IABSE NEWS

Newsletter of the British Group of the
International Association for Bridge and Structural Engineering

No. 21 **Spring 2005**

GATESHEAD MILLENNIUM BRIDGE

WINNER – IABSE OUTSTANDING STRUCTURE AWARD 2005

Contents

Editorial

Welcome to *IABSE News*, the newsletter of the British Group of IABSE.

The engineering profession in the UK has often been accused of not communicating effectively with the public at large what engineers do and the contribution that they make to society. To counter this we encourage ourselves to celebrate our achievements, but perhaps there is something in the character of an engineer that prevents us shouting from the rooftops - even when we have earned the right to do so! Now - in the spring of 2005 - a combination of events and circumstances presents us with new opportunities to do just that.

The Gateshead Millennium Bridge has been named as the winner of the IABSE Outstanding Structure Award for 2005, another honour to add to the many that this outstanding expression of engineering and architecture has rightly earned. Coming from a global organisation such as IABSE this award marks the achievements of British engineers on the world stage, an accolade of which all those associated with the project should be rightly proud. The spatial experience of walking across this iconic bridge is only matched by the grace with which the structure opens to allow river traffic to pass. A visit to see and use the bridge is highly recommended.

Having celebrated the engineering achievement of an outstanding project, the opportunity to celebrate excellence by an individual is presented by the annual invitation for nominations for the Milne Medal of our own IABSE British Group. Now in its third year, the Milne Medal recognises high achievement in structural design by an individual engineer. Details of how to enter may be found below. Please take a moment to think whether anyone known to you would be a suitable candidate for the Medal. Our Chairman, Professor David Nethercot, would be pleased to provide more information.

With best wishes.

Andrew Martin
Editor

Events

Thursday 30 June 2005 6.00pm (Tea from 5.30pm)	Milne Medal Lecture **'My Millennium and Beyond'** **Steve Brown** (Buro Happold) Milne Medallist 2004 IStructE HQ, 11, Upper Belgrave Street, London
Thursday 24 November 2005 5.00pm	Annual General Meeting IStructE HQ , 11, Upper Belgrave Street, London.
Thursday 24 November 2005 6.00pm (Tea from 5.30pm)	Annual Lecture '**Light but Strong and Safe? Assessing the Structural Integrity of Ships and Boats'** **Professor Ajit Shenoi** (Southampton University) followed by Annual Dinner. IStructE HQ, 11, Upper Belgrave Street, London.

Milne Medal 2004

As announced in the last *IABSE News*, the Milne Medal for 2004 has been awarded to Steve Brown of Buro Happold in recognition of his achievements in the design for Millennium Point, Birmingham, St Catherine's House, London, and the Queen Elizabeth II Great Hall at the British Museum, London.

Steve collected his award in person at a short presentation before the IABSE Annual Lecture at the Institution of Structural Engineers Headquarters in London on 9 December 2004 and was the guest of the British Group at the Annual Dinner later that evening.

As part of his prize, Steve Brown will present a lecture on his work at the Institution of Structural Engineers in London on Thursday 30 June 2005, entitled 'My Millennium and Beyond' (see *Events* panel for further details).

Steve Brown (centre) pictured with Mrs Elta Milne and Professor David Nethercot, Chairman of the IABSE British Group.

Milne Medal 2005

THE MILNE MEDAL FOR EXCELLENCE IN STRUCTURAL DESIGN

The British Group of IABSE invite entries from individual engineers for the annual award of the Milne Medal

The winner will receive the silver medal, a certificate and a financial contribution towards attending an international conference to present a paper on the winning design(s)

Short listed candidates will each receive a certificate

ELIGIBILITY: Candidates must be chartered members of a British Engineering Institution
JUDGING CRITERIA: The judges are looking for a design engineer who had demonstrated the ability to produce high quality designs both in overall concept and in attention to detail. Assessment will be against the following criteria:

Simplicity and efficiency of form and function
Appropriate use and application of materials
Economy and originality in design and construction
Fitness for purpose, including ease of use, durability, operation and maintenance
Elegance and delight achieved by the structural form
Sensitivity to the environment

Further information and entry forms, which must be submitted by 23 May 2005, can be obtained from: Hon Sec British IABSE, c/o Professor D A Nethercot, Department of Civil and Environmental Engineering, Imperial College, London SW7 2AZ or email: d.nethercot@imperial.ac.uk

IABSE Outstanding Structure Award 2005

As featured on the cover of this newsletter, the international IABSE Outstanding Structure Award for 2005 has been won by the Gateshead Millennium Bridge. Manfred Hirt, President of IABSE, will present the Award at the Opening Session of the IABSE Symposium in Lisbon, on 14 September 2005.

The citation for the award reads, "This outstanding structure represents a fundamentally simple concept which exactly matches the complex requirements of the brief. It has been implemented with great assurance and elegance to produce a very fine bridge for pedestrians and cyclists. The bridge can take its place confidently alongside the great bridges crossing the Tyne built by earlier generations."

Hearty congratulations are offered to all those involved with the project and in particular Gateshead Council (owner), Wilkinson Eyre Architects (architect), Gifford (structural engineer), Harbour & General Works / Volker Stevin (main contractor) and Watson Steel Ltd (steelwork contractor).

British Group News

New Members

The following new members have joined the IABSE British Group in recent months:

Ian Hills
Moshiuzzaman Mahmud
Milan Peric
Timothy Russell
Ben Sibert

A warm welcome is extended to all.

New IABSE British Group Website

The website of the British Group has been re-established and can be accessed at www.iabse-uk.org . It is intended that the website will allow broader and better communication of the activities of the British Group.

Now available on the website are the proceedings of the Henderson Colloquium 2004 'Designing for the Consequences of Hazards', including all the papers presented at the colloquium (in pdf file format which can be downloaded).

Grateful thanks are given to the Institution of Structural Engineers for their generosity in hosting and updating the website.

Structural Engineering International

The ongoing opportunity exists for all members to have articles published in *SEI*, the international journal of IABSE. Rules for publication are available through the IABSE website at www.iabse.org. David Doran is the UK Correspondent for *SEI* and can offer assistance to prospective authors. His contact details are given in the Directory at the end of this newsletter.

An Appreciation

Dr W.C. Brown (1928 - 2005)

*By **Professor Tom Wyatt***

With the recent death of Bill Brown, the UK steel construction community has lost one of the key contributors to its resurgence over the last 50 years. It is now very difficult to recapture the feel of British industry in the years following the end of the war in Europe; demoralised, squabbling and backwards-looking. Little had changed by the time Bill came from his first degree at Southampton to explore post-buckling behaviour of webs at Imperial College under Pippard and Sparkes, although the 1951 Festival of Britain had achieved some revival of spirit - and notable structures such as the Dome of Discovery. The BS153 design loading for road bridges was still the steam traction engine with a train of trailers, but this was about to change.

Bill went from Imperial College to Gilbert Roberts' team at Freeman, Fox and Partners. His first appearance on the professional stage was in the paper by Kerensky, Flint and Brown, introducing the new BS153 (ICE Proceedings, 1956). This is a paper well worth re-reading in 2005, with its introductions to lateral torsional buckling and to post-buckling behaviour of webs as well as to elastically-restrained compression chords. The lengthy discussion is also significant, not least Bernard Godfrey's call to note the German lead in steel structures. Again, change was afoot.

He had already made his mark at Freeman, Fox on the design of the Volta Bridge, a trussed arch (245m span) with simple welded box chords. The dominantly compressive stressing in service allowed direct force transfer across machined end faces of the chords, but the tensions in cantilever erection posed a major problem. This was overcome by providing internal longitudinal threaded rods across the splice at each corner. Effective tensioning of 70mm rods within the confines of a 600mm box section was a key step in a career of imaginative problem solving that never ceased to evolve.

The changing economic climate brought the new generation of power stations and the big bridges, the first Forth Road Bridge (basically the aborted 1948 proposal for the Severn) and then the Severn Bridge itself. These structures developed the theme of machined-butt connection for compression elements, the Severn Bridge towers achieving the ultimate in simplicity of stiffened plate panels, in antithesis to the multi-cellular built-up towers of the great American bridges. The more spectacular innovation at Severn Bridge was of course the streamlined plated-box deck structure, a new approach to solving the aerodynamic problem. Steel construction had come centre-stage, and on the creation of the MacRobert Award, Brown with Sir Gilbert Roberts' team shared the inaugural award with the pick of aerospace engineering, the team lead by Sir Stanley Hooker that had delivered the 'vectored thrust' key to creation of the Harrier aircraft.

Bill's clarity of concept and visualisation of the creation of three-dimensional structures in stiffened plating contributed over the years to a variety of the firm's structures, including cranes and radio telescopes as well as box-girder and cable-stayed bridges.

The Severn Bridge deck concept extended to the Humber Bridge, which remained the world's longest span for some 27 years, but even a perfect aerofoil has limited capability aerodynamically, then revealed in attempted competitive proposals for the Akashi Straits crossing. Bill explored improvements such as a multiple slotted deck, and set up a small wind tunnel explicitly for basic sensitivity studies of flutter performance, eventually choosing the twin (or multiple) aerofoil as the most promising direction. After setting up his own practice, Brown Beech & Associates, in 1987, he continued this research, with increased wind-tunnel capability.

The third key component of Bill's innovations for suspension bridges comprised improvements in the in-situ assembly of the parallel-wire suspension cable. The dramatic effect on the speed of creation of the cable reinforced his appreciation that cable wire is by far the cheapest element available to the designer in terms of cost per unit force capacity. Gravitational stiffness thus comes cheaper, and Bill reduced his preferred sag/span ratio, in contrast to bridges such as Storebaelt. Nevertheless, as consultant to the contractor in that case, his methods were applied to considerable advantage.

These factors came together triumphantly for the Messina Straits crossing. The design comprises three slim boxes incorporating curved soffit panels, so that carriageways with three lanes and a shoulder each way, plus a double-track railway, only require 15t/m of deck steelwork. At 3300m, the span will be 65% greater than Akashi Straits, and to support even this deck requires some 170000t of cable wire. It is indeed sad that he has not seen the execution of this culmination of his contribution to structural engineering.

Henderson Colloquium 2005

The annual Henderson Colloquium will be held again this year in the pleasant surroundings of Magdalene College, Cambridge. The year's event concerns the subject of 'Dynamics' and will be led by Allan McRobie of Cambridge University Engineering Department.

Following the established pattern participation in the Colloquium is by invitation, with the intention that the presentations and discussions will produce a body of information and guidance relevant to structural engineers and other interested parties which is then disseminated to a broader audience through published proceedings.

As in 2004, the proceedings will be published electronically through the IABSE British Group website making them accessible to readers world-wide via internet search engines and web browsers.

Conference Report

Young Researchers' Conference 2005

Institution of Structural Engineers, London. 16 March 2005.
*Report by **Chris Walker**, Flint & Neill Partnership*

Thirty-six post-graduates engineers once again gathered at IStructE HQ for the annual Young Researchers' Conference. Now in its seventh year, the one-day conference is a fantastic opportunity for researchers to present their work at the Institution in the company of their peers and promotes important interaction, discussion and networking between Young Researchers and the wider engineering profession.

Chairman Michael Dickson, Vice President IStructE, opened proceedings by inviting Peter Head to present the keynote address to the conference. Wearing the hat of Commissioner for the London Sustainable Development Commission Peter Head OBE, gave a thought-provoking presentation on the future for sustainability in engineering.

Mr Head pressed home the case for a far more wide-reaching drive for sustainability, arguing that Europe alone is currently using resources at a rate that were it to be sustainable, would require three planet Earths. The address emphasised the important role for the engineering profession in achieving this, but perhaps more significantly given the nature of the conference, the need for further research in the field. Mr Head argued that while the principles, ideas and objectives of sustainability are well documented, the way in which it can be attained remains unclear; we understand 'sustainable', we just don't know how to *do* sustainable.

In what was an inspiring start to the conference, Head, Director of Arup's urban design and development group, hailed bio-mimicry as a likely vehicle for delivering true sustainability. Bio-mimicry, is innovation inspired by nature; the mimicry of natural materials and processes to guide the direction of our own rather haphazard and pragmatic technological progression.

In the context of the last 200 years of industrialisation, bio-mimicry is radical in its approach – its ethos is far removed from the "heat, beat and treat" philosophy adopted up until now. Head argued that nature should be seen as a mentor for technological advancement and not as an eternal resource to, in the words of Francis Bacon, "be tortured for her secrets". Progress should not be at the expense of nature's capital but by

researching its methods and making them our own. The beauty of this approach lies in its simplicity; nature is the very essence of sustainability.

Drawing inspiration from Bacon, Peter Head wrapped up the address by summing up; "The purpose of technology in 2005 is to raise comforts and living standards in a sustainable way and to uncover the secrets of the natural world to accelerate better use of resources before it is too late". After the address, Michael Dickson proceeded to introduce the research on offer. Presentations took two forms, with successful applicants asked either to produce a 15 min oral presentation or an A1 poster summarising their research.

The day consisted of three sessions, during which eight oral presentations were made and between which delegates were free to inspect and discuss the posters on display downstairs. In all, thirty-six abstracts were received representing some nineteen UK universities including ongoing research into many of the problems facing structural design engineers today. Topics included Michael Smith's 'Oscillations in 3-armed capillary tubes', Sam Waller's, 'Non-linear elastic buckling of imperfect pin-jointed structures' and Ahmed Shaat's, 'The real strength of laterally restrained RC slabs'. No real emphasis was made on scope of topics, with equal time given to research on new steel and concrete design methods as well as rehabilitation or strengthening of existing structures using newer materials such as FRPs.

Prizes were awarded by the President of the IStructE after difficult deliberation by a panel of judges made up of senior engineers from sponsoring organisations and from the Research Panel.. David MacKenzie from Flint & Neill Partnership, who headed the panel, said that all candidates had, "excellent communication skills and demonstrated good knowledge in their fields".

Cash prizes were up for grabs for the winners; Mahmud Ashraf (Imperial College) took home £350 for top place in the oral presentations with his excellent work on 'Structural stainless steel design' in which he highlighted shortcomings in current design guidance when applied to stainless steel. Ashraf's proposed design model seeks to exploit the inaccuracy of current elastic-perfectly plastic material models when applied to materials with an ill-defined yield point such as stainless steel. By modelling a more realistic stress-strain curve, Ashraf believes material savings of around 25% could be realised.

Paul Davies of the University of Glamorgan took second place with his presentation on 'Controlling the ductility and deformability of FRP strengthened RC structures'. Davies discussed results from a series of experiments using RC slabs retro-fitted with CFRP sheets with a view to deriving a design index for use in determining ductility at ULS. Howard Clarke followed in third with an interesting experimental study into 'reinforcing wrought iron with CFRP'. Clarke hopes to develop design guidance for strengthening the thousands of nineteenth-century wrought iron railway bridges in use in the UK today.

First home in the poster category was James Norman's, 'Multiple-support earthquake ground input into long-span bridges' from the University of Bristol. Norman's poster presented validation of theoretical modelling for Multiple Support Excitation using experimental testing of a scale model. MSE is significant for long structures such as dams, pipelines and bridges where earthquake input may differ between supports and for which the structural response may be significantly higher. Feng Fu from the University of Leeds came in second place with a poster on 'Semi-rigid composite connection with steel beam and pre-cast hollow core slab'.

In all, the day provided a fantastic outlet for some excellent research and without doubt helped foster vital links between UK research institutes and the end-users of that research, industry. From the intense discussion going on during breaks in presentations, both delegates and researchers alike appeared to enjoy themselves in what was an inspiring insight into future developments.

The IStructE Young Researchers' Conference was sponsored by IABSE UK, ICE, Flint & Neill Partnership, Buro Happold, Arup, Scott Wilson and the Engineering and Physical Sciences Research Council (EPSRC).

Project Feature

Strengthening Coalport Bridge

*By **Julian De Voy**, Gifford.*

Coalport Bridge carries the Class 3 Broseley to Brockton road over the river Severn in the village of Coalport. It is owned jointly by Shropshire County Council (SCC) and the Borough of Telford and Wrekin (BTW). The bridge is a Grade II* Listed Building and a Scheduled Ancient Monument and is situated within the Ironbridge Gorge World Heritage Site. Prior to its strengthening the bridge was signed with a 2 tonne weight limit and crossings were limited to one vehicle at a time.

The first bridge on this site was a two-span wooden structure, built in about 1780. After its central pier was damaged beyond repair by floods in 1795 the wooden bridge was replaced between 1799 and 1800 with a cast iron arched structure supporting a timber deck. There were originally three iron ribs until 1818 when the bridge was widened with the addition of 2 further ribs and the timber deck was replaced with the cast iron deck that is still present today, shown in the accompanying photographs.

This iron deck supported a road of cinders and cobbles which was later surfaced and eventually replaced in the early 1980s with a reinforced concrete deck slab. The iron deck plates are supported off cast iron inverted ‘T’ beams (originally by wrought iron shims but latterly by wooden wedges) which are themselves supported off the arch ribs by cast iron vertical supports of varying length depending on their position along the bridge.

The main river span is approximately 32m between the arch rib springing points and on either side of the river span there are short approach spans. In addition the south abutment is hollow and contains 2 more short spans making a total of 5 spans.

The bridge carries about 2000 vehicles a day mostly in the rush-hours and comprising vehicles travelling to and from Telford and the villages to the south of the river. It was assessed by SCC as having zero live load capacity to BD21 but rather than close the bridge to traffic the bridge engineer at the time took the view that the bridge should be able to carry an additional 1% of its self weight as live load. The estimate at the time was that the bridge weighed 200 tonnes so a 2 tonne limit was arrived at, with only one vehicle at a time permitted on the bridge. The County experimented with various methods, both active and passive, to enforce this restriction, without success, but it was in 1995 when one of the County's Divisional Surveyors saw a fully loaded readymix concrete wagon crossing the bridge, with one set of wheels on the road and the other on the footway, that the decision was taken to erect goalpost type height and width restrictions.

Obviously there is only a loose relationship between the size of a vehicle and its weight but nonetheless these goalposts were effective in keeping grossly overweight vehicles off the bridge, even if this was achieved at the cost of the occasionally damaged roof-rack and on one occasion, the demolition of an empty horsebox towed by a very absent minded driver.

In 2001 Gifford was appointed by SCC, BTW and English Heritage to develop proposals to safeguard the future of the bridge, to improve the traffic calming and to strengthen the bridge with an aspiration to achieve 7½ tonne loading and remove the one-vehicle-at-a-time restriction which had proved impossible to police.

Unsurprisingly for a structure of this vintage, there were no original drawings available and it very quickly became apparent that a complete dimensional and structural survey of the bridge would be required before the current load carrying capacity of the bridge could be assessed, much less develop a strengthening scheme.

When the survey was completed there was sufficient information to construct a sophisticated finite element model of the main river span. The side spans plus the two hidden spans in the south abutment, known locally as the undercroft, are accessible to simple calculation but the main river span is not.

Initially the project team was hopeful that a more accurate analysis than was possible when SCC first started to look at the bridge would show that strengthening was not required and that the bridge was stronger than initially believed, but this proved not to be the case and the analysis confirmed the original rating of dead load only.

We then looked at different ways of strengthening the bridge and very quickly homed in on the solution that right from the start had intuitively felt to be the correct one, strengthening by plate bonding.

When we started to develop a plate bonding scheme it very quickly became apparent that the behaviour of the bridge is very sensitive to the support conditions at the ends of the ribs and the cast iron inverted T-beams. Educated guesses were made as to what these support conditions might be but when they were plugged into the model it was clear that either the existing cast iron must be massively stronger than the allowable code values or the assumed supports were wrong.

In attempting to refine the estimates for these support conditions, we revisited an earlier survey when the movements of the bridge had been monitored for a year. These data indicated that the bridge appeared to be moving an alarming amount. During our survey in 2001 it was found that the eastern vaults of the undercroft were significantly distorted. The concern was that if these movements were correct then this could be the cause of the distortion observed in the vaults and that this movement would be likely to render redundant any strengthening scheme for the vaults. We were a little sceptical of the results of the movement survey and could not find a satisfactory explanation for them. However, they could not simply be dismissed so the bridge was periodically revisited over a period of a year to see if we could reproduce the movements; we could not. Some small movements were measured but nothing like the range from the earlier survey.

One of the problems in developing the strengthening scheme is that the code value for the tensile strength of cast iron is only 46N/mm^2. This is understood to be a conservative value but using a higher value requires justification and there were no 'spare' parts of the bridge that we could cut up and test. This problem is compounded by the fact that there are basically two bridges - the 1799/1800 bridge and the 1818 bridge, with two different cast irons. Early cast iron is an inherently brittle and variable material so that to have any

confidence in the result it is necessary to test multiple samples, leaving aside what English Heritage might think about cutting bits off a National Monument, there were no spare bits to test.

We couldn't test the material but we could test the support conditions. Messrs Sandberg were employed to attach over 200 vibrating wire strain gauges to the bridge and design a data-logging system to record its behaviour every 15 minutes over a 2 month period. During a temporary road closure an accurately weighed 2 tonne vehicle was driven across to measure the response to live loading. The results from the monitoring and the live load test were then used to calibrate the finite element model.

The methodology for strengthening the main span was for the existing deck slab to be removed by hydrodemolition to avoid damaging the existing iron deck plates. Grade 355 steel was selected in preference to CFRP for the strengthening as the latter was found to be inappropriate in this instance as well as very expensive. Steel plates of 16mm thickness were bonded to the central 6m of the ribs, with the slab removed. The plates were clamped at their ends to resist peeling forces. A new structural lightweight reinforced concrete slab was then cast which spans between the verticals removing the need for the wooden wedges to support the deck. This procedure was followed in order to attract permanent load into the steel plates, leaving as much as possible of the permissible 46N/mm^2 tensile capacity of the cast iron available for live load.

It was not possible to meet the Clients' original aspiration for 7½ tonnes live load capacity but it was raised to 3 tonnes and the "one vehicle at a time" restriction was removed.

IABSE British Group

Chairman
Professor D.A. Nethercot FREng FCGI
Imperial College, London

Vice-Chairman
Mr I.P.T. Firth
Flint & Neill

Hon. Secretary
Dr G.P. Tilly
Gifford, Carlton House, Ringwood Road, Woodlands, Southampton. SO40 7HT.
Tel/Fax: 01252 621430 (H) E-mail: Graham.Tilly@tesco.net

Hon. Treasurer
Mr A.C. Oakhill
Gifford, Carlton House, Ringwood Road, Woodlands, Southampton. SO40 7HT.
Tel: 023 8081 7599 Fax: 023 8081 7600 E-mail: tony.oakhill@gifford.uk.com

Executive Committee

Mr A.S. Beard	Mott MacDonald
Dr C.J. Burgoyne	University of Cambridge
Mr C.R. Cockerton	GBG Structural Services Ltd.
Prof. H. Gulvanessian	BRE
Mr W.I. Liddell CBE FREng	Buro Happold
Mr A.M. Low	Arup
Mr A.J. Martin	Arup
Mr S.J. Matthews	WSP Civils Ltd
Dr J.B. Menzies FREng	Consultant
Mr J. Moriarty	London Underground Ltd.
Mr A.J. Pickett	Highways Agency
Mr N. Ricketts	Network Rail
Mr M. Springett FREng	Consultant
Dr J. Tubman	Scott Wilson
Mr K.R. Wilson	FaberMaunsell
Dr J.G.M. Wood	Structural Studies & Design Ltd

Members of Honour

Mr D.K. Doran FCGI	Mr D.W. Quinion FREng
The Lord Hacking	Mr A.C.E. Sandberg OBE FREng
Mr A.W. Hill	

'Structural Engineering International' UK Correspondent
Mr D.K. Doran
Tel/Fax: 020 8989 9082 E-mail: David.Doran@btinternet.com

Editor of 'IABSE News'
Andrew Martin, Arup, Admiral House, 78 East Street, Leeds. LS8 9EE.
Tel: 0113 242 8498 Fax: 0113 242 8573 E-mail: andrew.martin@arup.com

Website: www.iabse-uk.org