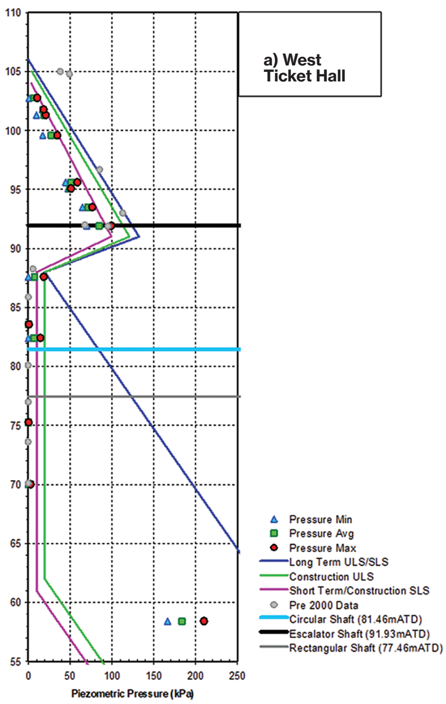
The site was also occupied by Lindsey Street House, a concrete-framed structure dating from the 1960s built on stilts founded at track sidings level. The remaining buildings around the site occupy the higher-level area behind the large retaining wall and date back to the 19th and mid-20th centuries, with single basements below surrounding street level. The East Ticket Hall site at the time of advanced works is shown in Figure 3.

Ground conditions

The general geology at Farringdon is typical of the London Basin, comprising made ground, alluvium (localised only), river terrace deposits, London clay, Lambeth Group, Thanet sands and chalk[1].

However, the ground around the site is very complex and heavily faulted, with London clay overlying Lambeth Group and Thanet sands (Figure 4). The layer of London clay is relatively thinner over the West Ticket Hall site compared to the East Ticket Hall site. Although the site is under-drained at depth, there are perched water tables and water-bearing gravels which create particular problems for tunnelling activities. The distribution of alluvium is restricted to the infill of the former River Fleet and any associated tributaries over the western part of the site.

There are two aquifers at Farringdon[1]: a shallow aquifer within the river terrace deposits and alluvium; and a deep aquifer within the chalk and the Thanet sands formation and Upnor formation of the Lambeth Group. The two aquifers are separated by the low-permeability London clay and low-permeability units of the Lambeth Group. The shallow and deep aquifers are both water-



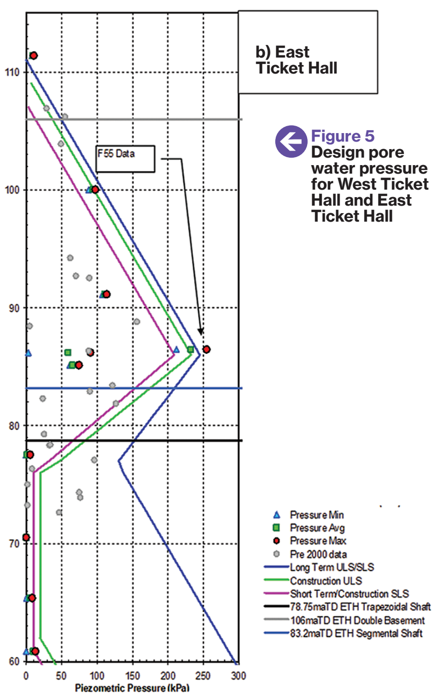


Figure 5 Design pore water pressure for West Ticket Hall and East Ticket Hall

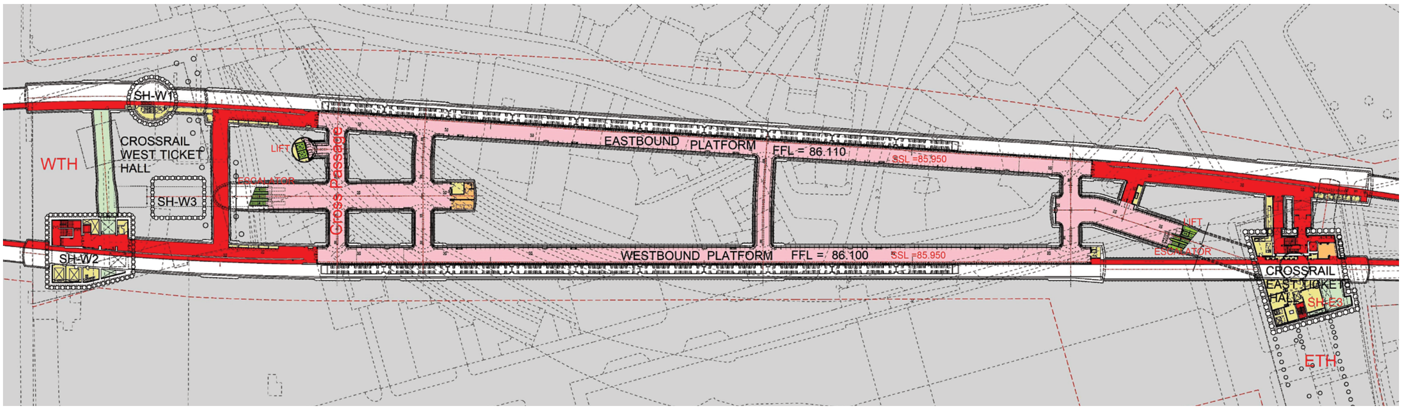


Figure 6 Platforms and passages (pink) were formed using SCL techniques

Figure 7 SCL enlargement of eastbound TBM tunnel

"THE OVERALL TUNNELLING STRATEGY AND CONSTRUCTION PROGRAMME EVOLVED OVER THE DESIGN PERIOD"

bearing. The water table in the deep aquifer is between 60 and 62mATD (meters above tunnel datum). The site geology, geotechnical risks posed by the heavily faulted ground, and presence of water-bearing gravel channels that could collapse during the tunnelling works, as well as the way these risks were mitigated through depressurisation and grouting, have been described in detail by Black (2017)[2], and Davis and Duarte (2015)[3].

Pore pressures were derived and the ultimate limit state values, during construction and in the long term, are summarised for both the ticket hall sites in Figure 5.

Construction strategy

The general tunnelling strategy across the other Elizabeth line station sites was for the 11.0m diameter platform tunnels to be constructed by sprayed concrete lining (SCL) enlargement of the bored and lined running tunnels formed by the passage of the TBM through the station. However, due to the variability of, and the risks posed by, the heavily faulted ground and presence of water-bearing gravel channels that could collapse during the TBM drive, a different strategy was adopted at Farringdon.

The original intention was to use a separate mini-TBM to depressurise the water in these channels and to form pilot tunnels between the two ticket halls which would then be enlarged using SCL techniques. This strategy also allowed for construction of the platform tunnels to start earlier in the programme, avoiding the need to wait for the TBMs to complete their journeys to Farringdon.

To facilitate the early start for the pilot tunnels, it was necessary to build the shafts at the West Ticket Hall quickly. This led to the use of bottom-up construction for the rectangular shaft (SH-W2) and semi-top-down for the circular shaft (SH-W1)[4] (Fig 2).

The overall tunnelling strategy and construction programme evolved over the design period, resulting in significant changes to the design and construction of the shafts. Subsequent geotechnical information, following a British Geological Survey three-dimensional (3D) model of the area combined with a Crossrail geotechnical database compiled over 20 years[3], was better than expected. This prompted a value engineering exercise which resulted in a decision to change the tunnelling strategy to use the larger-diameter TBM drives for the main running tunnel as pilot tunnels for the platform tunnels. The consequences of this decision for the design and construction are discussed in the following sections.

There was no opportunity to construct a cut-and-cover box as Farringdon is split between two sites (the West Ticket Hall site and the East Ticket Hall site) either side of the Grade II* listed Smithfield Market which are over 300m apart (Figure 6). Platforms were formed within the enlarged SCL tunnels (Figure 7). The four shafts at Farringdon are irregular in shape, are of different sizes and depths, and are close to existing rail infrastructure. Access to the piling platforms, several metres below road level, was difficult. Although diaphragm-walled construction can offer considerable benefits, such as smaller wall deflections and reduced overall wall thickness, the size and type of plant, and shape and size of shaft walls, meant it was not considered suitable for the small and constrained West Ticket Hall and East Ticket Hall sites, leading to the choice of secant bored-pile wall construction.

West Ticket Hall

Substructure

At basement level, the West Ticket Hall structure occupies the entire footprint of the former Cardinal Tower site. There is also a substantial sub-basement area for services connections between shafts, which also provides upper and lower machine chambers for the two banks of escalators. Above street level, the floors step back to suit the accommodation required by the Elizabeth line and to maximise the area available to the oversite development (OSD).

A piled raft at basement level is typically 1.5–2.0m deep with local thickening under heavy transfer structures. Vertical loads are carried by a combination of bored piles and shaft walls, and the design caters for the differential stiffness of these two foundation systems. A 2.0m thick and one-storey high cantilever wall, which acts as an inverted T-beam, transfers load from the pile-free zone on the northern side of the site above the eastbound SCL tunnel back to pile raft foundation and shafts. The shaft walls all comprise hard/soft secant piles consisting of 1200mm diameter bored piles at 1350mm centres, with 1200mm diameter soft piles in between. The hard piles were installed from a piling mat at about level 106.0mATD, with the toe level of the wall at 73.0mATD. The soft piles have a toe level into the London clay.

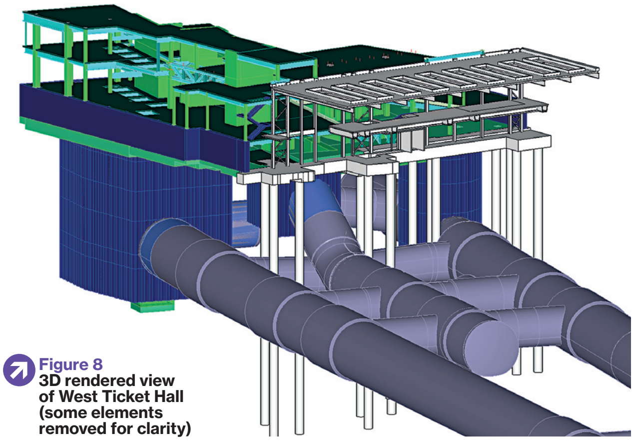


Figure 8 3D rendered view of West Ticket Hall (some elements removed for clarity)

Figure 10 Circular shaft SH-W1 (November 2012)

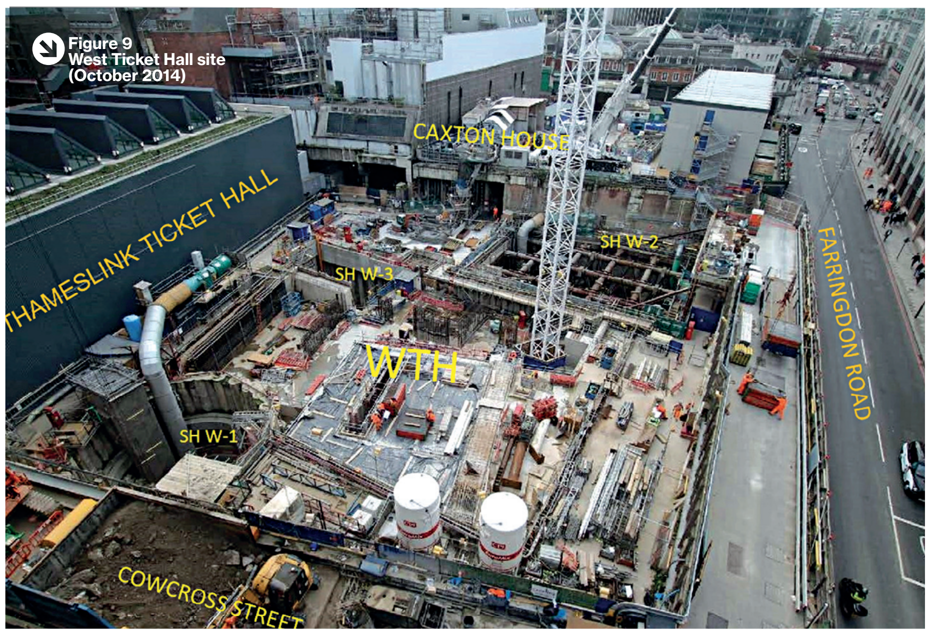


Figure 9 West Ticket Hall site (October 2014)

Figure 8 shows a 3D rendered view of the West Ticket Hall structure along with platform and escalator barrel tunnels. There are three shafts at the West Ticket Hall (Figure 9) and their design and method of construction varied depending on their function.

Circular shaft (SH-W1) on eastbound tunnel

The circular shaft is approx. 13m in diameter and 30m deep. The shaft was originally meant to be used for dropping and launching a mini-TBM for construction of the eastbound pilot tunnel, but the design had to be modified to accommodate the passing of the larger main TBM. Two openings in the shaft were formed using a stitch drilling technique, which provided access for construction of the SCL stub tunnels prior to the arrival of the eastbound TBM. It was then used as a construction shaft for access to platform level to form the enlarged platform tunnels and structures, to complete the fit-out within them, and to remove spoil from the enlargement.

The shaft was constructed using a hard/soft 1200mm diameter secant pile wall and was supported by 1.0m deep circular concrete waling beams during construction. Due to its circular shape, no propping was required during construction, as a series of ring beams resisted the applied lateral loading through compressive hoop forces (Figure 10). Subsequently, six levels of intermediate slabs, generally 600mm thick, were cast integral with the 400mm thick lining wall and circular waling beams through reinforcement couplers cast into ring beams. The 2.0m deep base slab of the shaft was constructed in stages to allow for the eastbound TBM to pass through at a lower level.

In its permanent condition, the shaft houses a service riser and maintenance stairs providing access to station platforms and tunnels.

Rectangular shaft (SH-W2) on westbound tunnel

SH-W2 is a large shaft, approximately rectangular on plan (25m × 21m). This shaft provides for tunnel ventilation, service risers and an emergency means of escape. Originally, the design had to facilitate rapid excavation of the shaft to allow the original pilot TBM to be launched. The subsequent change to the tunnelling strategy required changes to the temporary works propping and sequencing for the permanent works, as well as larger openings for the TBM to pass through.

The shaft is adjacent to Farringdon Road, which contains major services such as the Fleet sewer, major gas and water mains. The need to excavate the shaft rapidly had dictated the use of bottom-up construction, but ground movements were kept within specified limits by using stiff, tubular steel temporary frames at close centres. The shaft was propped with temporary steel frames at several levels as it was excavated, but the permanent works (i.e. the concrete walls and slabs) were constructed from the bottom up.

The shaft was excavated in two stages. In the first stage, it was only excavated to the level which allowed the TBM to bore through.

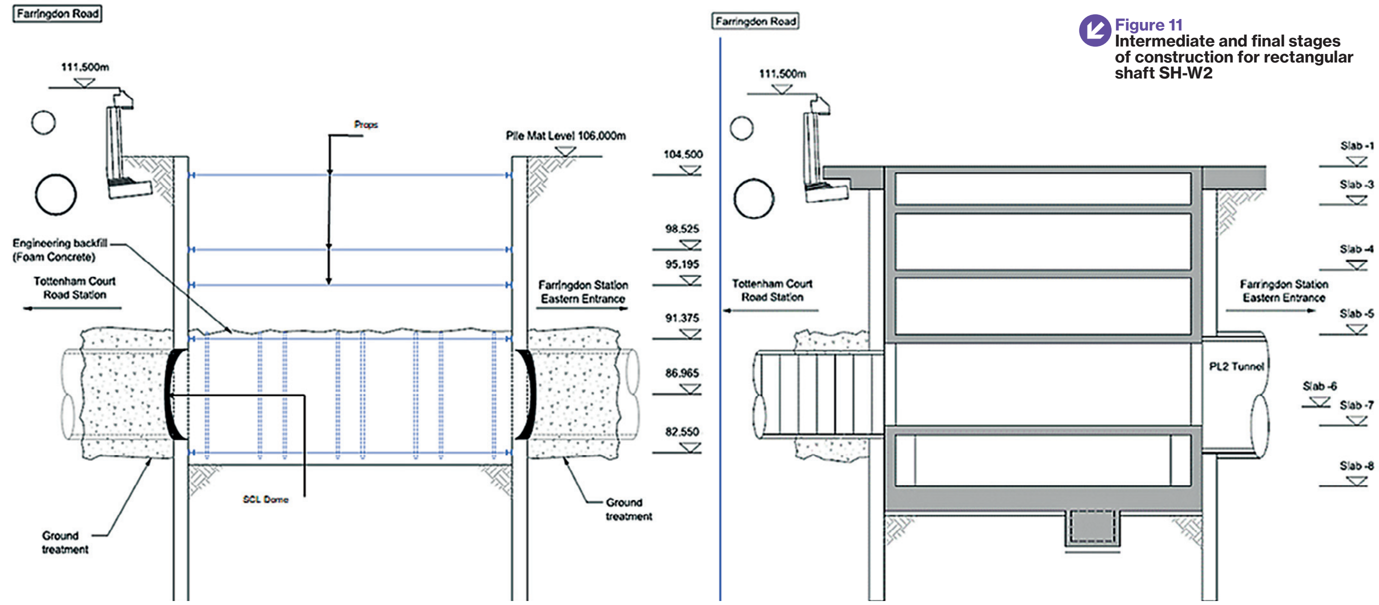


Figure 11
Intermediate and final stages of construction for rectangular shaft SH-W2

Subsequently, it was excavated further to base slab formation level (Level –8). Secant pile walls at both the east and west faces of the shaft were cut using stitch drilling techniques from inside the shaft, to form SCL domes and also to allow ground improvement works to be carried out before the arrival of the TBM. For stability, the shaft was filled with engineering fill (foam concrete) up to a height of 10m before the westbound TBM cut through the SCL domes.

The temporary propping installation and removal was sequenced such that it allowed sufficient headroom and construction access for operatives and machinery for downward excavation and for upward slab and wall installation. Figure 11 shows one of the intermediate stages and the final stage of the SH-W2 shaft construction sequence.

Lining and internal flange walls were installed to temporarily support the pile walls before the intermediate slabs were cast and propping was removed. The lining walls are subjected to full earth pressure due to several openings formed in the perimeter wall resulting in discontinuity of piles. The load path to the base of the piles is interrupted where the piles are cut for vent adits, running tunnels and platform tunnels. The lining walls are connected to the piles by drilled-in reinforcement such that the lining walls which span across the opening can act as a deep beam to transfer load from above, and also horizontal loads from the cut piles, back to the piles at lower slab levels.

Escalator shaft (SH-W3)

The (15m × 11m) escalator shaft was constructed bottom-up with one level of temporary propping. Its primary function was to facilitate the construction of an inclined SCL escalator barrel. It is a rectangular shaft/box structure, which is significantly shallower than the other two shafts, as it does not extend down to track level. It essentially acts as a work site from which the escalator barrel can be constructed down to platform level.

Superstructure

The ground floor and superstructure are steel-framed, with the steel beams generally designed to act compositely with reinforced concrete slabs. Slabs are cast on profiled metal decking which acts as permanent formwork. In view of the 120-year design life[5], the completed slab is reinforced to carry full design loads without any reliance on the metal decking. The frame is braced by reinforced concrete shear walls.

The OSD will be supported directly by the superstructure beams, columns and walls at predetermined locations. Storey-deep twin transfer trusses carry column loads from the OSD columns and span 21m over the apse and the service yard to provide a column-free zone at ground level. There are also more minor transfers of columns at the building perimeters.

Three main reinforced concrete cores provide overall stability for the West Ticket Hall and OSD structures and will interact with the stability of the integrated ticket hall when complete. The cores are designed to accommodate a maximum 10-storey OSD which will enable the full potential of the site to be realised. Horizontal wind loads are transmitted to these cores via the floor plates. In addition to the cores, portalised bays provide stability at Level +1 (mezzanine floors).

The Thameslink ticket hall, Elizabeth line West Ticket Hall and OSD are not separated by movement joints and therefore effectively act as a single structure.

The top level of each structure is designed as a crash deck, in accordance with the requirements of the Crossrail Civil Engineering Design Standards document[5], with plinths designed to accommodate the construction of the OSD columns. Cores typically incorporate couplers to allow them to be extended to full height throughout the OSD. Reinforced concrete crash walls are also provided between the OSD and the station.

All steel columns are encased in concrete for durability and fire protection, as are steel beams above the service yard.

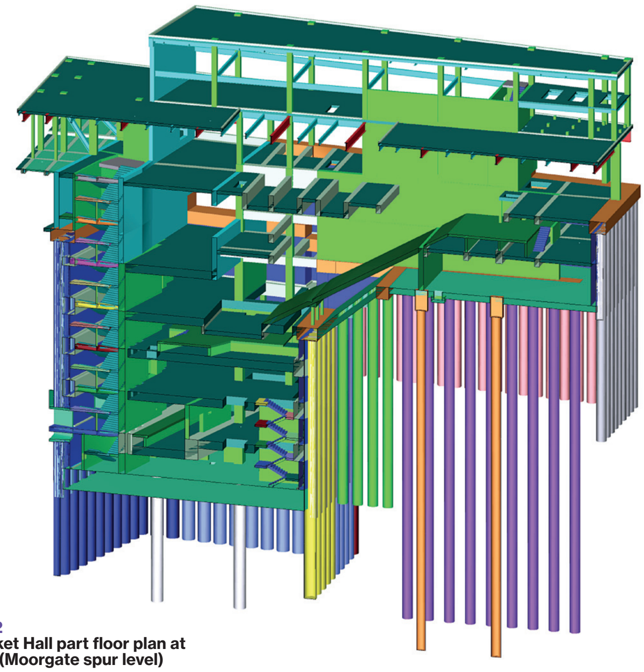
East Ticket Hall

Trapezoidal shaft (SH-E3)

The East Ticket Hall is built over a very constrained site between Hayne Street and Lindsey Street. A two-storey basement over the southern half of the site houses mechanical and electrical (M&E) plant, while the northern half of the site is occupied by a large deep trapezoidal shaft (SH-E3), measuring 30m × 25m on plan, which extends 35m below road level.

Its plan size is dictated by the need to accommodate tunnel ventilation, service risers, plant rooms, vertical transportation (two escalators and an inclined lift) and emergency means of escape. Space-proofing requirements have meant that the shaft extends to the site boundary on three sides. A part plan at Level –2 (Moorgate spur level) is shown in Figure 12.

Figure 13
East Ticket Hall 3D long section rendered view



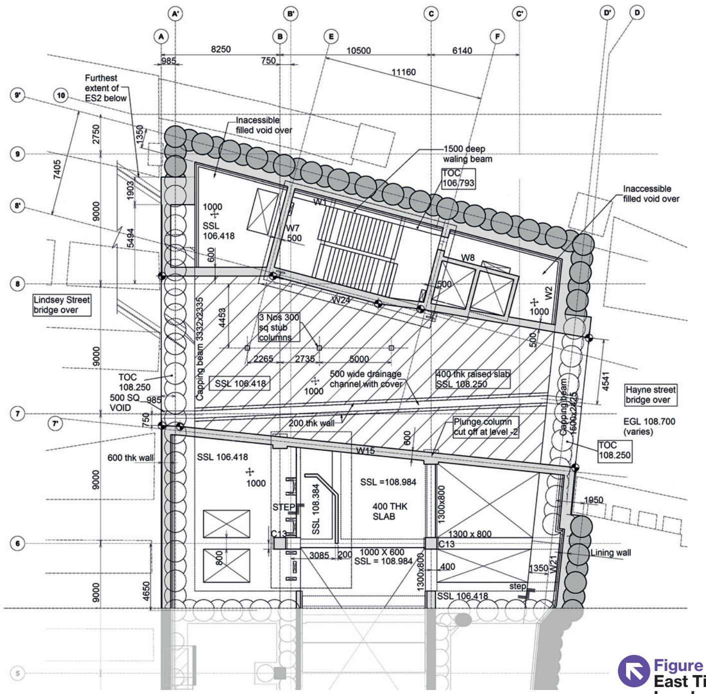


Figure 12
East Ticket Hall part floor plan at Level –2 (Moorgate spur level)

The trapezoidal shaft was constructed using hard-soft secant piles installed generally from the Moorgate spur level (Level –2, approx. 109mATD). The size and spacing of these piles are dictated by horizontal and vertical loading and lateral supports from floor diaphragms. Both secondary (male) and primary (female) piles are 1500mm in diameter. These are some of the longest (up to 51m long) cased piles (casing length up to 37m) ever constructed in the UK. The toe level of the wall is 12m below the base slab formation level at approx. 66.0mATD. A reduction in pile diameter below the temporary casing level (79.95mATD) from 1500mm (casing outer diameter) to 1400mm (auger diameter) resulted in a reduced size for the piling cage.

A 3D rendered long sectional view of the East Ticket Hall is shown in Figure 13.

The shaft is connected by the westbound running tunnel (twice), escalator barrel from the Elizabeth line platforms, two cross-passages and a ventilation adit from the eastbound Elizabeth line platform. Due to such a large number of openings on three sides of the shaft, vertical and horizontal loads are transferred through a complex mechanism utilising the combined stiffness and strength of the secant piles and the lining wall. At many locations, lining walls act as a deep beam and carry loads across the openings. Lining walls are connected to the secant pile wall through drilled-in steel reinforcement. Figure 14 shows the construction status of the East Ticket Hall

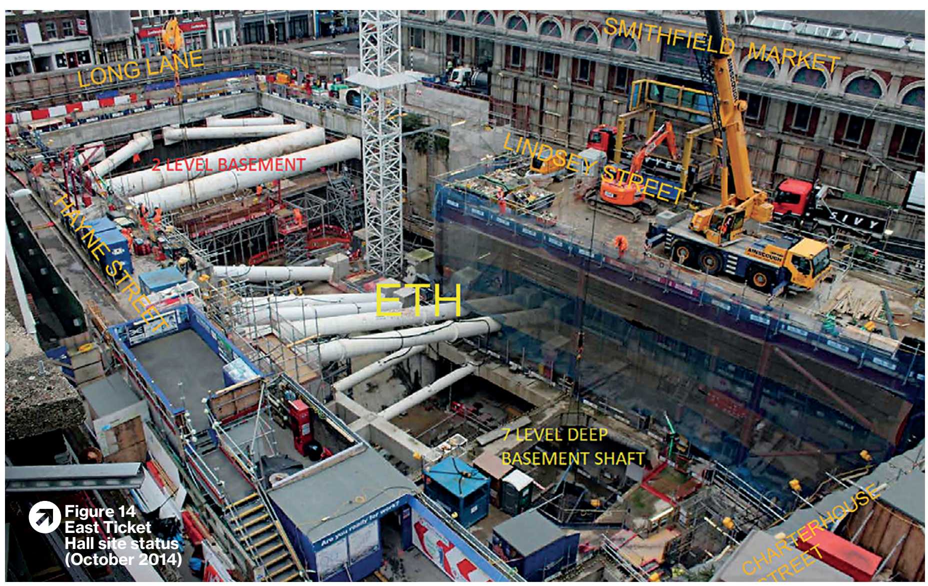


Figure 14
East Ticket Hall site status (October 2014)

in October 2014.

The shaft is arranged on six floors commencing at basement Level –2 down to the base slab at sub-platform Level –7. Internal floors within the shaft are of reinforced concrete construction, generally 1.0m thick. In the permanent condition, the floors are supported at the perimeter by the secant piles and internally by columns and walls constructed off a 2.5m thick slab at the base of the shaft. The base slab, designed as a piled raft, also resists the upward loads due to long-term hydrostatic pressures and soil heave.

The trapezoidal shaft was built using top-down construction methodology, which integrates the temporary and permanent works. Top-down construction is inherently stiffer than bottom-up and therefore tends to reduce wall displacements and associated ground movements. This was considered to be highly beneficial in the case of the trapezoidal shaft, the perimeter of which is very close to a number of London

Figure 15 Top-down construction of trapezoidal shaft SH-E3 with provision for construction access

Underground and other third-party assets, including the Grade II* listed Smithfield Market. Figure 15 shows a seven-level-deep shaft cast top-down with construction access using plunge columns. Figure 16 shows preparation for the base slab (Level –7) construction.

During construction, the edges of the slabs were supported on the perimeter secant pile walls; internally, support was provided by four steel plunge columns made up of built-up I-sections of size 500mm × 600mm, which were 'plunged' into concrete bored piled foundations from ground level, before the concrete had set. Shear studs welded to the columns provided support to the slabs. These steel plunge columns were subsequently cast into the base slab, reinforced concrete columns and walls, forming part of the permanent works. When required by the design, some parts of the lining wall were also cast during top-down construction.

Once the base slab was cast, bottom-up construction of the lining walls, internal columns, walls and stairs could commence. There were a number of programme-critical activities associated with the construction of the shaft, including the time-consuming nature of the excavation and construction of the trapezoidal shaft before the arrival of the westbound TBM, which stopped just outside the shaft.

Superstructure

Structural slabs at Levels +1 to +3 are generally cast *in situ* concrete slabs on profiled metal decking. They are designed on the assumption that the profiled decking acts as permanent formwork only. The composite metal decking floor slabs span between steel beams supported by concrete-encased steel columns. All columns are encased in concrete for durability and fire protection, as are beams above the ticket hall and within the large station fan plenum at Level +2.

Where the OSD columns do not align with the station columns below, transfer beams are provided. Cantilever beams are used to support overhanging OSD columns at the northern and southern boundaries. Raking columns, formed of built-up steel sections, are provided at the north end of the site to form transfer structures cantilevering over the London Underground tunnels. Horizontal forces from the raking columns are transferred through floor diaphragm action and reinforced concrete shear walls to the shaft substructure.

The ground-floor slab in this area is hung from first-floor level and a compressible material has been provided between the underside of the Elizabeth line structure and the top of the existing jack-arch structure to further ensure no load is imposed on the London Underground jack arches.

Oversite developments

At both the West Ticket Hall and East Ticket Hall sites, the new ticket hall structures and their foundations are designed to support future OSDs of a maximum of 10 storeys. Both ticket halls incorporate stub columns and a crash deck to allow construction at a future date. The Elizabeth line stations therefore do not form completed architectural entities, but rely on the future OSDs to re-establish the urban setting.

The West Ticket Hall OSD is a so-called 'collaborative' development. This meant that close collaboration was required with the chosen developer and its professional team to agree locations for the columns and cores, and also for the load imposed on the station structure from the OSD. The presence of existing piles at the West Ticket Hall from the demolished building and the area sterilised by the tunnels imposed severe restrictions on the location of new piles. Some piles are sleeved to avoid load transfer from the piles to the tunnels and/or to reduce the impact of negative skin friction. A deep raft slab, together with a series of transfer structures, carries superstructure loads to the piled raft foundation and secant piled walls of the three shafts.

The East Ticket Hall OSD is not a collaborative development, as no developer had been identified during the design of the ticket hall. A design was therefore developed by a separate AECOM team for coordination with the station design. The team has generated a rationalised grid and floor plan layout incorporating a central core for an OSD of a maximum of 10 storeys to optimise the value of the site. The design has assumed a lightweight composite floor construction for the OSD. Figure 17 shows the architect's impression of the East Ticket Hall with completed OSD.

Design summary and lessons learned

The final station design was influenced by a number of factors, such as changing tunnelling strategies, continually updated geotechnical information, the contractor's construction sequence/methodology and programme changes. The ground conditions, particularly the presence of at least four major and four minor faults and water-bearing sand

Figure 16 Construction of East Ticket Hall base slab (Level –7) (plunge column exposed)

layers across the site, presented significant geotechnical challenges.

Several bespoke solutions had to be developed to build the SCL tunnels and the ticket hall structures. To mitigate the risk of bore hole collapse, piles had to be temporarily sleeved up to a length of 35m from the ground level. Piles located very close to tunnels were permanently sleeved to a depth determined by the design. Some of the secant piles were cast with localised fibre-reinforced plastic reinforcement for subsequent ease in forming openings through the wall. Similarly, some secant piles required to carry vertical load, but cut partially to form openings in the wall, were cast with a small steel I-section spanning across the opening.

The basement slabs and walls within the shaft structures had to accommodate a large number of irregular and asymmetrical openings, discontinuity, restricted head room, staged construction and temporary provisions for construction access. This led to development of many innovative solutions through complex load paths, transfer mechanisms and finite-element modelling. Both of the ticket hall structures incorporated a number of precast concrete stairs, modular units and prefabricated steel elements. Overall design loads expected from the station structures, including the future OSD, downward negative skin friction load due to tunnelling works and restrictions on pile toe level, meant that all base slabs (except the two-storey-deep East Ticket Hall) had to be designed as piled raft foundations. Thus, there was no opportunity to use void formers below these base slabs to alleviate uplift pressure from both short- and long-term soil heave.

Shaft walls were constructed using secant bored piling. Top-down construction was used, except where programme requirements dictated the need to complete shaft excavation at the earliest opportunity. Ground movements were controlled by a combination of the sequence of excavation and the stiffness of perimeter walls and horizontal props. Third-party liability due to surface settlement was controlled using grouting and depressurisation along the route.

Elizabeth line station structures are designed to the Eurocodes and are compliant with the Crossrail Civil Engineering Design Standards[5]. Computer-assisted (CAD) drawings were produced in 3D using Building Information Modelling (BIM)-compliant Bentley Systems MicroStation[6]. The composite CAD models contained both civil and services fit-out information. Co-location of design teams greatly enhanced collaboration between all stakeholders.

Conclusions

One hundred and fifty years after the world's first underground railway was built in London between Paddington and Farringdon, the time had come to provide a new railway fit for the 21st century and with it a new major interchange at Farringdon.

Building a new station of such a scale that it stretches between two London Underground stations at Farringdon and Barbican is no small undertaking in the heart of London, surrounded by historic buildings and infrastructure.

The key drivers of safety, economy and constructability have underpinned the resolution of the constraints and challenges posed by the ground conditions, heritage, infrastructure, sequencing and programme. Equally important has been the collaboration with other consultants, third-party stakeholders and the contractor to develop and implement the solutions required to resolve these issues.

The construction of heavy civil and structural elements of the station structures is now complete and has given way to fit-outs, trial running, and commissioning of Elizabeth line operations ahead of services commencing in December 2018. The new Farringdon station has become a catalyst for regeneration of the local area, bringing many new opportunities.

Figure 17 Architect's impression of East Ticket Hall when complete with OSD

Project team

Client: Crossrail Ltd
Station lead designer: AECOM (URS/Scott Wilson)
Civil and structural engineer: AECOM
Architect: Aedas
MEP engineer: AECOM
SCL platform tunnels: Mott McDonald
Main contractor: C435 - Bam Ferrovial Kier JV (BFK)
Temporary works designer: AECOM (scheme design); C435 - BFK (final design)

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