The White City Viaduct

The aim of the White City Project is to provide a 21st Century shopping and leisure facility for West London. The finished development will include over 90,000 square metres of shopping space. Major retailers such as Marks and Spencer have already committed to taking up space in the new development. The scheme incorporates new leisure facilities and housing for key workers. When complete, it will be served by new stations on the West London and Hammersmith and City Lines, an upgraded station on the Central Line at Shepherds Bush as well as a new bus station.

Over one hundred years of history

The site has over one hundred years of railway history and still contains a major depot for the Central Line, which dates back to when the Central Line terminated at Shepherds Bush. For the White City exhibition, the Central Line was extended by looping the railway round the depot and through a new station at Wood Lane.

Subsequent extension to Ealing required two additional platforms forming a triangular station at Wood Lane, with further changes to the depot. Wood Lane Station and depot became a major constraint on the operation of the railway. Shortly after the Second World War, a new station at White City replaced Wood Lane Station, with further changes to the depot.

Sixteen sidings, a box, underpinning and piling

The scheme includes the construction of a new storage depot of sixteen sidings for the Central Line, with an enclosed box structure designed to allow development to continue above it. When complete and operational, it will allow development of the area currently used by the depot sidings, to be developed.

The depot requires a new feeder line from White City Station, which runs alongside the existing eastbound Central Line requiring widening of the existing cutting. When this line was extended to Ealing, it was squeezed between the underpinned piers of the (Hammersmith and City Line) brick viaduct adjacent to the steel bridge over Wood Lane, and beneath the underpinned abutment of the Wood Lane Bridge.

There was no room for another track, so a section of the brick arch viaduct and its foundations were removed and replaced with a new 20 metre steel span adjacent to the existing Wood Lane span. This will allow the single track cutting of the eastbound Central Line to be widened to accommodate the depot feeder line.

The eastbound Central Line is partly in cutting with mass concrete sidewalls, partly in covered way, and partly through the former Wood Lane Station. Widening alongside the eastbound Central Line requires piling alongside the open cutting, removing the roof of the covered way and the platform of the former Wood Lane Station; replacing the station invert with a new structural slab at lower level, and underpinning the station wall.

Roofing, and an in-situ concrete deck

Where the new depot feeder line becomes the entrance fan to the depot, it will be necessary to remove the station roof and sidewall prior to constructing the new box for the depot fan and putting a new roof over the eastbound Central Line.

The westbound Central Line, in open cut, is also to be roofed over so that the area can be used as part of the service road, as well as providing protection to the railway. This involves a row of piles either side of the existing cutting, together with pile caps and walls, pre-cast beams, and an insitu concrete deck to form the roof. Where the westbound Central Line is in a tunnel, with very little cover, a similar form of construction is used, except that the beams are a combination of prefabricated steel and concrete beams, designed to act as transfer slabs for the retail development being built above the tunnel.

Protecting the Underground

All the railway related works impact on the existing Underground services, which need to be protected from the construction works, or diverted, as the works or demolition of existing infrastructure conflicts with their route. The identification, protection and diversion of services is a key element of the project, and is carried out by a dedicated services team working on a project wide basis with each of the construction teams. Services include: traction power, power, lighting, tunnel telephone, signalling, telecommunications, air, water, and drainage.

Abutments and piers

The Eastbound Central Line passes beneath the existing Hammersmith & City Line viaduct and remained operational at all times throughout the construction of the new steel bridge, and the demolition of the existing masonry abutment, arches and pier. The Hammersmith and City line is at a 52 degree skew to the Eastbound Central Line and this was an added complication to all of the replacement works. The masonry arch structure of the original viaduct terminated at an abutment, which supported the east end of the old steel bridge over Wood Lane.

This bridge is carried by a new pier which is common to the existing steel deck over Wood Lane, and the new steel deck. This allowed the new pier to be built before the abutment was demolished. It was built in front of the abutment in the pavement of Wood Lane. When the old abutment was demolished, the existing bridge was shortened and supported on the new pier.

Hammersmith and City line train, running over the old viaduct, prior to possession being taken.

Slide

A long job for Waterman's

A variety of options were considered by Waterman's (Design Consultants), who were involved for a total of eight years, starting back in the 1990s when a scheme was developed to the point of obtaining outline approval from London Underground. The scheme revived in 2003, when a number of options were considered, before it was decided to construct the new deck and slide it into place during a long possession.

Two new concrete piers were built in advance. Extensive piling was needed to support them, over half of which had to be installed using low headroom rigs. An eighty-metres long contiguous pile wall was needed to provide temporary support for the new bridge, and then support the widened cutting.

For aesthetic reasons the new bridge follows the form of the old, with three main girders and cross beams, but now in filled with concrete rather than the riveted steel plates of the original. Detailing was difficult due to the high skew. At the east end there was insufficient room for the building of a crosshead on top of the piers, so one was built off-line and slid in with the bridge.

Built offline to be slid in

The new steel deck was built offline parallel to the Hammersmith & City line so that it could be slid into place once the masonry abutment, arches and pier of the Hammersmith and City line were demolished. Although one end of the new deck is supported on the new pier, which it shares with the existing steel deck, the other end is supported on a new abutment.

This abutment was constructed within the arches of the Hammersmith and City line viaduct. However, the restricted space available in the arches, and the skew of the existing arches, meant that the new abutment had to be intersected by an existing pier, which remained in place until the arches were demolished. The abutment could not be constructed to full height, as there was insufficient headroom within the arches so that the upper part of the abutment was constructed offline and slid into position with the bridge deck.

The piling

The first major new construction activity carried out was the piling. Piles of 600, 450 and 300 mm diameter were constructed. Tripod rigs were used together with low headroom Klemm rigs and Hutte rigs for the 300 mm diameter piles. Ground conditions were brick earth, overlying water bearing Thames gravel above London clay.

The piles were cased through the gravels with open bores in the clay. They were needed for the pier, the new abutment, the arch strengthening and the >

Bridge Slide in progress.

Phil Todd, Rail Director, Multiplex Constructions

Track being laid.

slidepaths as well as to form a contiguous pile wall alongside the new depot feeder line. There are a total of 290 piles, typically 25 metres long. The eastbound Central Line was protected from the piling operations by crashdecks placed above the open cut and above the covered way where assessment of the existing covered way roof slab indicated this to be necessary.

Monitoring and crack extension

Piling was followed by pilecap construction using conventional methods but with restricted plant. Throughout the construction works there has been a monitoring scheme in place to monitor movement of the existing infrastructure including the viaduct. Automatic real time monitoring was used with automatic theodolites, supplemented by precise levelling, manual theodolites, targets and tape extensometers.

Trigger levels were defined, as was the procedure to be followed in the event of any trigger level being breached. During inspection an extension to an existing crack in one of the arches was noticed. Pier settlement was within predictions, but the one pier, which had not been underpinned during construction of the Central Line, was settling less than its neighbours, which were underpinned as part its construction.

A decision was made to cease pilecap excavation within the arch and to complete the pilecap in stages, thus ensuring that any effects due to reduction in overburden or loss of horizontal restraint were minimised or eliminated.

Temporary service bridge and a signal

The existing brick arch viaduct carried Underground train services, which needed to be diverted prior to arch demolition. A temporary services bridge was built alongside the viaduct, at a high level, so that the new bridge could slide beneath it. Services have been diverted onto a temporary services bridge.

There was a signal on the portion of the viaduct to be demolished, so a new signal tower was built and a new signal erected and commissioned. Construction of the columns and crosshead beam forming the pier and construction of the abutments were conventional. The retained portions of the truncated arches were reinforced with shotcrete. Diaphragm walls were constructed within the arches to take the load of the retained portion of the arches down to the pile caps.

Waterproofed and ballasted

The slide paths were constructed using a bespoke trestling system on the temporary pile caps, and the top section of the abutment was constructed on the top of one of them. The new bridge deck was erected on the top section of the abutment on one side, and directly above the slide path on the other. This all took place above the operational Central Line.

The crash decks provided protection for some activities, but major lifts were carried out in engineering hours. The deck is a composite, and after the concrete was poured and waterproofed, it was ballasted to minimise the work to be done in the possession.

A twenty-seven hour possession

Work was also carried out on the existing bridge span. The old bridge has been truncated, to bear on the new pier, so the three main beams needed web stiffeners at the new points of support. Where accurate as built surveys alone were not sufficient, Perspex mock-ups were used and trial fitted, to ensure a good fit for the new stiffeners.

Existing rivets were removed in a controlled sequence where they interfered with the new stiffeners. Three main beams attach to the existing span resulted in twelve stiffeners, each with two angles, a main plate and packing plates. This work was done in engineering hours plus one 27-hour possession piggybacked onto a Hammersmith and City line possession elsewhere on the line, to increase the available productive time for sandblasting one of the existing girders.

The trial slide

With the pre-possession work complete, the real test was the trial slide. The new deck together with the upper part of the

abutment was slid along on Teflon pads. Two hydraulic jacks pushed the abutment carrying one side of the deck with one jack on the other side of the deck. The trial slide was completed with a thrust of only 6% of the dead weight.

The deck was pushed forward 1.5 metres and then retracted 0.5 metres just to prove it could be done if necessary as part of the final positioning. Demolition of the masonry abutment, pier and arches and the slide of the bridge deck was scheduled for a 4 day possession of the Hammersmith and City line over the weekend 29th July to 1st August, with the Central Line remaining open.

The possession was unusual with a private developer responsible for major works, and providing the railway with a major new asset. Protocols were modified or tested in the lead up to the possession, and whilst there were frustrations along the way, progress resulted from co-operation and a determination on the part of all concerned.

Multiplex Engineering Assurance

The documentation requirements were a major challenge, but once the purpose, scope, format and approval process for each document type was understood, the burden became manageable. Design compliance submission, demonstrating compliance with LUL requirements, allowed drawings to be released for construction.

Piling design, temporary works, safe load assessments, risk assessments, method statements, clearance approvals, and plant approvals, even tall plant concessions, were needed. All documents were prepared by the project team, then reviewed for safety and assurance within the team, before going to Metronet BCV or Metronet SSL, or both depending on which railway could be affected, before final approval by LUL.

Normal underground train service resumed across the new structure on programme

As work was completed, it was inspected and tested in accordance with approved inspection and test plans, with assurance provided to LUL by the Multiplex assurance team.

Not traditional demolish and drop

The concept of the demolition was not the traditional demolish and drop. Although the crash decks protecting the Central Line were designed for rubble, machine operation and impact, they were protected from impacts beneath and adjacent to the viaduct by modular scaffold towers and centring to the underside of the arches.

Demolition took place above a support structure and debris was then removed. As arch demolition was completed, followed by abutment and pier demolition, the scaffold support structure was cleaned off and removed and demolition continued to the next level of the modular scaffold. Consequently the final stages of preparation for the possession were the installation of the modular towers and centring.

96-hour possession

When the 96-hour possession was granted, the track was removed in panels in the immediate area of the section of the viaduct to be demolished. The 300 tonne mobile crane was available throughout the possession as a free issue skyhook. The conductor rail was pulled back clear of the possession using iron men. Ballast was removed by the excavators and dropped onto a spoil heap clear of the Central Line and its crashdecks for removal by road.

Metronet SSL took the opportunity of the possession to replace 400 metres of track on the Hammersmith and City line. As so often happens, other opportunistic work took place elsewhere in the possession. Before demolition could start, the weight of the existing steel deck over Wood Lane had to be transferred from the abutment onto the new pier using jacks adjacent to the bearing positions.

Demolition sequence

Demolition started with the parapet walls, which were pulled inwards onto the viaduct using small excavators. The focus then switched to the abutment, where it was necessary to free the ends of the main girders of the existing deck over Wood Lane. Demolition then moved back from the abutment face, to the top of the three minor arches within the cellular abutment, then to the main arches of the viaduct.

The main arches were demolished in narrow strips, so that until the very final stage of arch demolition, their integrity as arches was maintained. Demolition of the cellular abutment and pier followed, once the need to maintain the thrust on the arch had been eliminated. This process was complicated by the skew which meant that the cut >

FACT FILE

Client

Design and Build Contractor

Consultants

Structural Engineer

Sub-contractors

line started at the crown of one arch, dipped down to the pier, went through the pier and up virtually to the crown of the next arch.

The main demolition machine was a 25 tonne excavator working from the crash decks, supplemented by 5-tonne excavators working on the viaduct, first freeing the girders, then removing the minor arches above the cellular abutment, and then working on the cut line to ensure that the profile of the cut was achieved. When the work on the abutment had advanced clear of the existing steel deck, the existing was rough cut to about 400mm from the final profile, and then handed to the steelwork contractor for the final precise cut.

Following completion of the arch demolition, the abutment and pier demolition was completed down to a level, which permitted the bridge to be slid over the remainder of the abutment and pier.

Completing the slide path in time!

The principle was to ensure that the arch was removed before the structure, which provided the horizontal restraint to the arch. Towards end of the arch demolition, the effect of the skew was that the abutment might have had insufficient mass to provide the necessary restraint. So, two Macalloy bars were used to tie the arch from the abutment to the pier. Demolition stopped at crash deck level, but there was some flexibility between the minimum and maximum extent of abutment demolition, which allowed some contingency to ensure adherence to the overall programme.

During demolition the slide path was protected, but following the demolition a further section needed to be created. As a result of the skew and the new abutment, the slide path was on two arches separated by the pier. The pier was demolished to beneath slide path level, and a fabricated steel section was installed and grouted into place. The constraint on the bridge slide was the completion of the missing link in the slidepath before the deck reached it!

After the slide, grouting and waterproofing

Following the slide in of the bridge it was necessary to jack it up on the side of the new deck that shared the new pier with the existing deck, and then down onto its new bearings. The bearings were already in place on the other side, where the abutment top was slid in with the deck. The gap occupied by the slidepath had to be fully grouted to provide the permanent loadpath from the top of the abutment, which was slid in with the deck.

Another major grouting and filling operation was required to make good between the back of the new abutment and the existing viaduct along the demolition cut line. A large excavator with hydraulic breaker carried out this cut, which was trimmed using the small excavator mounted on the viaduct.

The skill of the operators in achieving this cut line to give clearance was crucial to the subsequent grouting and filling operation. This was carried out by spraying against a shutter, using a shotcreting technique to give the rapid set and strength gain that was necessary. Installing expansion joints, completion of waterproofing and installation of precast concrete panels at parapet level were all completed before the track was reinstated.

Ballasting, tamping and recommisioning of signalling

The bridge deck was slid in part bottom ballasted. However, further ballast was craned up onto the deck to complete ballasting, between the new works and the old viaduct. The new track was built up into panels in Wood Lane during the possession. This eliminated the risk of delivery during the possession. The track panels (18 metre lengths) were lifted in using the 300 tonne crane.

The track was lined and levelled and more top ballast was delivered in bags. Finally it was packed and tamped using Windhoff attachments to the Road Rail excavators. The length of track replaced included a block joint for the signalling system, so that completion of the track could be followed by the re-commissioning of the signalling system.

Management arrangements

Multiplex have a design and construct contract for the White City works, including the retail and leisure facilities. This included the new sidings box, the new sidings feeder line and the viaduct works. Multiplex let the majority of the works in trade packages. ■

"The complexity of these works was well recognised by all parties. The professional approach, hard work and perseverance of your team in the planning and execution of these works was commendable. Your successful hand-back of the railway was of greater significance given the current disruption to services (as a result of the events of the 7th July). Delivery of these works to programme will no doubt further enhance Whitecity's reputation and instil greater confidence throughout the wider LUL family. This achievement should not be understated."

Steve Washington: LUL