London Bridge Station Redevelopment

Institution of Structural Engineers: Structural Transformation Award

PROJECT SUMMARY

LOCATION

London, UK

PROJECT VALUE

£880M

CLIENT

Network Rail

ENGINEERS

Arcadis WSP joint venture

CONTRACTOR

Costain

ARCHITECT

Grimshaw

STATUS

Completed January 2018

PROJECT DESCRIPTION

INTRODUCTION

The London Bridge Station Redevelopment project has completely transformed the station. Since the 19th century, the through tracks on the northern part of the site evolved separately from the southern terminating tracks. The project brought the two parts together for the first time, creating a unified station with clear routes for passengers changing trains; accessing London Underground, buses and taxis; or walking or cycling.

This transformation has been made possible by excellent, creative structural engineering; innovative designs allowed the redevelopment to be carried out safely, while train services continued to operate throughout. The structures were designed to be elegant and efficient, and to minimise long-term maintenance.

The redevelopment of London Bridge is part of the Government-sponsored Thameslink Programme, which is an ambitious programme of enhancements to transform north-south travel through London. It delivers:

- New, longer and more spacious trains running through central London – every 2-3 minutes at peak.
- Improved connections to more destinations on an expanded Thameslink network.
- More robust tracks and modern signalling, using digital railway technology to make journeys more reliable.

London Bridge Station Redevelopment

Institution of Structural Engineers: Structural Transformation Award

HISTORY

London Bridge became the first railway terminus in the capital when the London & Greenwich Railway opened in 1836. The line was elevated for its full length of 5.5km on brick viaducts connected by bridges, in order to function independently of the road network. The station expanded rapidly, and by 1837 was also serving the South Eastern Railway, the London & Croydon Railway, and the London & Brighton Railway. In the 1840s the London & Greenwich was absorbed into the South Eastern Railway, and the London & Croydon amalgamated with the London & Brighton to form the London, Brighton and South Coast Railway.

Disagreement between the SER and the LBSCR led to the division of the site, and the two halves of the station were developed separately in each of the many subsequent expansions and refurbishments. John Betjeman wrote in 1972: *"London Bridge is …the most complicated, muddled and unwelcoming of all London termini. …I do not see how anyone of the thousands who have to use it during rush hours, can find his way about it without a long apprenticeship."*

Even the remodelling carried out by British Rail in 1983 did not unify the site – the terminus platforms were accessed directly from the concourse, while the through platforms were reached via a low-headroom underpass and a series of ramps. A footbridge was built to provide interconnection at the south-eastern end of the station, but the rust-brown colour of the cladding was reportedly chosen to match the brake dust from the trains.

In addition the track layout – with nine terminating and six through tracks – led to sub-standard platform widths and insufficient capacity. Thameslink trains were unable to serve London Bridge at peak times.

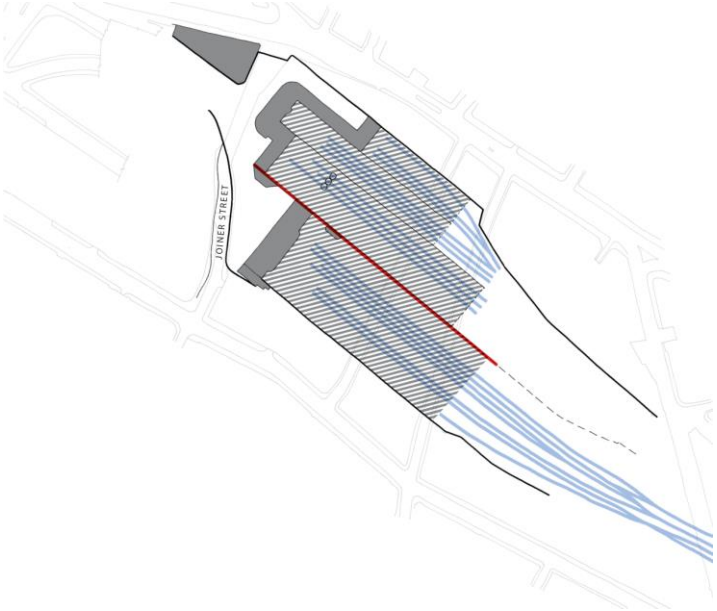


Figure 1 – London Bridge station in 1860 (Alan Baxter)

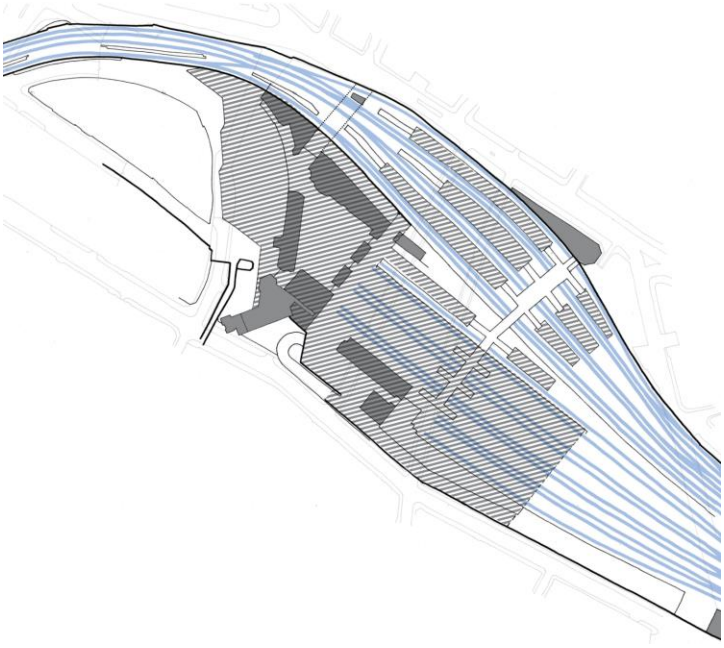


Figure 2 – London Bridge station in 1983 (Alan Baxter)

FINISHED PROJECT – GENERAL DESCRIPTION

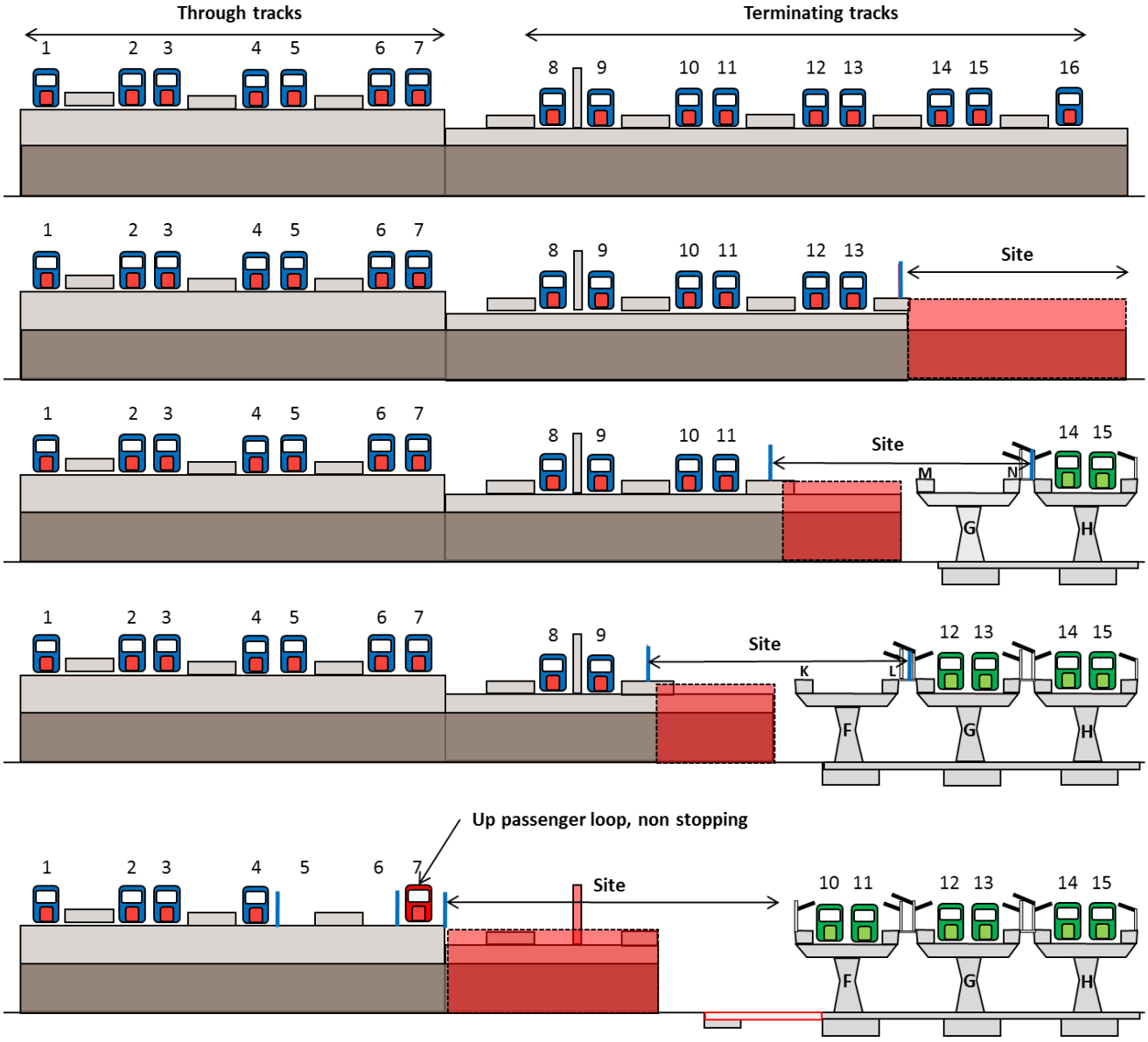
The redevelopment has completely transformed the station. A concourse has been created at street level that connects all the platforms via lifts, stairs and escalators, making the station fully accessible for the first time. All the platforms have been realigned, providing additional tracks for through trains and allowing a full Thameslink service to operate at peak times. The platforms were widened to cater safely for expected growth in passenger numbers, and new escape stairs were provided at the east end of the station. Full-length steel canopies provided weather protection and also allowed daylight to penetrate to the concourse.

London Bridge Station Redevelopment

Institution of Structural Engineers: Structural Transformation Award

The rail tracks were carried across the concourse on steel bridges, supported on visual concrete columns. New facades in steel and precast concrete were provided for the new street level station entrances. Away from the central area, the tracks were supported on the original 19th century brick arches; a new continuous concrete slab solved water penetration problems and allowed the arches to be used for plant rooms and retail. An arcade of two-way spanning “quadripartite” arches was extended with a new concrete structure, formed to match the original profile.

The construction sequence was planned carefully so as to maintain passenger services throughout. Starting on the south side, three platforms were closed. This left six terminating tracks – the number required for the final configuration – and six through tracks. Two new tracks were built on the south side of the station and the next two existing tracks were closed. This pattern was repeated until all the tracks had been renewed.



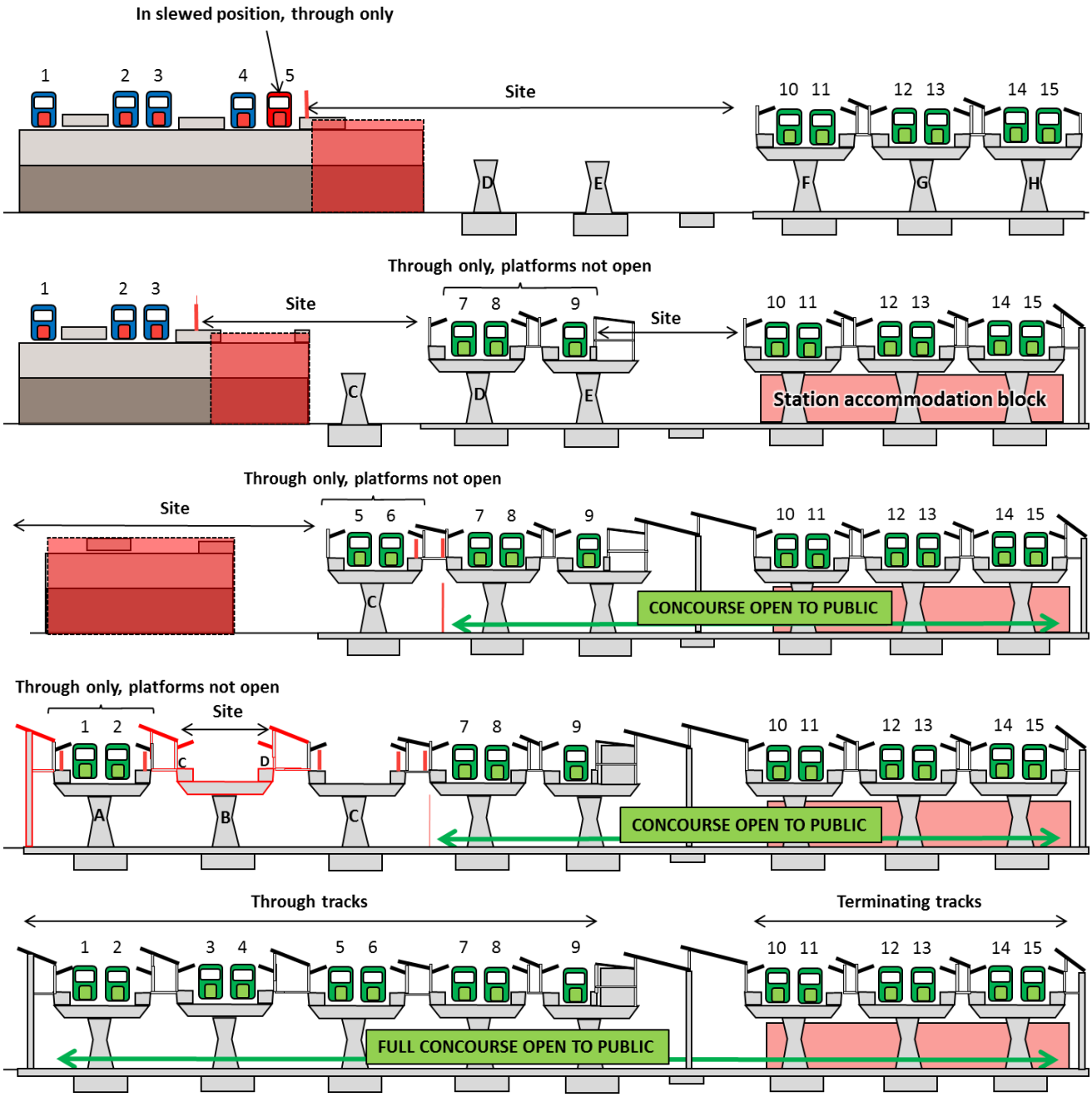


Figure 3 – construction sequence (Costain)

CONCOURSE AND BRIDGES

The concourse was created by removing a swathe of arches across the station. Prior to demolition, abutments were installed within the arches to resist the lateral thrust from the remaining arches on each side. Mini pile foundations for the abutments were designed for construction stage horizontal loads; larger permanent forces were taken through the concourse base slab and at the top by tie bars in the slab cast on top of the arches.

The concourse bridges comprised either three or four simply supported spans for each pair of tracks. Each span had six main plate girders, braced together and tied at the ends with trimmer beams. Following

installation the spaces between the beams were filled with concrete in order to reduce transmission of train noise to the concourse below. Fire engineering analysis showed that the concrete also acted as a heat sink and so no further fire protection was needed to the exposed lower flanges. After the concrete had been poured, the decks were waterproofed, ballasted and fitted with rail lines, platforms, and canopies. The station accommodation block was directly beneath three of the decks, making access for maintenance very difficult. Therefore the exposed lower flanges of the girders in these decks were made of weathering steel so that repainting would not be required.

Before leaving the fabrication yard, the bridge girders components were connected in pairs and a trial assembly was carried out to ensure perfect fit and alignment, de-risking the site operation. Steel subcontractor Cleveland Bridge devised an innovative erection method for the bridge decks using heavy capacity scissor lifts mounted on the top of Self-Propelled Mobile Transporters (SPMTs).

The bridges required large bearings, the installation of which was complicated by the limited space on the pier heads for longitudinal and rotational construction movement. This was resolved by a tapered plate between the bearing and the steelwork which counterbalanced the dead weight deflection. After the concrete had been poured, each bearing was jacked up and the tapered plates were replaced with parallel plates, restoring the rotational capacity of the bearing for imposed loads.

Bridge piers were cast using self-compacting concrete in steel moulds to achieve a high-quality visual finish. The crossheads in particular were heavily reinforced and, in order to ensure accurate fixing, the reinforcement cages were fabricated off site.

CANOPIES AND PLATFORMS

Elegant curves were integral to the architectural design, responding to the track geometry and curvature of the site. Striking full-length, undulating canopies of steel and aluminium emphasise and enhance the curves. The canopy roofs were prefabricated in modules using open sections; each module was approximately 9m deep by 3m wide. An astonishing 1,200 modules were used – each one a bespoke unit due to the changing rooftop geometry. The modules were craned into position during short night-time construction hours.

The canopy structural frame comprised Y-shaped columns, supporting a longitudinal spine beam formed from fabricated box sections with extended webs to create service routes. Platforms and canopies sat outboard of the bridge girders, supported on transverse “elephant ear” frames. As trains pass over the bridges, deflections caused the tips of the elephant ears to move longitudinally. The plates that connected the frames to the bridge girders were designed to balance strength and stiffness, in order to resist applied loads while remaining flexible enough to avoid fatigue. Towards the ends of the decks, fatigue movements were higher and radial spherical bearings were used.

The expansive central space at the heart of the concourse was covered using a longitudinal V-column to support a 5m deep vierendeel truss. North-facing glazing between the vertical members of the truss allowed daylight to reach the concourse.

The platforms were also prefabricated. Precast concrete was used, cast to shape in adjustable moulds using parameters taken from the BIM model. A trial assembly of the platforms and canopies was undertaken at the steel fabricator’s yard, in order to test fabrication details, erection methods and access to services.

FAÇADES

New façades have been created at each end of the concourse, to frame the entrances and to allow daylight into the space. The façades reflect the different environments of Tooley Street, in the north, and St Thomas Street, in the south.

The St Thomas Street façade took its inspiration from the adjacent listed arches. The rhythm of large and small arches was maintained, and the brickwork detailing was a modern take on the historic structure. The façade was built using precast panels on a steel frame for rapidity of construction. The brick facing was

attached to the concrete in the casting process. Joints were concealed wherever possible, with locations chosen so that panels could be transported and lifted easily.

The Tooley Street façade was given a more contemporary design. An arcade of steel columns on a varying radial grid was separated from the glazed façade. The pattern of the brickwork above the arcade – formed by rotating individual bricks out of the plane of the façade – matched the varying column grid below.

QUADRIPARTITE ARCADE AND ARCHES

London Bridge station was built on a bewildering array of arches, with different spans – and sometimes different span directions – for each of the different phases of the original construction. Away from the new concourse, these arches remain, and have been given new purposes and a new lease of life by the redevelopment. Arches that face the road have been refurbished and made available for retail units; the Stainer Street arch has been pedestrianised to increase the north-south permeability through the station; and many arches have been used for station plant rooms. At the eastern ends of the platforms, escape stairs have been threaded through the arches, avoiding demolition of the historic structure.

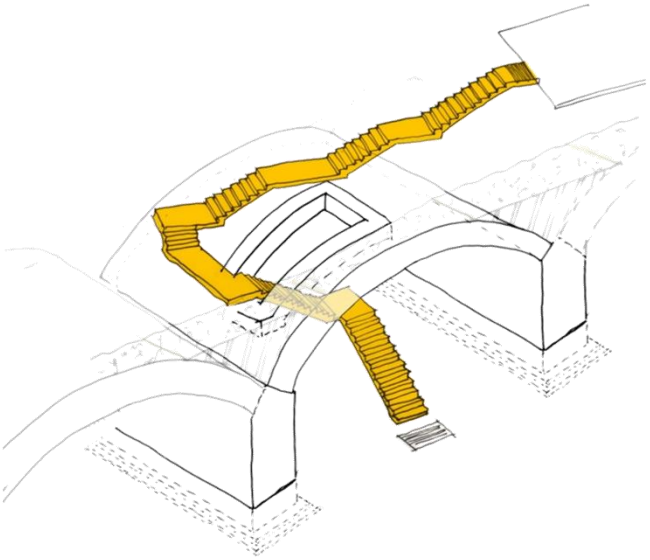


Figure 4 – escape stair

The link from the London Underground station to the new concourse passes through a quadripartite arcade. The western end retains the original brick structure, but new arches were used at the eastern end because of the damage caused by previous interventions. The new structure matches the form of the existing, using board-marked concrete to create a modern interpretation.

CONCLUSION

The London Bridge Station Redevelopment opened on time and to budget on 2 January 2018. Incorporating features such as ground source heat pumps, it achieved a BREEAM ‘excellent’ rating. The project has increased capacity, melded old and new structures, and has delivered a stunning transformation of the station.