UNDERGROUND

London
Underground

FRP Strengthening on the London Underground System

Graham Bessant – Head of Profession Bridges & Structures

FRP Strengthening on the London Underground System

Reasons for Using FRP 1

- Strengthening in the case of marginal assessment failures where we could not make a business case for reconstruction (i.e. no stock or speed restrictions)
- Plating is fraught with problems. It has been found very difficult to get a satisfactory weld to old steel and plating a rivetted structure within the short work “window” and limited space is impractical.
- FRP is a cold applied strengthening method and is light and easy to handle. It is also fast and easy to apply in short possessions.

FRP Strengthening on the London Underground System

Reasons for Using FRP 2

- As strengthening on Cast Iron structures where their position makes it prohibitively expensive to replace them. It often proves impossible to make the business case for replacement when there is no stock or speed restriction involved

FRP Strengthening on the London Underground System

Successes

Cast Iron struts at Shadwell

Covered way CW12/58 at High Street Kensington

MR46A

D90B at Olympia

COMPOSITE STRENGTHENING

at

BRIDGE MR46A

Station Road, Harrow
for London Underground's Metropolitan Line

Article reproduced by kind permission of
THE STRUCTURAL ENGINEER
Reprinted from 4th March 2003 issue

CONCRETE
REPAIRS LIMITED

Cathite House, 23a Willow Lane, Mitcham, Surrey CR4 4TU Tel: 020 8288 4848 Fax: 020 8288 4847
Email: mail@concrete-repairs.co.uk Website: www.concrete-repairs.co.uk

Regional Offices: Sheffield, Bristol, Falkirk, Manchester, Jersey

Under the bridge

The ageing Hammersmith Road Bridge crosses three rail lines and is part of one of west London's busiest roads. When the time came to strengthen the weakening structure, the use of specialist materials kept disruption to a minimum. **Helen McCormick** takes a closer look.

WEIGHT CONSCIOUS: To reduce the weight of the bridge the existing surface was removed and replaced with a lightweight concrete

MULTITRACK : The bridge spans three railway lines, including a freight line and the London Underground District Line.

Strengthening a 145-year-old road bridge over several railway lines in one of the busiest parts of west London was never going to be an easy task. Replacing the bridge altogether was not an option because of the massive disruption that would be caused, so a quicker solution had to be found. A lightweight carbon-fibre polymer proved to be the ideal answer.

Hammersmith Road Bridge, part of the A315 near Olympia, is a three-span bridge over two Network Rail (NR) lines and a London Underground (LUL) track. It is situated between the London Borough of Hammersmith and Fulham, and the Royal Borough of Kensington and Chelsea. Most of the bridge is owned by the two councils, except those sections that pass over the railway lines

Short-term solution

It was originally constructed in 1860 from 13 longitudinal cast-iron girders per span, supported on brick abutments and piers. But the bridge is well under the 40t required capacity for modern traffic, with a deck plate resistance of just 3t and a beam capacity of 17t.

As a result, the number of lanes on the deck was limited and a weight limit applied. This was not a long-term solution because the road concerned is bustling Kensington High Street on one half, and traffic-laden Hammersmith Road on the other. It also serves both the Earls Court and Olympia exhibition venues

"The new London buses are also quite heavy, and the bridge wasn't up to the task," says Sam Luck, director rail south division at Mouchel Parkman, the designer on the project.

"Massive strengthening was needed, but it had to be as light as possible and quick to install," he adds. "The Tube is obviously always busy, and the NR lines carry freight trains as well as being the Eurostar's route to its depot, so it was very difficult to get the trains to stop for any length of time."

Continuous service

Full reconstruction using pre-cast beams or a steel/concrete composite arrangement was not appropriate. This was because of the potential disruption to the railway, the A315, Olympia, Earls Court and the services carried within the bridge's structure – of which there were many, including two large-bore water mains, several gas mains and a cluster of unclaimed fibre optic cable banks) "Replacing the bridge would have cost an absolute fortune because of the services," says Luck. "The diversion alone would have been enormously expensive."

Several options were examined to reduce the dead load of the bridge, including replacing the existing concrete and fill material with a modern, lightweight concrete or foamed concrete. Some suggestions went ahead, such as separating the traffic lanes to reduce the load, and reducing surface depth to 100mm from the existing 180mm

The method of strengthening eventually chosen was carbon fibre reinforced polymer (CFRP) plate bonding, a technique pioneered by Luck and Mouchel. This expertise arose from a longstanding Mouchel JV with structural engineer Tony Gee and Partners.

NR commissioned the JV to produce a report on the development and implementation of advanced composite fibre-reinforced polymer materials for strengthening structures, in particular railway bridges. Under a subsequent agreement with NR, detailed design of this type of strengthening must be carried out by Mouchel, and independently checked by Tony Gee and Partners (or vice versa).

"This is relatively new technology, and we need to ensure it is applied in the proper way by specialists," says Luck. The technique has been used in more than 400 sites over the past four years. In 2002, the first all-composite bridge was built in Oxfordshire out of a mixture of carbon fibre and glass fibre. "Its reduced weight meant we could build it offsite for transportation with a mobile crane, and fewer foundations were needed," adds Luck. "It also has excellent durability over the long term, so whole life costs are significantly less"

A strong bond

The process of CFRP plate bonding is similar to the steel plate bonding developed in the early 1970s. The stronger, stiffer plate of material is bonded to the lower flange of a beam. The plates are made of two main materials – stiff carbon fibres and a protective, more flexible material.

Steel plate bonding has been used extensively in renovating structures, but suffers from several insurmountable design issues: the steel corrodes; it is not significantly stiffer or stronger than cast iron; and it is dense, so the increase in strength is often offset by the increase in dead load.

CFRP plates, on the other hand, cause a negligible increase in dead load and do not corrode. The plates are bonded using a two-part cold-cure epoxy adhesive and are not mechanically fastened in any way, a benefit when affixing to cast iron, which because of its brittle nature is not suitable for drilling

Apart from the technical requirements of the Hammersmith project, there was also an extremely tight and inflexible schedule to be taken into account. The bridge, and therefore the railway lines underneath it, could be closed only for very short periods of time. "This was the only viable way of strengthening the bridge in a realistic timeframe without causing massive disruption in that part of town," says Luck.

The strengthening of the LUL span took place mostly during a rare 96-hour possession over New Year 2005. The main task was the CFRP strengthening of the main beams. The metal surface is prepared by grit blasting, and there have to be strict environmental controls in place, particularly in the winter, to ensure the adhesive functions correctly.

Lightweight

The design of strengthening for the main central span required dead load reduction. Some of the fill material was removed and replaced with a lightweight concrete. This had to be performed in a staged construction method to allow the road to remain open. The surfacing of the whole bridge was stripped off and a concrete screed put down to bed a new waterproofing membrane and surfacing.

Further work was carried out during the weekend of 23 to 24 July 2005. This was successfully completed on site within 48 hours, despite being delayed due to a train in the wrong location. The LUL span is now rated at 40t.

The completion of the scheme depends on the availability of long possessions on the other spans. Normal possessions (around eight hours) will be used over the next couple of months to grit-blast the NR-span deck plates. Luck is confident the project will be completed within the next 12 months and says the bridge shouldn't need any major work for the next 40 years, which should please both the road and rail commuters of West London. ☐

Factfile: Project timeline

- Preliminary feasibility: July 2000
- Secondary feasibility: April 2004
- Detailed design: Summer 2004 – spring 2005
- Site construction: New Year 2005
- Night possessions: January 2005
- Weekend possession: July 2005

Factfile: Hammersmith Road Bridge

- Value of design work: £250,000 (including site supervision)
- Value of site work: £3.5m
- Designer: Mouchel Parkman Services, Advanced Engineering Group
- Main contractor: Colas
- Supervising contractor: Edmund Nuttall
- Specialist subcontractors: Concrete Repairs (CFRP bonding), Tone (scaffolding), Nixa (grit blasting and painting)
- Material suppliers: Epsilon (Degussa/MBT), London Concrete, Lytag
- Computational software: Mathsoft Mathcad, Ansys

FRP Strengthening on the London Underground System

Recent Difficulties

FRP Composites : Life Extension and strengthening of metallic structures 2001, Thomas Telford.

This recommends a design life for FRP of 40 years! What is the basis for this?

Effectively, this destroys any business case, as at best in theory we will only get a 40 year life extension on a structure that has much of its' life already expired.

FRP Strengthening on the London Underground System

Question – What do we mean by Bridge/Structure life?

Bridges will last for as long as they will carry their required load! A proportion of LU bridges are old than 120 years and so in theory they are fully depreciated and therefore have no value. In practice this is untrue, there are of full strength in good condition and are likely to remain for at least another 100 years, their replacement cannot be justified on any economic grounds, and to do so would cost huge sums of money in disruption costs.