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Gateshead Millennium Bridge, UK: fabrication, assembly and erection
K. Butterworth, D. Carr and P. Kassabian
Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, March, 11–19

On 20 November 2000 the Gateshead Millennium Bridge was lifted into place, in one, over the UK's River Tyne. The spectacular nature of the bridge design—the world's first vertically rotating bridge—and the audacity of the erection scheme attracted large crowds and significant publicity. The bridge currently takes its place as part of the regeneration of the Gateshead Quayside. This paper describes the fabrication and erection of the bridge structure by Watson Steel.

El Ferdan Bridge, Egypt: the world's longest swing bridge
N. Fuchs, K. Tomlinson and R. Buckby
Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, March, 21–30

The world's longest span swing bridge was opened on 14 November 2001 by President Mubarak of Egypt. The combined road and rail bridge crosses the Suez Canal close to the Egyptian town of Ismailia. The adopted solution, based on an illustrative design provided by the client, Egyptian National Railways, is a double swing bridge with a steel truss superstructure and a span of 340 m between pivot pier centrelines. The total weight of the bridge is 13 200 t. This paper describes the procurement, design and construction of this unusual project.

Castle Bridge, Weston Super-Mare, UK
C. James
Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, March, 31–37

Castle Bridge is a minimal-cost solution to the dilemma of a restricted crossing of a main railway line within a residential development area. The works employs reinforced earth embankments, integrated bridge deck and abutment construction and precast parapet solutions to overcome and minimise the safety, maintenance and cost issues associated with the scheme.

Weathering steel bridges
C. N. Dolling and R. M. Hudson
Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, March, 39–44

Weathering steel is a high-strength, low-alloy steel that in suitable environments forms an adherent protective rust 'patina', to inhibit further corrosion. The corrosion rate is so low that bridges fabricated from unpainted weathering steel can achieve a 120-year design life with only nominal maintenance. Hence a well-detailed weathering steel bridge in an appropriate environment can provide an attractive, very low maintenance, economic solution in many locations. This paper highlights the benefits of weathering steel bridges, describes the limitations, and comments on both the material availability and the appearance of such bridges. It also provides advice on a range of issues including design and detailing, fabrication and installation, inspection and maintenance and remedial measures, should corrosion rates exceed those anticipated at the design stage.

Jiangyin Yangtze River Bridge, China
J. Young
Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, March, 45–53

The Jiangyin Yangtze River Highway Bridge is a dual three-lane, 1385m-span suspension bridge that crosses the Yangtze River and forms a vital part of the expressway network of Jiangsu Province, China. Innovative engineering was required to meet the challenges faced during the design and construction of the bridge and its successful completion was achieved by the effective co-operation between Chinese and British designers, consultants and contractors. This paper outlines the studies undertaken to select the preferred location and form of the bridge. The development of the design of the principal elements of the bridge is discussed and the construction process described. During the project's planning and implementation, full consideration was given to the social development, safety, environmental and economic issues that were essential to ensuring the overall sustainability of this major river crossing. These aspects are covered in the second half of the paper.

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Dynamics of the Hungerford Millennium footbridges, UK
M. S. Fletcher and J. S. Parker
Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, June, 57–62

Hungerford Bridge Millennium Project in London, UK—a complex seven-span multi-cable-stayed structure—was under construction at the time of the oscillations of the nearby Bankside Millennium Footbridge. The design criteria and methods of calculation used to assess oscillation and displacement are described. The results of physical testing of the bridge by mechanically induced vibration and by a walkover test are compared to the calculated values. The calculations predicted performance in service with adequate accuracy. Measurement of structural damping during the physical tests indicated that it was lower than expected.

Real strength of high-performance concrete bridge deck slabs
S. E. Taylor, G. I. B. Rankin and D. J. Cleland
Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, June, 81–90

Deterioration of bridge deck slabs due to corrosion of reinforcement has become increasingly evident over the past 40 years and continues to be the cause of costly repair programmes. Detailing to reduce the risk of corrosion is simpler if the percentage of reinforcement is low. It is now recognised that laterally restrained slabs exhibit strengths far in excess of those predicted by most design codes. This increase in strength can be attributed to arching or compressive membrane action (CMA), and by recognising it in design, lower percentages of reinforcement can be specified. CMA has been incorporated into a small number of design standards. However, problems still exist in translating the arching theory into slabs in practice. The problem is in the assessment of the degree of external lateral restraint inherent in slab structures. This paper presents the results of tests on eight one-third-scale bridge deck edge panel models with target compressive strengths of 100 N/mm^2. The test programme aimed at realistically modelling the restraint conditions intrinsic in the edge panel of a real bridge deck slab. A method for assessing the real restraint in such a slab was incorporated into an existing arching theory by using an effective slab width concept. The procedure showed good correlation with the test results and with other results reported in the literature.

Design of strengthening works for an 1890s steel rail bridge
G. Waley, S. D. Wilkins and H. Barbour
Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, June, 99–107

The project involved the strengthening and deck replacement of a five-span lattice truss viaduct that carries the West Highland Line across a steep-sided gorge near Crianlarich. The bridge was designed and constructed for the lines opening in 1894. Railtrack Scotland awarded a design-and-build contract to Edmund Nuttall Ltd with White Young Green as Design Consultants to assess the options to strengthen the bridge and to meet current design standards, and to upgrade the capacity of the line for future increases in the weight of freight vehicles. White Young Green's input also involved detailed design, site supervision and the design of enabling works for free-standing and suspended scaffold structures. Innovative truss-strengthening measures included the installation of an external post-tensioning system deflected from the bottom members of the bridge truss. This increases the live load capacity of the truss by reducing permanent load stresses The system allowed the capacity of the trusses to be increased without the practical difficulties associated with adding additional metalwork to the top and bottom truss members. The scheme adopted comprised full deck replacement (still to be carried out), strengthening of the main truss members, and replacement of tertiary bracing members. The predicted response of the bridge under load was determined by developing a space frame model, which included all members of the truss and post-tensioning system. The analysis was used in conjunction with Freyssinet Ltd to develop the stressing system of deflected bars and strand tendons. Real rail vehicle loading, both stationary and slow moving (to minimise dynamic effects), was used in conjunction with strain gauges to confirm that the behaviour of the bridge before and after modification was as expected by the analysis. Monitoring proved that actual and predicted results were within 10% of each other. Some of this variation was attributed to the loads detected by strain gauges in secondary members. In conclusion, the post-tensioning process proved to be rapid and straightforward, with one span being post-tensioned per night shift. Other repair methods would have required much longer 'no train' periods to construct. The post-tensioning option was considered to offer the best value for money to Railtrack, and has the potential to be used on other rail bridge strengthening schemes.

Experimentally-based assessment of masonry arch bridges
P. J. Fanning and T. E. Boothby
Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, September, 109–116

This paper presents a summary of a continuing research programme intended for the development of generally applicable assessment procedures for masonry arch bridges, for which the assumptions and assessment results can be justified by experimental observations. The research is being undertaken in three phases. Phase I consists of experimental testing of bridges under service loads for the purpose of observation of bridge behaviour. A further purpose of the experimental programme is to provide data for the validation of three-dimensional non-linear finite-element models. In Phase II, three-dimensional non-linear finite-element models capable of capturing the principal features of the bridge response, based on a prescribed procedure and using standardised values of strength and stiffness, were developed. In Phase III the application of a two-dimensional model for the assessment of stone masonry bridges was considered. The assessment method used is based on a prescribed procedure using standardised values of strength and stiffness, which can be implemented in any general structural analysis programme. This phase also included a comparison of the proposed assessment method with other methods in common use.

The construction of Taney Bridge, Ireland
D. Collings and P. C. Brown
Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, September, 117–124

LUAS Line B consists of a new light rail system from Sandyford to central Dublin. Through Dundrum the line crosses a busy road junction. The client and their design consultants chose a cable-stayed structural form with a single asymmetric tower for this bridge. An alternative segmental deck design was carried out by Benaim for the contractor Graham Construction that would utilise

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previous experience with segmental construction. This paper outlines the construction philosophy and the development of the alternative design. The deck form, which is a precast concrete shell composite with an in-situ concrete infill, is unusual. The advantages of this form over the more conventional all in-situ or all precast type are discussed.

The reconstructed Lions' Gate suspension bridge, Vancouver

P. G. Buckland and D. D. Matson

Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, September, 125–133

A case study is presented of how the entire suspended structure of the 60-year old Lions' Gate Suspension Bridge in Vancouver, Canada, was replaced during 10-hour night-time closures plus a few longer closures at weekends. The bridge was open to full traffic at other times. Because the new structure was significantly different from the old, and because there was lack of moment continuity at the working front, the design had to consider every stage of construction. Investigations were key to the viability of the project. These included derivation of long-span traffic loads and load factors, and wind-tunnel testing in both smooth and turbulent flow. The main structural details are given. Fabrication and erection are described briefly. The result is a wider, safer, more durable bridge that citizens consider an aesthetic improvement.

Dynamic measurements on bridges: design, rehabilitation and monitoring

Á. Cunha, E. Caetano, R. Calçada, G. De Roeck and B. Peeters

Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, September, 135–148

This paper aims to stress the relevant role that the experimental assessment of the dynamics of bridges can play during the phases of conception and design, construction, reception, rehabilitation and monitoring (temporary and long-term). The importance of the experimental approach in these phases is essentially derived from experience gained from involvement in dynamic tests on several bridges: the Jindo (South Korea), Infante D. Henrique, Vasco da Gama, Luiz I (Portugal) and Z-24 (Switzerland) bridges.

Synchronised pedestrian excitation of footbridges

T. M. Roberts

Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, December, 155–160

A simple theory, based on the governing differential equations of motion, has been developed for predicting the critical number of pedestrians likely to induce synchronised lateral excitation of footbridges. Detailed prescription of the lateral forces, produced by pedestrians synchronising their motion in response to lateral accelerations of the bridge, is not required. The theoretical prediction is compared, and shows close agreement, with the results of full-scale tests on the London Millennium Footbridge.

Project history of Dublin's River Liffey bridges

M. Phillips and A. Hamilton

Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, December, 161–179

A significant geographical feature of Dublin, the capital of the Republic of Ireland, is that the River Liffey divides the city into the north side and south side. As there has always been significant traffic needing to cross the river, ancient fords and ferries gave way to a series of bridges. It is assumed that the first stone bridge across the River Liffey was built in the thirteenth century. Most of the surviving bridge infrastructure was built in the nineteenth century. Four road bridges were built in the twentieth century. The first bridge crossing in the twenty-first century was a footbridge commissioned in 2000. A further road crossing was completed in June 2003 and a sixteenth crossing is under consideration. A significant departure for Dublin was engaging an international designer for these latter bridges. The historical progression of river crossings is described and linked to a comprehensive set of 16 photographs. Historical reviews are provided of the approach used in bridge design and construction, the time and cost outcomes, the principals contracted to deliver the bridges, and certain aspects of the construction where such information was recorded. All original imperial measurements are also given in metric, and for ease of comparison all monetary values are given in Irish pounds (1 euro=IR£0·78).

Design and construction of the Bangladesh–UK Friendship Bridge

D. Collings, D. Mizon and P. Swift

Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, December, 181–190

The BangladeshRUK Friendship Bridge crosses the River Meghna in the north east of the country. The Meghna is the third largest river in Bangladesh. Further south it joins the Padma on its way to the Bay of Bengal. The main spans of the bridge known as Bhairab Bridge during the design and construction period are in total 929 m long, formed from multiple 110 m span prestressed concrete box girders supported on large-diameter bored pile foundations. There is an approach viaduct and highway on an embankment each side of the main structure, together with extensive river training works. The project was planned, designed and constructed using British technical expertise and was partly funded by the UK Government through the Department for International Development (DFID). This paper outlines the project history, engineering studies, design and construction. Of particular technical significance are the innovative solutions adopted to build this bridge in deep water.

An integral composite bridge of high skew

B. Bell

Proceedings of the Institution of Civil Engineers—Bridge Engineering, 2003, **156**, December, 191–198

At Killsharvan, west of Julianstown, Co. Meath, the new M1 between Dublin and Belfast crosses the River Nanny. Although only about 6 m wide in the summer, the river floods the adjacent fields during the winter. With the advent of the embankment carrying the new dual two-lane (future three-lane) motorway, the river has been widened, trained between sheet piled walls 20 m apart. Owing to the 48 degrees of skew and the 2·5 m allowance for footpaths each side, the span of the bridge is 40 m. A three-span multi-cell in-situ concrete bridge formed part of the contract awarded to Siac-O'Rourke Joint Venture. The central span was arch-shaped, 2·5m deep at the sides and 1·25 m deep at the centre. The river was expected to flood to the underside of the 'arch' at its sides. As part of a value engineering proposal, an alternative integral bridge was offered by the contractor, of composite construction. The paper describes the features of the bridge, some of them unusual.

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Gateshead millennium bridge—an eye-opener for engineering
J. Johnson and P. Curran
Proceedings of the Institution of Civil Engineers—Civil Engineering, 2003, **156**, 16–24

The Gateshead Millennium Bridge over the River Tyne in north-east England is an unique tilting bridge for pedestrians and cyclists. Opened by the Queen in May 2002, the inspirational 105 m span structure subsequently became the first bridge to win the Royal Institute of British Architect's 2002 Stirling Prize for 'building of the year'. This paper provides an overview of what has become known as the 'blinking eye' bridge and of the processes adopted to achieve and deliver it - not least the spectacular superstructure installation.

Hungerford Bridge millennium project—London
J. Parker, G. Hardwick, M. Carroll, N. Nicholls and D. Sandercock
Proceedings of the Institution of Civil Engineers—Civil Engineering, 2003, **156**, 70–77

The £50 million Hungerford Bridge millennium project in London provides two stunning new cable-stayed footbridges across the Thames, one on each side of Charing Cross railway bridge. Effectively it recreates Brunel's 1846 suspension footbridge to Hungerford market, the piers of which remain in the railway bridge structure. Heightened fears over unexploded bombs in the river bed led to a major redesign just after work started but a switch to the NEC contract helped ensure a smooth completion.

Electrification of US opening rail bridges
R. Wilson
Proceedings of the Institution of Civil Engineers—Civil Engineering, 2003, **156**, 86–93

Electrification of the final stretch of the busiest passenger railway in the USA required substantial modification to five existing opening bridges - some nearly 100 years old - to accommodate 25 kV overhead power lines. This paper reports on the development and installation of an innovative, moving catenary system, believed to be the first of its kind in the world, which has breathed new life into an ageing infrastructure.

Briefing: Reducing road congestion
A. Tetley
Proceedings of the Institution of Civil Engineers—Civil Engineering, 2003, **156**, 100

Three years into the UK Government's ten-year sustainable transport plan and the country's road and rail networks are more congested than ever. Andrew Tetley of the Institution of Civil Engineers' transport board says that the Government needs to set some clearer, more deliverable objectives.

Crowd-related failure of bridges
B. Wolmuth and J. Surtees
Proceedings of the Institution of Civil Engineers—Civil Engineering, 2003, **156**, 116–123

Over the past 180 years there has been a significant number of crowd-related bridge collapses around the world. Barring natural disasters or human conflict, they have involved greater loss of life than any other form of structural failure. This paper reviews crowd-related bridge collapses over the years, providing details of geographic and chronological distribution, form of structure, primary materials, imposed loading, crowd behaviour and the extenet of injuries. It concludes that those responsible for bridge design and maintenance must ensure that design details are robust, structures are properly maintained, and crowds are effectively managed.

Health and safety in tunnelling
D. Lamont
Proceedings of the Institution of Civil Engineers—Civil Engineering, 2003, **156**, 130–136

Over the past decade there have been several advances in health and safety practice in tunnelling. Industry standard publications have been revised, new and revised legislation has come into effect and a series of CEN (European Committee for Standardisation) standards for tunnel-machinery safety have been drafted. Extensive research related mainly to health and safety in compressed air tunnelling has also been undertaken. This paper reviews the health and safety risks of tunnelling and, through reference to standards, legislation, research and guidance, provides some indication as to how a reduction in these risks is being achieved.

Briefing: Time for action on waterways
M. Kendrick
Proceedings of the Institution of Civil Engineers—Civil Engineering, 2003, **156**, 151

Waterways have long been recognised as offering sustainable transport solutions but they remain low on worldwide political agendas. Mary Kendrick of Pianc reports on a new call for action and some promising new developments in the UK.

Highway bridges and environment—sustainable perspectives
K. Steele, G. Cole, G. Parke, B. Clarke and J. Harding
Proceedings of the Institution of Civil Engineers—Civil Engineering, 2003, **156**, 176–182

Civil engineering infrastructure is generally maintained in accordance with safety, economic and technical issues. But what of the environmental impact of such activities? Regular maintenance can have a significant environmental impact - particularly in the case of bridges, where closure can result in traffic jams and lengthy detours. Higher cost but lower maintenance components and transfer of structures to lower-grade sites are possible answers which, until now, have been difficult to assess. This paper reports on a life-cycle assessment method developed to factor environmental impact into bridge maintenance strategy. Though developed for bridges, it has potential application throughout the facilities management sector.

Channel Tunnel Rail Link: 1971 to 1990
B. Gambrill
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 1—Channel Tunnel Rail Link, Planning and People, 2003, **156**, 4–10

The £5·2 billion rail link between London and the Channel Tunnel opens in 2007, a full 13 years after the tunnel it is built to serve. As this paper shows, a detailed design was all but ready to be built in 1990 - but a combination of heavy-handed consultation, loss of

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public confidence and lack of Government funds left it for dead. Nevertheless, some valuable lessons were learnt.

Channel Tunnel Rail Link: from options to approval
B. Gambrill
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 1—Channel Tunnel Rail Link, Planning and People, 2003, **156**, 11–17

This paper describes the elaborate planning, development and consultation process that successfully took the £5·2 billion channel Tunnel Rail Link scheme from four independent options in 1990 to a fully approved scheme in 1997. Learning from the failed 1980s planning process, it introduced several innovative approaches to consensus building, option refinement and consultation - providing a benchmark for future infrastructure projects.

Channel Tunnel Rail Link: the hybrid Bill process
B. Gambrill
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 1—Channel Tunnel Rail Link, Planning and People, 2003, **156**, 19–23

This paper describes the hybrid Bill process by which the £5·2 billion Channel Tunnel Rail Link received its necessary enabling legislation in the form of an Act of Parliament. Even though the select committee became the longest-running ever to consider such a Bill, enactment took just two years. Petitioners achieved several minor changes to the project as well as 645 undertakings and assurances.

Channel Tunnel Rail Link: community relations during implementation
B. Gambrill
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 1—Channel Tunnel Rail Link, Planning and People, 2003, **156**, 24–27

This paper summarises the community relations and public affairs activities on the £5·2 billion Channel Tunnel Rail Link project since its implementation in May 1996. The fact that there have been no public protests or demonstrations since this vast project started on site in October 1998 is a testament to the success of the consultative process. Experiences on the project have now been embodied in a construction industry code of conduct.

Channel Tunnel Rail Link: financing and risk transfer
M. Bayley
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 1—Channel Tunnel Rail Link, Planning and People, 2003, **156**, 28–35

The £5·2 billion Channel Tunnel Rail Link is one of the world's largest public-private infrastructure projects ever undertaken. This paper describes the innovative funding and risk-sharing arrangements that were developed to lower the cost of capital - and maintain risk transfer tot he private sector - despite the initial failure of Eurostar to meet revenue forecasts and the later failure of Railtrack. It could serve as a model for the future public-private procurement of major transport infrastructure projects worldwide.

Channel Tunnel Rail Link: the property challenge
S. Bowman
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 1—Channel Tunnel Rail Link, Planning and People, 2003, **156**, 36–40

The 109 km Channel Tunnel Rail Link required a vast amount of property to be compulsorily purchased, legally leased to the project and the surplus resold - and all done as fairly and as quickly as possible. This paper reports on the series of innovative strategies and processes adopted by Union Rail Property to ensure the scheme got the land it needed on time and without fuss.

Channel Tunnel Rail Link: a contract partnership
A. Cathcart
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 1—Channel Tunnel Rail Link, Planning and People, 2003, **156**, 41–44

The £5·2 billion Channel Tunnel Rail Link is the largest project to date to adopt the popular partnering-based NEC Engineering and Construction Contract. this paper describes the strategy behind adopting a partnering approach and the detailed processes and behaviours that were necessary for successful implementation. It also reports on how the approach was taken a radical step further on contract 430 at Ashford, with the creation of a completely seamless team.

Channel Tunnel Rail Link: quality management
D. Keeling
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 1—Channel Tunnel Rail Link, Planning and People, 2003, **156**, 45–48

Like any major project, quality management is at core of the £5·2 billion Channel Tunnel Rail Link project. It operates at various levels, from the individual civil design and construction contracts to the design, commissioning and operation of the whole transport system. This paper describes the complex yet essential quality management structure that was established for the smooth delivery of this massive undertaking.

Channel Tunnel Rail Link: the case for safety
S. French
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 1—Channel Tunnel Rail Link, Planning and People, 2003, **156**, 49–53

The Channel Tunnel Rail Link is designed to carry up to 16 international passenger trains an hour, travelling at speeds approaching 300 km/h, high speed trains and freight traffic. Safety is thus absolutely critical, but fortunately the project team had the perfect model just at the other end of the Channel Tunnel: there has not been a single passenger fatality on the French Ligne a Grand Vitesse in 20 years. This paper describes the processes and systems that are enabling the project to achieve its all-important railway safety case.

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Channel Tunnel Rail Link: the complaints commissioner
J. A. Kennerley
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 1—Channel Tunnel Rail Link, Planning and People, 2003, **156**, 54–58

A complaints commissioner was appointed on the £5·2 billion Channel Tunnel Rail Link to act as mediator of last resort in judging the reasonableness of construction-related complaints. This paper explains how the role worked in practice and the benefits that it brought to the way the whole project has been built.

Channel Tunnel Rail Link: Cobham Ashenbank management scheme and Rail Link countryside initiative
D. Standen
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 1—Channel Tunnel Rail Link, Planning and People, 2003, **156**, 59–64

The package of environmental compensation and mitigation that accompanies the construction of the £5·2 billion Channel Tunnel Rail Link is widely seen as a model for future major development projects. The success of two innovative compensation schemes, agreed during the Parliamentary hearings, demonstrates the value of compromise and the partnership approach.

Channel Tunnel Rail Link section 1: an overview
M. Glover
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 2—Channel Tunnel Rail Link: Section 1, 2003, **156**, 5–11

British Prime Minister Tony Blair opened the first 74 km section of the new £5·2 billion high-speed rail link between the Channel Tunnel and London in September 2003. It has cut 20 minutes from the Eurostar service to Europe and brings Paris to just over 2·5 hours from London. This paper provides an overview of the design and construction of the first section, which has set new records for infrastructure as well as a wide range of new operational, safety and environmental standards for future high-speed rail projects in the UK

Channel Tunnel Rail Link section 1: an environmental route
T. Allet and J. Mitchell
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 2—Channel Tunnel Rail Link: Section 1, 2003, **156**, 12–15

Environmental considerations were at the heart of the route selection process for the Channel Tunnel Rail Link. Decisions were seldom clear-cut, but, with section 1 now built and operating, the majority seem to have proved right in environmental terms. With the benefit of ten years' hindsight, this paper reviews the environmental input to route selection and how it worked in practice - particularly the tough choices relation to Ashford, Boxley Valley and Medway.

Channel Tunnel Rail Link section 1: environmental management during construction
P. Johnson
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 2—Channel Tunnel Rail Link: Section 1, 2003, **156**, 16–20

The first 74 km section of the £5·2 billion Channel Tunnel Rail Link is entirely in Kent - the 'Garden of England'. This paper reports on the environmental management system that was set up to minimise the potentially huge environmental risks and impact of the scheme throughout its design and construction. In addition to management issues it reports on the approaches taken to relocating wildlife and controlling noise and vibration.

Channel Tunnel Rail Link section 1: archaeology and heritage works
H. Glass
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 2—Channel Tunnel Rail Link: Section 1, 2003, **156**, 21–2

Building a continuous 74 km stretch of new railway through the historic south-east corner of England presented and unrivalled opportunity to learn more about pas settlements, cultures and technologies. As such, the archaeological investigation associated with section 1 of the £5·2 billion Channel Tunnel Rail Link was one of the biggest ever undertaken in the UK and produced a wealth of new information. This paper explains how integrating the archaeological team within the project management team ensured that disruption to construction work was kept to an absolute minimum. It also highlights some of the more significant archaeology and heritage works on section 1.

Channel Tunnel Rail Link section 1: diversion of utilities
I. Clemmitt
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 2—Channel Tunnel Rail Link: Section 1, 2003, **156**, 25–27

A total of 423 utility diversions were required for the first 74 km section of the £5·2 billion Channel Tunnel Rail Link. The project was unprecedented in that the developer Union Railways had the power to design and build the diversions directly in order to avoid delays - though the utilities proved they could actually do the work quicker. This paper reports on the complex access and financial issues relating to diversions and highlights solutions adopted for maintaining overhead power cables and pumping sewage over a tunnel.

Channel Tunnel Rail Link section 1: ground engineering
N. O'Riordan
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 2—Channel Tunnel Rail Link: Section 1, 2003, **156**, 28–31

Some of the most innovative engineering design on the first section of the £5·2 billion Channel Tunnel Rail Link related to groundworks - ranging from dynamic analysis of trackbeds and pile slabs to dry soil mixing techniques and 3D groundwater modelling. This paper provides a brief overview of the geotechnical engineering work on section 1 and explains how the need to reduce design risk to a minimum resulted in valuable new industry guidance.

Channel Tunnel Rail Link section 1: Medway viaduct
K. Martin, S. Bennett and M. Kirk
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 2—Channel Tunnel Rail Link: Section 1, 2003, **156**, 33–39

The viaduct carrying the first section of the £5·2 billion Channel Tunnel Rail Link over the River Medway near Rochester is a uniquely styled bridge. the 1·25 km long, 25-span prestressed concrete box girder has become a symbol for the new railway and the 152 m main span has extended the limit for high-speed train

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crossings. This paper reports on it design and construction, which used both balanced cantilever and push-launched techniques. The viaduct was awarded the Concrete Society Award for Civil Engineering in 2002.

Channel Tunnel Rail Link section 1: North Downs tunnel
P. Watson
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 2—Channel Tunnel Rail Link: Section 1, 2003, **156**, 40–48

The 3·2 km tunnel under the North Downs in Kent is the longest tunnel on the first section of the £5·2 billion Channel Tunnel Rail Link. It also has the largest cross-section of any rail tunnel in Europe since no pressure relief shafts were allowed in the area above. This paper reports on how a value engineering process led to a significant change to the tender design, resulting in a 15% saving in cost and programme. Extensive tests of the overlying chalk showed it was stiffer than predicted, thus permitting the use of a thinner unreinforced secondary lining and a flat invert.

Channel Tunnel Rail Link section 1: Ashford
J. Hollaway
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 2—Channel Tunnel Rail Link: Section 1, 2003, **156**, 49–53

Ashford in Kent is the only station on the first section of the £5·2 billion Channel Tunnel Rail Link, requiring the high-speed route to run directly through the town and connect with local services. It is perhaps therefore not surprising that this was one of the most difficult parts of the project, requiring complex tunnelling and bridging works in a busy urban environment. this paper provides a brief overview of contract 430, which - thanks partly to an innovative working relationship between the contracting and project management teams - was complete on schedule despite one of the wettest winters on record.

Channel Tunnel Rail Link section 1: landscaping
T. Armour
Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 2—Channel Tunnel Rail Link: Section 1, 2003, **156**, 54–59

Landscape design and planting the first 74 km section of the Channel Tunnel Rail Link was a vast and sensitive undertaking. It involved placing and shaping 10 million m3 of fill around the track to help it blend into the landscape and then planting 1·2 million trees and shrubs and 245 ha of grass and wildflower seed. This paper reports on the many innovative techniques that were used in addition to the great care used in plant and seed choice.

Channel Tunnel Rail Link section 1: track and power supply
D. Bush

Proceedings of the Institution of Civil Engineers—Civil Engineering, Special Issue 2—Channel Tunnel Rail Link: Section 1, 2003, **156**, 60–63

The track and power supply used on the Channel Tunnel Rail Link is closely based on the French TGV system. The first 74 km section in Kent uses a ballasted track, with UIC60 rails on composite sleepers. But, unlike other high-speed railways, the route has numerous tight blends and a requirement to carry lower-speed traffic, resulting in compromised cant values. Traction power is provided by a French-style overhead 25kV catenary system, though Eurostar trains also have to run on a 750 V third rail system when stopping at Ashford station.

Performance of an oil interceptor incorporated into a pervious pavement
S. Wilson, A. P. Newman, T. Puehmeier and A. Shuttleworth
Proceedings of the Institution of Civil Engineers—Engineering Sustainability, 2003, **156**, March, 51–59

The use of pervious pavements is an important technique used for source control in sustainable drainage systems (SUDS) that allows water to infiltrate into hard surfaces and then slowly releases it to either a drainage outlet or into the ground. SUDS also remove low levels of pollution from the water by filtration and biodegradation of hydrocarbons that are adsorbed to materials within the construction. Current pervious pavement systems are not used in locations where the risk of pollution occurring is high or if they would allow the infiltration of water into the ground where groundwater protection is a concern. This paper describes trials of an oil interceptor that can be incorporated within pervious surface construction. The testing was undertaken to assess how the system retains pollution within it under simulated worst credible pollution and rainfall events. The results demonstrated that it can effectively contain hydrocarbon and metal pollution thus providing improved water quality. The water that flows out of the system has 50 times less oil pollution than the requirements specified for a Class 1 oil interceptor, when lubricating oil is applied to the surface. The water quality is over ten times better than the specified requirement when diesel is applied. Where detergents may be present they can cause minor contamination of the outflow waters and secondary treatment may be required.

Sustainability of bitumen use in highways
R. A. Peden
Proceedings of the Institution of Civil Engineers—Engineering Sustainability, 2003, **156**, June, 95–99

Crude oil is a finite resource, and bitumen, as part of the oil refining process, shares its common future. In 1973 predictions were that oil resources would be entirely depleted in 30 years' time. We have now reached that deadline. This paper examines the current oil reserves position, and considers the continued use of bitumen in highway maintenance and construction, from the stance that sustainability means 'acting today with tomorrow in mind'. Proven oil reserves and production ratios are examined to determine the future availability of oil and more specifically bitumen, in both the short and long term. The factors affecting bitumen availability, such as competition from other hydrocarbon uses and manufacturing implications are discussed and expressed in terms of sustainability. The source of suitable bitumen crude is examined and explained in terms of the overall refining barrel. The misapprehension that bitumen is a waste product at the end of the refining process is exposed. The features of bitumen that mark it as a unique petroleum product are highlighted, and the impact of oil sand deposits on the future supply of bitumen is assessed. Enhanced binder performance through polymer modification, hardened grade and emulsification/foaming techniques has facilitated more sustainable highway construction and maintenance procedures. The relationship between the binder and composite materials is examined in terms of sustainability and environmental performance. The case is made for incorporation of sustainability criteria within code and procurement procedures, in terms both of binder specification and of the maintenance and construction techniques employed.

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Sustainable chalk fill transfer from Channel Tunnel Rail Link
A. Phear, D. Patterson and C. Warren
Proceedings of the Institution of Civil Engineers—Geotechnical Engineering, 2003, **156**, April, 63–73

Between 1999 and 2001, the Channel Tunnel Rail Link (CTRL) and the A2/M2 widening scheme between Cobham and Junction 4 of the existing M2 motorway were both under construction in central Kent. The activity was particularly intense immediately to the east of the River Medway, where the earthworks for the two projects were immediately adjacent. Nearly 300 000 m^3 of surplus chalk was exported from the CTRL works to the A2/M2 widening project in a fill transfer agreement that represented the successful culmination of about three years of negotiations between the two project teams and the local planning authorities. It was a good example of waste minimisation, sustainable design and construction, and cooperative working, and involved the resolution of several planning, technical and construction management issues. The ways in which these were successfully overcome are addressed in this paper.

Experimental study of vibrations in underground structures
N. I. Thusyanthan and S. P. G. Madabhushi
Proceedings of the Institution of Civil Engineers—Geotechnical Engineering, 2003, **156**, April, 75–81

Vibrations produced on the ground surface by engineering construction processes can damage underground structures. At present there is little knowledge of the level of surface vibrations that could cause such damage. The relevant British Standards, BS 5228 and BS 7385, have little relevance to underground structures. This paper presents experimental investigations on small model tunnels that were instrumented with miniature accelerometers. Impulsive and vibratory loadings were produced on the soil surface by a drop hammer mechanism and an electric eccentric-mass motor respectively to simulate dynamic loading from construction activity. It was found that tunnels with different lining materials absorb different amounts of vibration energy. Power spectrum analysis of the acceleration signals showed that the vibrations are transferred into a brass model tunnel at lower frequencies than for a plastic model tunnel. A relationship has been proposed for the ratio of energy transferred and the ratio of impedance mismatch between soil and tunnel lining. Similar experimental studies can be carried out to understand the energy transfer from ground into underground tunnels with various linings (precast concrete lining, shotcrete or steel).

Tunnelling through varying soil conditions in north-west Greece
V. N. Georgiannou
Proceedings of the Institution of Civil Engineers—Geotechnical Engineering, 2003, **156**, April, 97–104

Tunnel S2 of the Egnatia Motorway is excavated through heavily fractured limestone and sheared sediments. Originally a fold and thrust belt was formed in the Alpine orogenic phase. Post-orogenic tectonics resulted in heavy fragmentation. The underlying material consists of clays and clayey sandy gravels. The basement of the clastic formation consists of evaporites. This variety of geological conditions resulted in considerable variability of tunnelling conditions and the need for extensive primary support measures. Owing to the mixed and rapidly changing geological conditions the type and intensity of primary support measures were selected according to geomechanical conditions at the crown. Slope stability problems were encountered during the excavation of the entrance portal, and because of the associated risk an additional study has been carried out to determine appropriate soil parameters for the excavation works through such a medium. Oedometer tests and direct shear tests were carried out to investigate the susceptibility of the material to structural breakdown and to define peak and post-rupture strength characteristics.

Local settlements and sinkholes due to EPB tunnelling
J. N. Shirlaw, J. C. W. Ong, H. B. Rosser, C. G. Tan, N. H. Osborne and P. E. Heslop
Proceedings of the Institution of Civil Engineers—Geotechnical Engineering, 2003, **156**, October, 193–211

Most of the tunnelling for the North East Line in Singapore was carried out using earth pressure balance (EPB) shields. Settlements were generally well controlled; however, there were occasional large settlements, exceeding the design estimates, sinkholes or losses of ground. Most of the larger surface settlements, sinkholes and losses of ground can be related to the use of insufficient face pressure. Other documented experience of settlements over EPB shields is also reviewed and the same pattern of occasional, but large, settlements or sinkholes is found repeatedly. The factors associated with such settlements are also common in many of the cases reviewed.

Use of alternative fuels in the UK road haulage industry
A. K. C. Beresford, G. D. Smith, S. J. Pettit and P. Nieuwenhuis
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 11–17

The market share of alternative fuels in UK road freight transport is less than 1%, despite several promotional initiatives. However, the use of fuels other than diesel in heavy goods vehicles is potentially one of the key methods of improving the environmental performance of transport and therefore making it more sustainable. This paper investigates a number of factors that affect the actual and potential adoption of alternative fuel technologies within the UK road haulage industry. The study focuses on the political and commercial environment surrounding the uptake of alternative fuels and suggests how the distribution network structure may determine the level of penetration of alternative fuels into the road-based freight transport sector. UK policy initiatives such as Powershift are important in this context.

A review of the UK cycle network
R. J. Blackwell
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 19–24

There are hundreds of thousands of new bikes sold in the UK every year but until recently the number of people cycling has fallen every year for the last 20 years. This paper explores some of the reasons for this decline in use and reviews the role the National Cycle Network in trying to reverse the trend. The provision of funding and the maintenance requirements of cycle routes are also explored.

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Why restore inland waterways?
A. J. M. Harrison and R. D. Sutton
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 25–33

Most of the inland waterways of England and Wales were constructed in the late eighteenth century for the carriage of freight; they are now mainly used for amenity and recreational purposes. This paper describes the campaign of the Inland Waterways Association to retain the waterways threatened with closure and to promote the restoration of those that were derelict. Although the income generated from waterways covers only about half the operational and maintenance costs, substantial economic benefits to the adjacent communities justify their restoration. The paper discusses the restoration process and the changing sources of funding. With the advent of The Waterways Trust and British Waterways' new freedom to engage in restoration work, the pace of waterway restoration has quickened. Whether that pace will be maintained now depends largely on the availability of funding.

Conservation of historic railway infrastructure
J. S. Cornell
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 35–42

Conserving the nation's built heritage has gathered strength and commitment during the past 20 years. It is increasingly recognised that excellent opportunities exist to find alternative uses for buildings no longer required for their original purpose, thus delivering conservation through regeneration. Historic railway buildings and structures are important examples of our built heritage. This paper describes the initiatives adopted by the railway industry with the aid of the Railway Heritage Trust in usefully protecting the works of some of our greatest engineers and architects.

Urban street tree plantings: identifying the key requirements
S. Pauleit
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 43–50

Trees fulfil important aesthetic, social and environmental functions in urban areas. However, tree life is increasingly under stress, leading to poor vitality and tree decline, particularly in urban streets. The requirements for healthy tree life are broadly known. Criteria for the design of planting sites in streets, choice of tree species and maintenance requirements are outlined in the paper. However, a European survey reveals the wide variance of tree planting and management practice. UK cities and towns performed poorly against criteria such as level of expenditure for trees, street tree quality and site preparation. Evidently, trees are very much undervalued and only an afterthought in the process of planning, design and management of streets. There is an urgent need to develop and apply comprehensive concepts for sustainable urban forests and specifically for street tree plantings. Standards for site planning, as well as increased knowledge of suitable tree species and tree quality standards are key to achieving this goal. Information on best practice needs to be more widely disseminated. The European pilot survey was a first step towards establishing an information network across Europe to collect the information needed for this purpose. There is a need for close collaboration between civil engineers and landscape architects from a very early stage to integrate tree plantings into the design of streets, in order to maximise their benefits and avoid potential conflicts with traffic and utilities.

Load spectrum for utility trenches in the footway
A. J. Reid, C. A. Fairfield and A. Sibbald
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 57–66

Local authorities are concerned about the adoption of cable television networks after they reach two years of age. Concerns have been raised about the shallow burial depth (250Rmm to the crown for ducts in footways), the longevity of the reinstatement, and the possibility of future damage to footways under vehicle loading. The aim of this research was to develop a realistic load regime for footway utility trenches. This was achieved by parking surveys counting the type (HGV, LGV or car) and frequency of footway loading incidents. The final output from the parking surveys was used to derive a load spectrum for future application to laboratory trench box tests. From these daily survey results, extrapolated worst-case load regimes for a 20-year design life were derived to assist engineers in their assessment of cumulative footway damage.

Briefing: Making the Connections: Final Report on Transport and Social Exclusion. Report by the Social Exclusion Unit 2003
B. Simpson
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 81–83

Although some may argue that there is not yet an accurate definition of 'social exclusion' and of those who fall into this category, this briefing examines the issues of how transport has contributed to such problems. The author gives a brief summary of each of the 13 chapters of the Transport and Social Exclusion report before moving on to discuss wider issues such as value judgements and land-use policies. Finally, the briefing considers the implications of these various processes for the report and for lasting solutions.

Briefing: Safer travel by design: reducing crime on public transport
J. Stafford
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 87–88

This article explains how careful attention to straightforward design features can make travel safer and reduce levels of crime. It draws conclusions from national initiatives introduced in UK railway and bus systems. A checklist of good practice is included.

Transport, social exclusion and young people in rural England
P. Dibben
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 105–110

Social exclusion is high on the UK Government's agenda, and over recent years there has been an increased recognition that transport should be seen as a central issue in this debate. In particular, a range of evidence has pointed to the need for adequate transport in rural areas and drawn attention to the needs of young people. At

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the same time, there has been a growing acknowledgement that those who are 'socially excluded' should have a voice in decision making, as evidenced in the Local Government Acts 1999 and 2000 and in the Transport Act 2000. Against this background, this paper examines the experiences of young people in relation to transport provision, and also the extent to which they feel that they 'have a say' in local decision making. To do this, it draws on a research study involving in-depth interviews with over 200 people in a rural county, paying particular attention to those undertaken with young people. The paper concludes by highlighting the implications for both transport planning and government policy.

Social inclusion implications of park-and-ride
G. Parkhurst
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 111–117

Park and ride (P&R) schemes are often promoted as an efficient means of extending the effective catchment of public transport networks into car-dependent areas with low population densities, such as rural districts. However, using P&R typically requires the traveller to have access to a car. As car ownership is often used as an indicator of social inclusion, providing P&R for motorists is not an obvious means of reducing exclusion from travel opportunities. Nonetheless, the present article argues that policies to promote interchange from cars to bus or rail can act as a force for either greater or less social exclusion, depending on who can access the services and what the alternative options would be in the absence of P&R being provided. The conditions under which inclusion is most likely to be promoted are reviewed. Key findings are that P&R facilities should not be developed at the expense of investment in conventional public transport and that the services should not be exclusively aimed at motorists. A particular situation in which motorists on relatively low incomes might benefit from P&R provision is where they would otherwise face high access charges to urban areas, in the form of road tolls or parking fees.

Improving access to transport in developing countries
T. Savill, J. Stone, C. Venter and D. Maunder
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 149–153

Improving access and mobility of people with disabilities is an essential component of the alleviation of poverty in developing countries. Disabled people are among the most socially excluded members of society and poorly designed and inaccessible transport can contribute to this situation by restricting access to education and health facilities and employment opportunities. This paper summarises the first phase of a Department for International Development (DFID) funded project which identifies the barriers experienced by disabled people when using public transport services in urban areas of the developing world.

Briefing: On the move: by foot
R. Huxford
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 159–161

This briefing sheet is a summary of *On the move: by foot*, a discussion document published by the Department for Transport, 30 June 2003. The aim is to contribute to a strategy document on walking that will contribute to the broader liveability agenda being developed by Government. The full document can be downloaded from: http://www.local-transport.dft.gov.uk/consult/walking/

Making Irish roads safer
S. Proctor and F. Crowley
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 179–183

This paper charts the development of road safety engineering in Ireland, from its roots in An Foras Forbartha (The National Institute for Physical Planning and Construction Research) in the mid-1960s, to the partnership arrangements that exist between government and local agencies today. The authors describe the development of local safety schemes, traffic calming and road safety audit, and look towards future developments within the context of Irish road safety targets.

Driver distraction by advertising: genuine risk or urban myth?
B. Wallace
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 185–190

Drivers operate in an increasingly complex visual environment, and yet there has been little recent research on the effects this might have on driving ability and accident rates. This paper is based on research carried out for the Scottish Executive's Central Research Unit on the subject of external-to-vehicle driver distraction. A literature review/meta-analysis was carried out with a view to answering the following questions: is there a serious risk to safe driving caused by features in the external environment, and if there is, what can be done about it? Review of the existing literature suggests that, although the subject is under-researched, there is evidence that in some cases overcomplex visual fields can distract drivers and that it is unlikely that existing guidelines and legislation adequately regulate this. Theoretical explanations for the phenomenon are offered and areas for future research highlighted.

Travel patterns at two secondary schools in Ireland
N. F. Gray and D. Kelly
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 273–280

The rapidly increasing level of car ownership and usage in Ireland is resulting in progressively more traffic congestion throughout the country. Traffic management teams are examining ways of reducing traffic density as part of a broader transportation policy. However, there are currently very limited statistics on travel patterns in Ireland. Secondary school children travel to and from school at peak traffic flow periods, adding significantly to local traffic congestion and pollution. In order to explore ways of minimising vehicle density around and on the approach roads to schools, the travel patterns of secondary school children in Ireland were investigated by means of a classroom-based survey. Two schools were studied: one in a rural location in County Leitrim and the other in Dublin. There was no difference between the three age groups studied, although significant differences in travel patterns were observed between the schools. Recommendations as to how school travel in Ireland could be made more sustainable are presented. The benefits gained from the inclusion of travel plans into the existing green schools programme are considerable both

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in terms of reducing accident rates and reducing car usage, which in turn have positive environmental and social impacts.

An analytical and experimental assessment of flexible road ironwork support structures
F. A. Mohammad, A. C. Collop and S. F. Brown
Proceedings of the Institution of Civil Engineers—Municipal Engineer, 2003, **156**, 281–287

This paper describes work undertaken to investigate the mechanical performance of road ironwork installations in highways, concentrating on the chamber construction. The principal aim was to provide the background research which would allow improved designs to be developed to reduce the incidence of failures through improvements to the structural continuity between the installation and the surrounding pavement. In doing this, recycled polymeric construction materials (Jig Brix) were studied with a view to including them in future designs and specifications. The paper concentrates on the finite-element (FE) analysis of traditional (masonry) and flexible road ironwork structures incorporating Jig Brix. The global and local buckling capacity of the Jig Brix elements was investigated and results compared well with laboratory measurements. FE models have also been developed for full-scale traditional (masonry) and flexible installations in a surrounding flexible (asphalt) pavement structure. Predictions of response to wheel loading were compared with full-scale laboratory measurements. Good agreement was achieved with the traditional (masonry) construction but poorer agreement for the flexible construction. Predictions from the FE model indicated that the use of flexible elements significantly reduces the tensile horizontal strain on the surface of the surrounding asphaltic material which is likely to reduce the incidence of surface cracking.

Shear strengthening of existing concrete bridges
P. Valerio and T. I. Ibell
Proceedings of the Institution of Civil Engineers—Structures and Buildings, 2003, **156**, 75–84

The shear capacity of existing concrete bridge beams is often inadequate and unable to meet current code requirements. This is often due to increased traffic loads, inadequate shear-resistance provision in the original design or deterioration of materials due to aggressive environments. This paper deals with a new type of shear strengthening for existing concrete bridges. It is proposed that vertical steel or fibre-reinforced plastic bars be inserted into pre-drilled holes and fastened in place using epoxy resin. This method has the advantage that only the soffit of the concrete bridge beam (or slab) is required for access, allowing the top surface to remain undamaged during strengthening. This could allow the bridge to be used during strengthening works, with traffic relatively unhindered by work being carried out below. Further, no threaded bars and plates are required in this scheme, solving the notorious installation and maintenance problems associated with present shear-strengthening schemes. Ten laboratory tests are presented here to demonstrate the system, and comparisons are made against current code predictions for the strength of such concrete beams with and without transverse reinforcement. An upper-bound plasticity-based solution is also provided as a means to explain enhancement in shear capacity in specimens with very few embedded vertical bars. The results of this work show that the proposed strengthening scheme is effective and provides significant improvement in the shear-carrying load capacity. Additionally, code predictions for capacity of the strengthened beams are rather accurate, so that this strengthening method may be adopted with confidence.

Strengthening of London's Lambeth Bridge
A. Kumar
Proceedings of the Institution of Civil Engineers—Structures and Buildings, 2003, **156**, 151–164

This paper summarises the findings of the principal inspection and load assessment of Lambeth Bridge, which had identified a structural deficiency in the original construction of the arched steel ribs of the bridge. The design for the strengthening of the bridge involved rectification of this deficiency as well as consideration of other repairs and repainting of the bridge. The paper briefly describes the various site operations involved in the works contracts resulting in the strengthening of this landmark bridge in London.

Thermal actions on a steel box girder bridge
J. -M. Lucas, A. Berred and C. Louis
Proceedings of the Institution of Civil Engineers—Structures and Buildings, 2003, **156**, 175–182

Most studies of thermal actions on bridges have been devoted to concrete structures. In this paper, we focus our analysis on steel box girder bridges. The statistical analysis is based on data collected over a three-year period by temperature gauges placed in appropriate places on the Normandy Bridge, France. Temperature–time series are generally known to contain a deterministic and a random part. The deterministic component is due to the natural seasonal fluctuation over a whole year. The same phenomenon has been observed in the case of the Normandy Bridge. At design stage, engineers need to know the extreme fluctuations of thermal actions (average temperature and thermal gradient) to ensure the durability and safety of a structure. Design codes prescribe extreme values called characteristic values defined on a return period of 50 years. The statistical analysis allows the calculation of these characteristic values as well as frequent and quasi-permanent values.

Wind-induced vibration analysis of the Hong Kong Ting Kau Bridge
C. Su, D. J. Han, Q. S. Yan, F. T. K. Au, L. G. Tham, P. K. K. Lee, K. M. Lam and K. Y. Wong
Proceedings of the Institution of Civil Engineers—Structures and Buildings, 2003, **156**, 263–272

Because of their high flexibility and relatively low structural damping, long-span bridges are prone to wind-induced vibration. An efficient wind field simulation technique for wind-induced vibration analysis of long-span bridges is first introduced in this paper. The time-domain expressions for the buffeting and self-excited forces acting on long-span bridges can then be found from the wind velocities. Based on the above theory and the aerodynamic parameters obtained by wind tunnel tests, a study of the wind fluctuations and aerodynamic forces is carried out on the Hong Kong Ting Kau Bridge, which is a cable-stayed bridge comprising two main spans and two side spans. The buffeting response of the bridge is analysed in the time domain by using step-by-step numerical integration techniques. The aerodynamic behaviour of the bridge can therefore be obtained, and the safety performance of the bridge against strong wind can further be

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evaluated. Numerical results basically agree with the experimental data, indicating that the theory presented in this paper is applicable to engineering practice.

Environmental impact of brick arch bridge management
K. Steele, G. Cole, G. Parke, B. Clarke and J. Harding
Proceedings of the Institution of Civil Engineers—Structures and Buildings, 2003, **156**, 273–281

Historically the management of infrastructure assets has been governed by social, economic and technical constraints. However, in the latter part of the twentieth century, with the advent and growth of the sustainability agenda, it became increasingly apparent that a fourth issue, environment, must also be included in decision-making. Surrey County Council (SCC), as the principal owner of highway assets within its boundaries, is directly responsible for over 1000 road bridges. To meet the authorities own environmental and sustainability objectives, it is clear that there is a need for knowledge on ways in which the organisation can reduce the environmental impact of its activities. The addressing of this need has called for an entirely new approach to assessing structure management activities. With the adoption of life-cycle thinking, a methodology has been developed to enable environmental comparison of alternative structure management strategies. In the context of brick arch highway bridges, the scope of this paper is to present this method and the findings it can produce. The development of the approach is important for SCC objectives, but also provides insight for the wider civil engineering industry, and gives perspectives on how it may tackle the issue of environment.

Construction over nineteenth century brick railway tunnels
A. J. H. Brown
Proceedings of the Institution of Civil Engineers—Structures and Buildings, 2003, **156**, 339–345

The construction of the new BullRing in Birmingham, is sited on two brickwork railway tunnels, built between 1849 and 1864, both of which are in full use. This paper is concerned with the construction requirements and process above these tunnels, and how these risks were identified, analysed and mitigated.

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