CONSTRUCTING EXCELLENCE
Innovation in Practice

Hammersmith Flyover - Construction Case Study

Introduction

This case study should be read in conjunction with the Constructing Excellence design stage case study (CE Ref : CE001), written in early 2015. This case study has been created to highlight project construction activities and achievements.

Principal Contractor:	Costain LTD
Client:	Transport for London (TfL)
Case Study Ref. No:	CE0002
Project Number:	4000
Publication date:	March 2016
Region:	London
Sector:	Infrastructure
Contract value:	Confidential
Project timescales:	Contract Award - April 2013 Early Contractor Involvement (ECI) Phase ended -28 October 2013 Construction Phase Completion - Summer 2015
Project Themes:	Integration, collaboration and value for money

Project Summary

Hammersmith Flyover was constructed in the early 1960's and is situated in West London. The flyover itself lies within the boundary of the London Borough of Hammersmith and Fulham. The 622m long structure comprises sixteen spans, with a post-tensioned segmental deck and integral piers, supported on roller bearings at the base. An expansion joint located at the seventh span from the west abutment divides the flyover into two separate continuous structures.

Post tensioning tendons running through the structure were found to have been deteriorating at a significant rate, affecting the flyover's ability to support live loads. In December 2011, following intrusive inspections, a higher than expected rate of deterioration of the post-tensioning tendons was revealed due to the ingress of water and salts. The Hammersmith flyover was closed under emergency conditions as a consequence.

Initial strengthening works were undertaken on five spans on the eastern end of the structure, using full and partial closures of the carriageway. This was the first phase of works, completed in summer 2012 prior to the Queen's Jubilee weekend and the London 2012 Games. Phase 2 of the works programme to refurbish and strengthen the remaining spans of the bridge has commenced on site and is planned to be complete in 2015.

Added Value

The project team is rightly proud of their achievements; the award section at the end of this case study is testament to this. Whilst key performance indicators have been used to monitor the project, a positive approach to stakeholder engagement has had an impact on the local community. So whilst the project team has made achieving the client's success criteria a high priority, technology and team integration have improved delivery certainty. As a consequence the project has delivered more than originally anticipated to TfL and the local community. These themes (success criteria, technology and team integration) are explored below.

Success Criteria

The process of Early Contractor Involvement (ECI) has paid dividends through the construction phase. ECI has engendered a one-team approach during design and construction allowing client, contractor and suppliers to collaborate. Focus on the client's success criteria has driven team behavior and activity to achieve:

- Safer, practical solutions using new technology
- Reduced time working in confined space
- A good design aesthetic and elegant strengthening solution
- Significant extension to the life of the Hammersmith Flyover
- A solution designed and constructed with maintenance in mind
- Sequencing of works to minimise traffic disruptions
- Recruited twenty apprentices
- Taken a pro- active approach to local community engagement

The project works have extended the life of the flyover with a 120 year design life on the new elements, which is a significant step forward considering the condition of the bridge only a few years previously. Ensuring the continued safe use of the flyover was the key benefit of delivering this project. The cost to the UK economy for the flyover being out of service was estimated at £101m per annum.

Key Performance Indicators

The project team agreed a number of key performance indicators (KPI's) with the client, TfL. These included:

- Health and safety
- Financial
- Customer
- Quality
- Supply Chain
- Time
- People

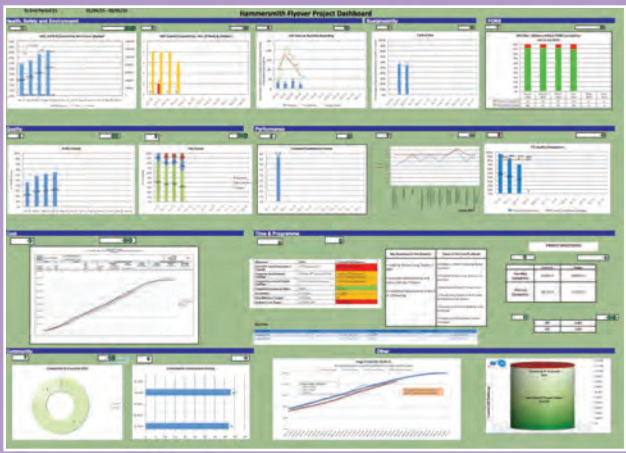

Figure 2: an extract from the project balanced scorecard logging KPI progress.

Each indicator listed was given a number of measureable objectives then allocated a RAG (RAG – 'red / amber / green) status on a monthly basis, depending on progress. Each objective has been allocated an owner who captures the data required for reporting processes. The data captured is also presented in a graphical format on a monthly reporting dashboard.

The results demonstrate a transparency between project and client and a drive for continuing improvement.

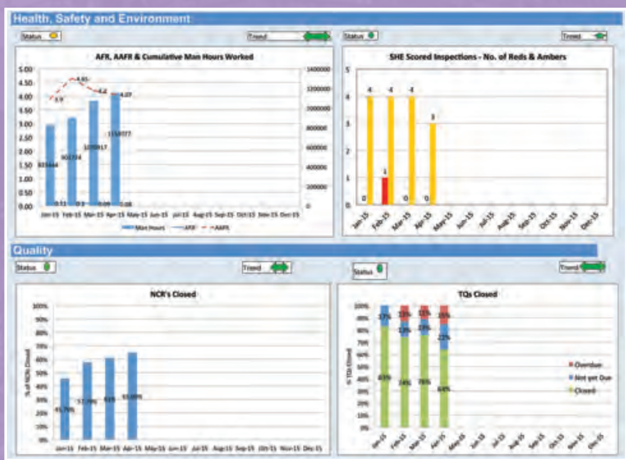

Figure 3: extract showing the project dashboard

Technology

The project team researched archive information and used digital scanning and 3D modeling techniques to minimise the risks associated with refurbishing the flyover structures. The model was created from the original as-built construction drawings and verified against 3D laser scans. The 3D model was used extensively throughout the duration of the project as a vital planning, design and construction tool. This enabled the project to identify hazards, constraints and risks for both design and construction. The 3D model accurately demonstrated the visual impact of the scheme to the client and key stakeholders. The technology approach adopted has benefitted the team, significantly improving their ability to identify clashes. 3D printed models have been created to support the clash detection process.

Integrated Teams

The team considers the success of the project is due, in a significant part, to the integrated team environment and the culture that has evolved. Teamwork and communication has been essential to resolve project challenges efficiently. The co-location of the integrated project team was the client's strategy to inspire innovation. Throughout the life of the project TfL, Costain, RPB, Freyssinet and SSL have worked closely to develop the innovative design and construction solutions for the post tensioning system, bearing replacement and pier jacking.

The ECI phase also allowed the team to develop safe and practical construction methodologies, including the design, manufacture and testing of bespoke equipment.

Construction Activities and Challenges

Lean philosophies to manage and control site construction were adopted. Space constraints and efficiency requirements have driven this approach. Careful articulation of project activities through detailed planning brought focus to and supported a 'right first time' mantra.

Regular workshops were held throughout the lifetime of the project to support the design development process. One such challenge was the structural strengthening works required at each end of the flyover sections to accommodate the post tensioning and abutment tie bars. The picture of the 3D printed model below demonstrates the extent to which the project team interrogated this activity. The model identified the potential reinforcement and cable duct clashes, allowing a pre-agreed solution to evolve prior to site works commencing. Reinforcement was assembled outside of the bridge as a first run study. This activity prepared site workers for the challenge of constructing the steel reinforcement cage within the confined space of the bridge deck. Once shuttering was installed the concrete was poured, from above, through diamond drill holes cut through the existing bridge deck. A C50 Tarmac top-flow self-compacting concrete mix was used to ensure concrete compaction and finish quality.

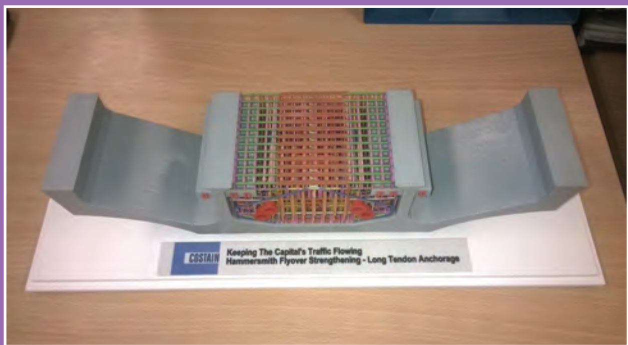

Figure 4: the 3D printed model used for clash detection

Equally a significant team effort has been required to resolve unforeseen challenges; which is often an issue for any refurbishment project. A significant amount of in-situ core drilling (in excess of 2000 holes) has been undertaken, principally at the location of each blister (A blister is a specialist concrete component made from fibre reinforced concrete which is connected to the existing structure to support the new external post tension cables.)

Figure 5: the blister is attached to the existing bridge deck as an anchor or guide for the new post tensioned cables

Desktop studies of as-constructed steel reinforcement drawings and ferro scanning at blister locations was undertaken to allow core drilling to progress. However core-drilling activity was regularly halted having identified unexpected reinforcement steel within the existing concrete structure. Each instance was checked using the 3D model before approval to recommence drilling was given by the design team.

During the bearing replacement, the team identified poorly compacted concrete within the existing foundation pit construction. Again surveys and design checking was required before a revised construction solution could be implemented. Some of the innovative installation solutions adopted by the integrated team are described below.

Bearing installation

The new bearings require an installation tolerance of ± 0.5mm to ensure their design load is not exceeded and that their design life is fulfilled. Extensive monitoring was installed in each of the 15 bearing pits to measure the movement of the piers relative to the pits in all three dimensions to an accuracy of 0.1mm. The diagram below shows the temporary and permanent works required to replace the bearings. Tendon installation

Tendon installation

Working at height and close to live traffic, injury to pedestrians and cyclists was recognised as major risk for the project. The adoption of Freyssinet's "Plug and Play" system for the external post tension cable system mitigated some of the risks. Installation was quicker as the number

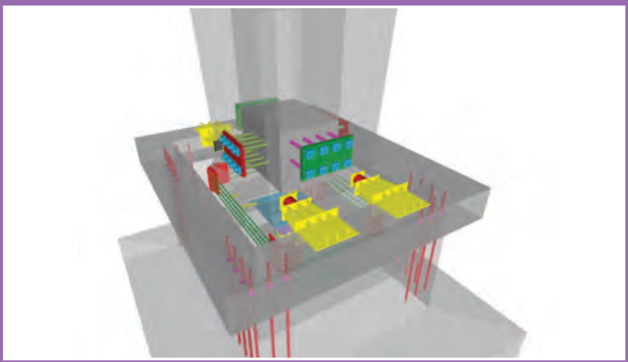

Figure 6: the bearing replacement temporary and permanent works

of work operations were fewer, thus reducing the number of man-hours working at height and the total duration of road closures. It also permitted installation and stressing of individual strands (as opposed to complete tendons), which introduced flexibility into construction methodology and supported programme certainty. The Plug and Play system's rapid installation reduced that element of the programme by ten days, requiring fifteen fewer road and lane closures.

Blister installation

The team designed and fabricated a bespoke lifting tool capable of positioning the concrete anchorage (blister) units (weighing over two tonnes) six metres above carriageways and footways with millimetre accuracy. Efficient installation and the reduced footprint improved safety and resulted in fewer road closures, reducing the impact on local residents and businesses.

Figure 7: blister installation

Bespoke Syringe:

A conventional concrete pump was not appropriate for in-situ concrete installation, owing to the thixotropic nature of the specialist fibre reinforced concrete. The team developed a bespoke "syringe" concrete injection system. This solution allowed small quantities of the expensive concrete to be poured slowly and accurately, with minimum waste.

Figure 8: the concrete injection system

These innovations have led to a significant reduction in the quantity of concrete and steel and the number of hours worked on-site, which, combined with efficient manufacturing off-site, has provided major cost and programme savings.

Culture

In discussion with the project team it is clear team working has enabled a positive culture and work environment. This facilitated dynamic decision making as the co-located team worked openly and honesty to resolve challenging technical details. For example, weekly technical meetings invited all key stakeholders to participate in delivering the most economical and practical design solution. Principal design standards and acceptance criteria were agreed in an efficient manner.

Health and Safety

A best practice health and safety culture has been adopted to reinforce positive behavior in a number of ways:

- Rewards have been given on a random selection basis for the completion of health and safety observation cards.
- Operatives have been nominated and rewarded for 'safety player of the month' for demonstrating a commitment to health and safety.
- Director's tours have supported transparent communication across the project team and been welcomed at all levels.
- Project team members have undertaken training modules to support an ongoing focus.
- Behavioural safety experts have been engaged to provide role-playing workshops to the site team giving the opportunity to observe the consequence of poor communication and behaviour.

The project constructed an off-site mock-up, which was used to test emergency scenarios in order to ensure the Emergency Rescue Plan was robust. Operatives were provided with medium risk confined space training to cope with the constrained work environment.

Figure 9:
3D modelling assisting with reinforcement fixing

Stakeholder Engagement

The project has taken numerous steps to engage with the local community. The community liaison officer has been a focal point for community communication and engagement. Keeping a log of enquiries, complaints and 'thanks' demonstrates the community spirit that has evolved during project activity.

"Our team has consistently commented on how helpful and constructive your team is. I know it is not always easy to create such a culture so we are particularly grateful to you." Simon Downham, Vicar & Senior Pastor, St Paul's Church Hammersmith.

The project has made a difference to the community, the local school has benefitted from new playground facilities whilst the local church has, with help, realised additional parking spaces, which are at a premium in the area. The Costain team has made a positive impact:

"With such an enormous project at the end of the playground…we were understandably nervous of the potential disruption. However, we couldn't have asked for a better contractor." Head Teacher at St Paul Primary School.

Help has been forthcoming in times of difficulty, when the school fence blew down in high winds the project team repaired and subsequently replaced this essential school asset. Safeguarding school pupils from project activities has been a priority.

Local church facilities have been used for project team briefings. Finding a suitably sized space for briefings, to deliver a consistent message from team leaders to directors, suppliers and site operatives has been an essential part of team integration.

The project team has supported the Princes Trust, offering time to support secondary school children to refine their CV and interview skills. The Princes Trust said participants felt they would use the skills they have learnt in the future.

"I came away happy that I had achieved something and it has made me want to achieve more. You were "enthusiastic and encouraging" and "gave us a better chance of getting a job in the future."

Lessons Learnt

The Costain project team has regularly contributed to the parent company's initiative to share lessons learnt. The Hammersmith flyover project has shared experience of 3D modeling, BIM and confined space working with the wider Costain community. Other topics have been addressed over the project lifetime including those listed in the table below:

• Site set up and Organisation	• Communication
• SHE Management Plans	• Management of Team
• Procurement	• Design / Designers
• Community	• Commercial change control
• Programme delay capturing & sharing	• Structural Monitoring
• Interface planning	• Design Management
• Innovation	• Programme / Progress reporting
	• Lean methodologies

The team is confident the appropriate use of technology and integrated team working has underpinned their success. Regular and transparent communication about commercial, technical and health & safety issues has supported team achievements.

Corporate Social Responsibility - Challenge 150

In addition to the positive impact the project team has had locally, they are also engaged in a Costain Group initiative to commemorate a 150 year history. The ambitious target is to raise £1 million throughout 2015: "The Costain 150 Challenge". All the money raised will be split equally between four major national charities: the British Heart Foundation, Macmillan Cancer Support, the Prince's Trust and Samaritans.

Awards

The project is proud of a number of key regional and national awards

- ICE London Re-engineering award for innovative design and construction techniques
- CIHT Award for innovation for the short tendon system
- ROSPA Gold award
- CE Award outcome finalist

The project team hopes the success of this project will lead to future appointments under the TfL framework.

Constructing Excellence,
4th Floor, 33 Cannon Street,
London EC4M 5SB

T: 0845 605 5556
E: helpdesk@constructingexcellence.org.uk
www.constructingexcellence.org.uk
@constructingexc