



IABSE UK NEWS

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

No. 36

December 2014

Cool Designs: Engineering at the End of the Earth



Halley VI research station in Antarctica, designed by Peter Ayres - 2014 IABSE British Group Annual Lecture

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IABSE British Group News

Editorial

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

Happy New Year! The IABSE UK 2015 calendar is already full of interesting events which all the IABSE UK members will enjoy. Aren't you a member of IABSE UK yet? You should then make this your new year's resolution! (Online applications at [IABSE website](#))

In the following pages, you will be able to read about the conferences, seminars, lectures, meetings, and site visits that were organised and sponsored by IABSE UK and that took place over the second half of 2014. Peter Ayres delivered a fantastic lecture about the design of Hayley VI, the UK research station in Antarctica, and the extreme conditions that determined the design. The conferences Footbridge 2014 (sponsored by IABSE) in London and the 37th IABSE Symposium in Madrid were very well attended, with excellent presentations about the latest designs and research, with plenty of opportunities to interact, meet and network with other professionals. There were also lot of events organised by, and for, Young Engineers (YE)...and for all others like us who, not being considered YE by IABSE (under 35) anymore, have a young mind and are enthusiastic about learning and sharing knowledge in this field of bridge and structural engineering. 'Future of Design' and 'Journey to Success' are now completely consolidated, and are being replicated by other IABSE national groups. In these events, the passion, knowledge, and experience of senior and well-known engineers is merged with the interest, enthusiasm, and brightness of the youngest generations of graduate engineers and students. The keynote lectures at Future of Design were exceptionally good and formative. If you have not attended one of these events yet, make sure that you mark in your calendar the dates for this year. In this News, we also have a very extensive and interesting report about 2014 Henderson Colloquium on Digital Design, the abstracts from the best YE presenters in the last edition of Future of Design, and the reports from the site visits to two excellent and carefully designed footbridges recently built in London. Thanks to everybody who worked hard to make these events possible and to those who participated in them.

I would like to finish this first Editorial by expressing our gratitude to Brian Duguid, who served as Editor of IABSE UK News until this number. He did an excellent work that is very much appreciated. He will continue collaborating with IABSE UK as a member of the Executive Committee. As new Editor of the IABSE UK News, I would like to invite you to submit contributions: reports about technical events, pieces of news that are of interest to our readers, and also short notes about design and research projects that you are involved in. Feel free to use this newsletter to disseminate them across our members.

Ana Ruiz-Teran, Editor

Events

<u>Date</u>	<u>Time</u>	<u>Event</u>
11-12 February 2015	9am-10pm	IABSE Workshop: 'Safety, Robustness and Condition Assessments of Structures' Helsinki, Finland
27 March 2015	8:30am - 6pm	Future of Design 2015 University of Manchester, Manchester, UK
28 March 2015	9:30am - 2pm	Manchester Bridge Walking Tour Manchester, UK
23-25 April 2015		Structures Congress 2015 Portland, USA co-sponsored by IABSE
13-15 May 2015		IABSE Conference Nara, Japan Elegance in Structures



21 May 2015	5pm	<u>Annual General Meeting</u> IStructE HQ, 47-58 Bastwick Street, London, EC1V 3PS
21 May 2015		<u>Annual Lecture (by Prof. Mike Schlaich) and Dinner</u> IStructE HQ, 47-58 Bastwick Street, London, EC1V 3PS
1-3 July 2015		<u>MSLB - International Conference 'Multi-Span Large Bridges'</u> Porto, Portugal Co-sponsored by IABSE
23-25 September 2015		IABSE Conference 2015. 'Structural Engineering - a solution provider to global challenges' Geneva, Switzerland

Disclaimer

The views and opinions expressed in IABSE UK News are those of the respective authors and not those of either the Executive Committee of the IABSE British Group or the Editor. Whereas effort has been made to ensure the accuracy of statements and acknowledgements, we reserve the right to be as wrong as everyone else.

To all members - Are your contact details up to date?

We want all members get the most from their membership of IABSE and maintaining contact with members is therefore very important both to the IABSE HQ in Zurich and to the British Group in the UK. To ensure that you continue to receive the IABSE Structural Engineering International journal and newsletters from both IABSE HQ in Zurich and the IABSE British Group please ensure that your email contact details are up to date. To check your contact details and to update the information just visit the members area of the www.IABSE.org website. If you hear of any of your colleagues who are members of IABSE but are not receiving the SEI or the newsletters please ask them to update their data on the IABSE website.

Receive our latest news through the IABSE British Group website www.iabse.org.uk and in Twitter via @IABSEUK



Our members will be able to access the latest news about all the activities organized by the IABSE British Group through our website www.iabse.org.uk and also following us in Twitter via @IABSEUK.

With these tools, all our members will be able to access the latest information about all the activities organized by the IABSE British Group. They should become a very useful tool in promoting, celebrating and enjoying membership of IABSE in the UK.

We already have more than 250 followers in Twitter! Many thanks to Philip Goodall who is responsible for their maintenance.

A snapshot of our @IABSEUK in Twitter



Structural Engineering International

The ongoing opportunity exists for all members to have articles published in *SEI*, the international journal of IABSE. It is abstracted and indexed at the Web of Science, Science Citation Index Expanded (SciSearch), and Journal Citation Reports/Science Edition, among others. Rules for publication are available through the IABSE website at www.iabse.org. Tony Harris is the new UK Correspondent for *SEI* and can offer assistance to prospective authors (see Directory). We would like to express our gratitude to Brian Duguid, who has been the UK Correspondent for *SEI*.

Forthcoming issues are expected to include the following themes:

- SEI 1/2015: (Feb.) ‘Tensile and Membrane Structures’
- SEI 2/2015: (May.) ‘Research and Project Papers’
- SEI 3/2015: (Aug) ‘Engineering for Progress, Nature and People’
- SEI 4/2015: (Nov.) ‘Elegance in Structures’



IABSE UK NEWS

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

Call for contributions – Issue 37

The Editor of the IABSE UK News would like to invite the members of the IABSE British Group to actively participate and contribute to this Newsletter by submitting their reports for the next issue (No 37) to be published in July 2015. The IABSE UK News is an excellent medium for informing other members about events that IABSE has sponsored and organized, about interesting projects which members are working on, and it is also an effective way to introduce new members to our professional community.

Contributions on the following topics are particularly welcome:

- Short reports (200 – 1000 words, and photos) from participants and organizers about events sponsored or organized by IABSE (from January to July 2015).
- Presentation of New Members of the IABSE British Group (50 – 100 words, and photo)
- Short description (200 - 1000 words, and photos/figures) of interesting structures that are being planned, designed, constructed, maintained, refurbished, or demolished.
- Short description (200 – 1000 words, and figures) about research projects that are being conducted and PhD theses that have been completed.

If you wish to submit a report, please first send an email to the Editor (Ana Ruiz-Teran e-mail: a.ruiz-teran@imperial.ac.uk) as soon as possible, in order to agree the submission.

We look forward to receiving your proposals and contributions!



New Members of the IABSE British Group Executive Committee

At the AGM in May 2014 elections were held for the British Group's Executive Committee. Seven spaces were available with the following being elected:

Brian Duguid, Mott Macdonald
Philip Goodall, WSP
Bill Harvey, Obvis
Andreas Lampropoulos, Brighton University
Fergus McCormick, Buro Happold
Tom Osborne, Knight Architects
Caroline Tong, CH2M Hill

Each member will serve on the committee until 2018. More information on the executive committee can be found at iabse.org.uk.

Below, two of our new committee members, and one returnee, outline what IABSE means to them.

Andreas Lampropoulos- Brighton University



I am a Senior Lecturer at the University of Brighton. I am the module leader of two modules, 'Construction Materials' and 'Design of Reinforced Concrete structures', and I am also the Admissions tutor for the Civil Engineering courses in the University of Brighton.

My research agenda spans the areas of earthquake strengthening/retrofitting existing structures, new cement free concrete materials and Ultra High Performance Fibre Reinforced Concrete (UHPFRC). I have extensive experience on the development of new materials and on the numerical and experimental investigation of strengthened elements. I have published more than 25 journal and conference papers including a series of papers in top peer-reviewed journals.

IABSE is a unique opportunity to gain first-hand knowledge of the main structural engineering needs and issues. My involvement in the Executive Committee of the British group of IABSE and in Working Group 7 for Earthquake Resistance Structures enables me to promote activities and transfer knowledge on sustainable construction materials, novel strengthening techniques & design methods.

Brian Duguid- Mott Macdonald



I am a technical director with Mott MacDonald, and our bridges practice leader for the UK. My role involves coordinating professional development, business planning, and day-to-day collaboration across our network of regional bridge engineering teams. I frequently act as project director or technical lead on a wide variety of bridges projects, and I am currently being kept busy as the lead civil engineer for a major new railway scheme in central Manchester. More generally, I have a keen interest in bridge architecture, particularly for pedestrian bridges, and enjoy working at the creative edge of bridge and structural design.

I was introduced to IABSE via the 2007 Henderson Colloquium which discussed bridge design competitions – having been involved in a number of contests which failed to produce actual bridges, I had a desire to see whether they could be improved. I was part of the IABSE Working Group which subsequently produced a new international guidance document for bridge design competitions. I edited the IABSE British Group's newsletter for some time. I'm currently assisting with plans for a Future of Design



event to be held in the north of England in March 2015. I value the opportunity that IABSE offers to meet a wide range of fellow professionals both within the UK and internationally.

Philip Goodall, WSP



I am a structural engineer for WSP in London, where I have been working since graduating from Surrey University in 2011. I have worked on a wide variety of projects in that time including London Bridge Place, Crossrail Bond Street Station and the London Bridge Station Redevelopment.

I first heard of IABSE when receiving an advert for the Future of Design conference in 2012- something completely different to the standard ICE/IstructE lectures. It was great to see so many enthusiastic young engineers whilst also meeting experienced designers who were happy to share their experience and knowledge. I volunteered to help organise the conference in 2013, and have also created our British Group website- iabse.org.uk. If anyone has any suggestions for improving the site please let me know!

Future of Design 2015 - Manchester

Call for papers

Young Designers:

Young designers (35 years or less) are encouraged to submit a one-page paper of their innovative work or research for presentation during the conference. The authors of the 12 papers judged to be the best will be invited to present their awards at the conference and will receive a free ticket to the conference. Prizes for the best presentations will be awarded to four young participants (a winner and runner up from two groups).

The one-page papers need to be submitted before 16th February 2015. Papers can be submitted using the form below and need to be formatted as per the submission guidelines.

If you have any problems with this please contact us directly (fodnorth2015@iabse.org.uk)

Important Dates

16th February 2015	Deadline for one-page paper
2nd March 2015	Notification of results
27th March 2015	Present at the conference

Open page paper template and guidelines available at <http://iabse.org.uk/wp-content/uploads/2014/12/FoD-2015-One-page-paper-template-and-guidelines.doc>

Annual Lecture: Peter Ayres - Cool Designs: Engineering at the End of the Earth

Report by Fernando Madrazo-Aguirre, Imperial College London

The 2014 Annual Lecture, presented by Peter Ayres (AECOM), took place on the 15th of May 2014 at the RIBA in London. The talk focused on the award-winning Halley VI British research station in Antarctica. In fact, Peter had just arrived hours before the lecture from New York, where Halley VI was awarded the "Best Education and Research Project in the World" by the Architizer A+ Awards. The lecture was an interesting incursion in the design of structures in unconventional locations.

After a brief introduction by Ian Firth (Chairman of IABSE UK), Peter Ayres started talking about the background of the project. Antarctica is chosen by scientists for being one of the most appropriate locations to monitor both the planet (climate, atmospheric physics, etc.) and the outer space, due to the clean environment. Nevertheless, many unusual factors make the design a real challenge:

- Extreme climate conditions: wind and cold.
- Difficult ground conditions: existence of crevasses and constant movement of the ice shelf. The thickness of the ice shelf is constant, but the ice melts under the water and new layers are created by the snow on the top, leading to a vertical movement with a velocity of approximately 1 m/year.
- Logistics: remote location and limitation of the maximum weight due to the fragility of the ice shelf in some locations.
- Tight environmental rules, which are mainly related to the energy consumption.

With these restraints in mind, the design of Halley VI led to a modular and highly prefabricated structure. In words of Peter, the project was about "a building process, not a building".



Halley VI research station in Antarctica.

Peter did an interesting historical review of the trends in the design of buildings in Polar Regions: initially tents used to be employed; these evolved to timber buildings, which used to be buried under the snow easily; as a result, buried structures were designed, with the problem that after several years they would end far from the ice shelf surface. Nowadays, the trend is building elevated structures that do not produce a barrier effect, and consequently do not tend to be buried. This is the system employed for Halley VI: a structure supported over extensible hydraulic legs to adapt to the vertical movement of the ice shelf.

The result of the design is a research station that reduces operation works during service life, and allows for more time for science. The structure consists of frames made of very ductile steel to avoid brittle failures in cold weather conditions. The design was highly driven by the living conditions of the scientists that would work in the station (e.g. colours of rooms and offices were selected by a psychologist, as curiosity). Halley VI has resulted in a highly efficient building in terms of energy consumption compared with previous stations, but the real challenge for the future is achieving a zero emission base.

As Peter concluded: Halley VI is the "first piece of architecture in Antarctica". After the corresponding Q&A session and a closing talk by Mark Bulmer of AECOM, some of the participants headed to a nearby restaurant for dinner.

Client: British Antarctic Survey. Architect: Hugh Broughton Architects. Engineer: AECOM. Principal Contractor: Galliford Try International.



Figure: Peter Ayres and Ian Firth during the Q&A session.

2014 Footbridge Conference

Report by Joan Valls-Mestre, Ove Arup & Partners

Last summer took place in London the 2014 Footbridge conference, which was held at Imperial College London facilities in South Kensington Campus, from the 16th to the 18th of July, during the warmest days recorded in London in that month. The 2014 Footbridge conference was the fifth in the series of triennial conferences on footbridges which started in Paris in 2002.

The conference consisted in more than 160 delicately selected papers presented, some in form of theatre lectures and others in form of poster presentations. The large number of first class keynote speakers and a wide variety of interesting subjects covered, made of the conference a really enjoyable experience for those interested in bridge engineering.

The three days of conference started with the always unpredictable British weather in our favour (heard many comments on the luckiness of finding such good weather). Coffees and pastries welcomed the attendees (pastries were great), followed by plenary sessions. Series of 15 minutes theatre lecture presentations grouped by topics were given, and poster exhibitions were displayed during the breaks. The sessions finalised with events such the Footbridge Awards 2014 on Wednesday the 16th, the Gala dinner on the Symphony Boat Cruise on Thursday evening and the Young Author award on Friday afternoon.

As a postgraduate student at just one month ahead of starting my career in the industry, I had the opportunity to attend this event and collaborate by helping in the IABSE desk. Being my first international conference, I enjoyed it plenty and meet lots of engineers and other professionals from numerous countries. I was delighted to see so many people from all over the world sharing the same passion, from graduates to seniors. It was also a great occasion to see how the ideas, new developments, wins and losses are shared among those interested in keep pushing the boundaries of this profession forward, to deliver more quality and innovative pieces of engineering.

I found the conference really inspiring. Some engineering solutions with splendid taste were presented; worth mentioning how some outstanding professionals can turn a problem into an opportunity to produce something effective, innovative and beautiful at the same time. It was interesting to see how footbridges are rapidly evolving, from shapes to materials, from colours to lightning.



Lucas Epp, winner of the Young Author award, receiving his trophy from Ian Firth and Joanne McCall, Chair of the Judging Panel.



Tom Osborne, runner-up in the Young Author award, receiving his certificate from Ian Firth and Joanne McCall, Chair of the Judging Panel.

Overall a great experience that I would recommend to anyone passionate about bridge engineering. Looking forward to attend the next conference in three years' time and maybe give a presentation myself (who knows?).

Greenwich Reach footbridge Visit, 28th August 2014

A visit to the Greenwich Reach footbridge was organised by the IABSE British Group. The bridge is now completed and opened to the public use since January 2015.



Greenwich Reach footbridge. Design: Flint & Neill with Moxon Architects and Eadon Consultants. Contractor: Raymond Brown Construction with SH Structures

Workshop on Bridge Design, September 2014, Madrid, Spain

Report by Fernando Madrazo-Aguirre, Imperial College London

The first edition of the International Workshop on Bridge Design was held on the 2nd of September in Madrid, prior to the 37th IABSE Symposium. Following the successful Future of Design (FoD) set of conferences in the UK, the Spanish Group of IABSE in collaboration with San Pablo CEU University organised this event focused on young designers.



Chris Walker delivering his lecture during the morning session

The conference gathered near 85 international delegates, including both students and practicing young engineers. The event was divided in two sessions, the first one consisting in individual lectures given by senior and young designers, and the second one being the actual workshop. Professor David Nethercot, the current IABSE Chairman, opened the event by giving a brief introduction about IABSE. Antonio Martinez Cutillas (Carlos Fernandez Casado, SL), Lee Franck (Arup), Alvaro Serrano Corral (MC2), Christian Bernal (freelance) and Laurent Rus (Arup) were responsible for giving some inspirational ideas and thoughts about the job of civil engineers in general, and structural engineers in particular. A coffee break aimed at networking followed these talks. In the second half of the morning very inspiring projects were presented by Mike Schlaich (SBP), Maria Mingallon (Arup), Chris Walker (Flint&Neill), Matt Carter (Arup) and Fernando Porras-Isla (Madrid Rio). The morning session ended up with a short colloquium in which delegates were given the opportunity to make questions to the speakers.

The novel part of the event came in the afternoon: the workshop. All the delegates were given a problem statement nearly a month before the event. The problem consisted in designing a footbridge over the Manzanares river in Madrid, and young designers had to prepare some initial ideas and sketches to be discussed during the workshop. Ian Firth (Flint&Neill and the current IABSE BG Chairman), Roberto Revilla (ra arq & ing) and part of the morning speakers helped delegates to develop their designs, and if necessary, suggested changes. The workshop ended up being a very dynamic and interactive meeting between senior and young designers, and some interesting designs were developed.



Attendants discussing design proposals with tutors during the afternoon workshop.

Delegates were given two more days to finish their footbridge proposals and a jury formed by some of the workshop tutors selected 4 finalists. During the closing ceremony of the IABSE Symposium on the 5th of September, the winner of the design competition was announced: a team formed by architecture students Jesus Gallego and Guillermo Sanchez. Their proposal consisted in a suspended footbridge with two different decks at different levels to separate the pedestrian and cycle traffics; the approaches and surroundings of the footbridge were also carefully designed. The event finished with a cocktail as part of the YEP Party in Zarzuela Hippodrome, designed by the Spanish engineer Eduardo Torroja.

The Spanish Group of IABSE is currently preparing a booklet with all the proposals. The programme of the event can be found at:

http://issuu.com/geiabse/docs/workshop_on_bridge_design

'Engineering for Progress, Nature and People', 37th IABSE Symposium

Report by Martin Kirk, Arup

A successful conference was held this year in Madrid with typical Spanish flamboyance and timing including traditional flamenco music and dance. A young person's day was held on the Tuesday, this started with a "Workshop on Bridge Design" where participating young people/students had been set a bridge design task beforehand.

In the morning eminent engineers gave short talks followed in the afternoon with a workshop where these engineers assisted the groups in developing their designs. In the evening all Young Engineers (under 35) attending the Madrid Symposium were invited to a cocktail social event on the terrace of the Zarzuela Hippodrome.



Cocktail social event on the terrace of the Zarzuela Hippodrome

The Symposium theme was 'Engineering for Progress, Nature and People', and over 440 papers were accepted on:

- Innovative Design Concepts
- Sustainable Infrastructures
- Major Projects and Innovative Structures and Materials
- Analysis
- Forensic Structural Engineering
- Construction
- Operation, Maintenance, Monitoring, Instrumentation Education and Ethics
- Cooperation and Development Projects

Over the three days of the symposium, key speeches were held on “New Developments and Challenges in PC Bridge Design in China” by Dong Xu, Junli Zhao, “Inspection, Monitoring, and Maintenance of Infrastructure Systems in a Life-cycle Context: Emphasis on Bridges” by Dan M. Frangopol, Mohamed Soliman and, “Spanish Bridges” by Javier Manterola, “Recent research in the field of railway bridge dynamics” by Raid Karoumi, “Creative Teaching for Educating Creative Structural Engineers” by Maria E. Garlock, “Forensic Structural Engineering: Opening doors of opportunity to change” by Robert Ratay, “Bridges to Prosperity: Designing bridges to connect people, nature and engineering” by Avery Bang, “Computational modeling of



concrete as a complex material: past, present and future trends” by Xavier Oliver and “Delivering Architectural Quality in Design-Build and PPP Projects” by Matt Carter.

Following the normal traditional technical tours and evening events where held. Most notable were cocktails in the Prado museum, evening gala dinner with entertainment in the glazed patio of Madrid City Hall and on the Friday a visit followed cocktail dinner on the pitch of Real Madrid’s Santiago Bernabeu stadium.

We are looking forward to next year’s event in Geneva when a more open and exciting format is being developed; ideas to be submitted by 15th October.

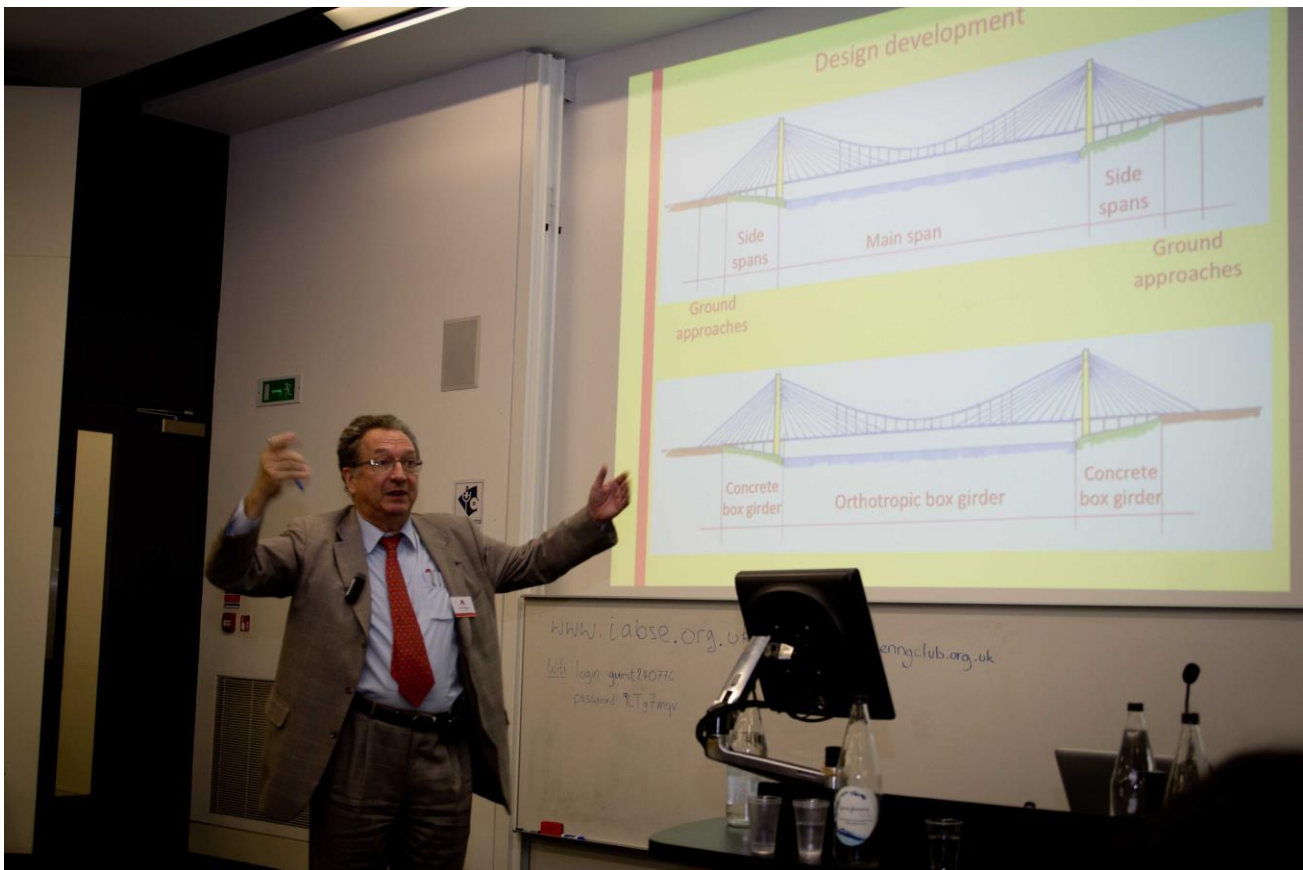


Cocktail dinner on the pitch of Real Madrid’s Santiago Bernabeu stadium

IABSE Future of Design 2014, 18th September 2014

Report by Thomas Prospert, Arup

The IABSE British Group hosted its 6th edition of the Future of Design Conference on September 18, 2014, at Imperial College London. The full-day conference aimed at inspiring younger generations of engineers and attracted an international record audience of 170 delegates. A series of inspiring presentations by some well-known keynote speakers such as Michel Virlogeux, project engineer of the Millau Viaduct, set the scene for what has been a highly applauded event.



Michel Virlogeux delivering his keynote lecture

Josef Hargrave opened, speaking candidly on the need for a 'cradle-to-cradle' approach in engineering. Phillip Hall-Patch and Francis Archer followed with their talk on the Garden Bridge, one of London's most high-profile and contentious construction projects. Julia Barfield, meanwhile, delivered an inspiring talk on Kew Gardens' Treetop Walkway and the Brighton i360.

Highlights of the late morning session included Keith Brownlie defining 'engineering Zeitgeist' as 'fashion, made possible by technology', Ralph Parker and Tim Lucas presenting on Heathrow Terminal 2's new 'Slipstream structure', and Mungo Stacey presenting passionately the engineer's value and status in the age of technology.

Following the success of previous editions, a Young Designers competition was organised to showcase innovative projects talented young engineers and designers have worked on. Having passed the scrutiny of the jury panel consisting of four industry experts, abstracts of 12 young engineers have been retained and the authors were invited to present their projects to what has been a highly engaging audience. Due to the high number of incoming abstracts, the competition was held in two separate rooms to accommodate more presentations. In a combination of jury as well as public votes, two winners, Audrey Zonco & Katerina Vatti, as well as two runner-ups, Anne Marie MacDonald & Prejay Patel, came out of the competition. Two distinguished panel discussions followed subsequently, debating the current engineering issues 'Ethics in Practice' and 'Designing London's Skyline'.

The successful event concluded with a drinks reception, offering delegates the opportunity to further network and exchange their views on what has been a very inspirational day. Delegates who decided to join the evening dinner were offered an exquisite three-course dinner at the Radisson Blue Edwardian Vanderbilt in South Kensington, which was particularly well attended and set a great stage for the close of a memorable day.

Journey to Success, Manchester, 16th October 2014

Journey to Success is an informal evening of discussion and debate about how to make a successful career in engineering. This is an opportunity to hear leading figures from industry reflecting back on their career and sharing their own personal story about their journey to success. The panel discussion is followed by a Q&A session, and then an informal dinner.



Journey to Success 2014 Panel Members. From left to right: Helen Gribbon (Reinassance) Claire Hall (Ramboll), Prof Paul Lambert (Mott MacDonald), Keith Gardner (Skanska), and Brian Duguid (Mott MacDonald)

The video of this event is available at <http://iabse.org.uk/journey-to-success-manchester-october-2014/>

Merchant Square Visit, 24th October 2014

Report by David Knight, Flint & Neill

The "fan" bridge (formally the Merchant Square Bridge) across Paddington Basin is a delightful expression of structure and engineering as a sculpture. Discrete in its service position, it opens theatrically to create a shape based on a Japanese fan and allow narrow boats through to mooring positions at the end of the basin.

This IABSE UK Young Members Programme site visit included illuminating talks from Martin Knight (representing Knight Architects); Daniel Bosia from AKT II, the structural engineers; Michael Thorogood from Eadon Consulting about the M&E engineering; and Mark Randerson from SH Structures who spoke about the fabrication and installation of the steel fingers. An impressive level of tolerance control (fabricated to within $\pm 3\text{mm}$) was achieved to ensure that the 20m span would fit within the existing canal walls and lock into stainless steel location pins.

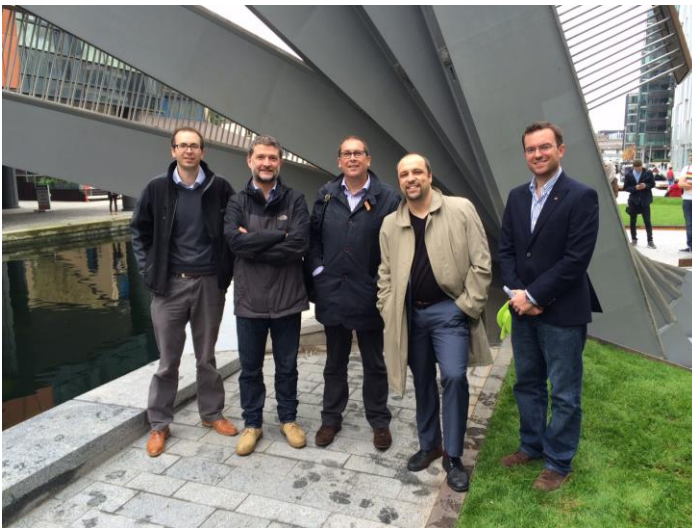
On a small structure, detailing is critical, and site visit attendees enjoyed discussing and critiquing some of the less obvious details. The bright green mechanical equipment provoked an enjoyable response, as did the way the counterweight sections created a set of steps in the open position. In particular, the conceit of labelling each counterweight with a machined value representing the weight enclosed was much admired!



Timed to coincide with the opening of the nearby Heatherwick/Packman Lucas Rolling Bridge, the visit showed off the cutting edge of opening bridge design. Thanks go to the design team for speaking knowledgeably and interestingly on the challenges and excitements of design, and particularly Tom Osborne (Knight Architects) for organising the visit.



The footbridge opens during the visit organised by the IABSE British Group



Project team by Merchants Square Bridge Project Team. From left to right: Michael Thorogood (Eadon Consulting), Martin Knight (Knight Architects), Mark Randerson (SH Structures), Daniel Bosia (AKT2), and Tom Osborne (Knight Architects).



Digital Design: A seminar to share the outcome of the IABSE Henderson Colloquium 2014, 3rd November 2014

The Henderson Colloquium was held from the 9th to the 11th July 2014 in Cambridge. Since 1975 the British Group of IABSE have held a two day colloquium in Cambridge every summer for about 25 invited participants. The purpose of the event is to exchange views on a structural engineering theme of topical importance. Each participant is invited to make a short presentation to trigger constructive discussions in the relaxed surroundings of Christ's College. The theme of the 2014 colloquium is Digital Design.

In order to disseminate the outcomes of this Colloquium, and to debate the key messages and areas for future focus, the IABSE British Group organised a seminar at the Institution of Civil Engineers last autumn. A very detailed report about this Colloquium is also included in this News.

Journey to Success Speed Mentoring – London, 20th November 2014

Report by Marcello S. Valerio Castelo, 4th Year Civil and Environmental Engineering Student, Imperial College London

As a final year undergraduate, one is overwhelmed with the vast amount of information given from companies and in career fairs about graduate programmes, charterships and career paths. Unfortunately, instead of serving as useful advice to pursue our careers and goals, these events and promotions eventually create a “jungle” like environment in which students are pressured to fight for the best “job” or “firm”. To my mind, this makes us to lose focus on what really is important for our future, from finding what we really like and how we can progress to achieve it, and neither Universities nor Companies really provide the means to know more about how this is done or how others have managed to achieve it.

When I heard about Journey to Success 3 (JTS3) - Speed Mentoring event, I instantly signed up. I have to admit that initially I was somehow sceptical about if it would be helpful as I had attended other “career events” in companies and none had ever been really clarifying. I am glad to now say that JTS3 was something else, something really inspiring. The “speed-mentoring” format was a real success. I had the opportunity to sit down face to face with four very experienced engineers to discuss my aspirations and the paths they took in their careers. The most important aspect of the event was its informal approach, which allowed me to really feel at the same level of my mentors when sharing my thoughts. Being able to get advice from excellent engineers was not only priceless but very motivating and inspiring. They really provided me with a different vision on how one can pursue his passion and personal goals in the Civil Engineering industry. I was very pleased to see the initiative that IABSE and my department at Imperial College have taken to promote these mentoring encounters. In my view, these are the kind of events that really can drive the success of young engineers by giving them the key decision tips that can enlighten their paths towards their professional and personal objectives.



Henderson Colloquium 2014 Summary Paper - Digital design

Report by Ed Clark, Arup

Introduction

Since 1975 the British Group of IABSE have held a two day seminar in Cambridge every summer to exchange views on a structural engineering theme of topical importance. This year's Henderson Colloquium looked at the impact of digital tools and technology in construction. Delegates included engineers, architects, contractors and academics.

The emergence of digital technology has undoubtedly influenced the way we work and the skills that we need to have. It has led to great opportunities in terms of design creativity, complexity and efficiency. However, we are faced with daily challenges about how to get the best from these tools. The pace of progress is rapid and leads us to question how the construction industry prepares, evolves and adapts for an increasingly digital future.

The discussions at the colloquium were wide-ranging and covered the following key subject areas:

- parametric modelling
- design optimisation, visualisation, and documentation
- design collaboration
- construction automation
- the impact of big data and open source design
- the impact on education, training and skill development

The purpose of this note is to summarise the outcome of the colloquium and is not a full chronological record of the presentations and discussions. Some topics of conversation generated a consensus of opinion amongst the delegates, whilst other subjects led to a range of views and constructive debate. There are few definitive 'right answers'. The output from the event is therefore not a fully defined road-map for the future, but rather a starting point for further development.

What do we mean by digital design and how does/can it help?

In broad terms the term 'digital design' was deemed to include the use of computers in our analysis, design, documentation and construction process.

The digital revolution has been relentless for the past fifty years and continues to evolve. Over that period we have moved from a position of hand calculations and hand drawings through 2D CAD and the birth of finite element modelling to a position where digital tools and 3D modelling have started to become routinely used for much of our work.

We use these tools to carry out tasks more accurately and quickly than we would be able to do otherwise, and in some cases deal with levels of complexity that we could not do otherwise. Like the impact on society of the mechanical revolution in the 20th century we have embraced this new technology and the potential of what it can do for us to make our lives better. However, this enthusiasm by some is matched by scepticism in others. A wariness of the machine, a lack of trust and concern about the effect on us (our role, our ability, our enjoyment) by handing over control.

This raised the question of whether the use of digital tools can lead to a de-skilling within our industry. The reliance on computer modelling and analysis and the decline of hand sketching, hand calculation and the use of physical models might be limiting the development and application of engineering judgement and understanding.

A counter-position on this issue is that digital tools and techniques should be viewed just as an alternative rather than a replacement of more traditional analysis and design approaches. Exploring design alternatives through the use of digital models can be an equally valid way of learning how structures behave and developing our intuition. Computer models allow us to test solutions that we would not be able to assess by other means and these solutions can be both good and bad.



Complexity of design has become more affordable through the development of these tools and this can lead to overly, inappropriately, complex design solutions. Put simply, just because we can doesn't always mean that we should, and judgement is required to differentiate between where increased computing power is leading to a better output or just a more detailed understanding of a flawed concept. Strive for 'simplicity' not complexity.

Perhaps the term 'digital design' is in itself a fallacy as the power and responsibility for design choices still rests always with the designer.

There is however an acknowledgement that the cutting edge of development often lies in geometrically complex projects, but that these types of project make up only a very small proportion of the construction industry as a whole. It is felt that significant opportunity lies in the translation of the techniques and skills acquired on complex project being applied to more regular or conventional new structures.

For certain building or bridge typologies where the constraints are highly prescribed it may be possible to develop the level of standardisation and automation of design through the increased use of digital tools. Developing these tools in parallel with new construction techniques could have a big effect on design economy and buildability (speed and safety of construction) for these types of structures.

There is a real danger that this approach would lead to a homogenisation of design and a commoditisation of the design process where the designer is engaged more in the development of the process and the tools rather than the design itself. The alternative view is that by automating the areas of design that can be standardised would allow more attention to be focused on areas that ought to be bespoke, and that this could lead ultimately to better quality and more diverse designs. We have seen this for example in the design of sports stadia over recent years and it was felt that this approach could be developed more broadly within the industry.

The process of digital design. Challenges and opportunities.

There was a lot of discussion about the detailed process of using digital tools and techniques on projects both in terms of what to model and different approaches that can lead to benefits at different stages through design and construction. Emphasis was placed on an appropriate level of modelling at different stages to deliver genuine value and the pitfalls associated with trying to model too much or apply too much detail too early in the process.

The subject of parametric modelling featured heavily. The approach of building geometrically associative models using software such as Grasshopper/Rhino, Catia/Digital Project or Inventor/Dynamo to explore different variants of a structural typology, often linked to structural analysis and optimisation routines. It was felt that this type of approach offered great potential to develop creative design solutions and improve collaboration between disciplines but that there are a range of challenges in how these techniques are applied and implemented on projects.

One such challenge is that by defining parameters that are built into the model we are already constraining the range of potential solutions in a certain direction. It was felt that a level of 'fuzzyness' at the early stage of design is often helpful to the process and that it can be difficult to meaningfully build this level of freedom into a parametric schema.

Through the design process we need to deal with many parameters and constraints simultaneously. Building design was described as a 'wicked problem'. The relationship between different (often competing) parameters can rapidly lead to a very complex schema where it's difficult to determine what parameters are, or ought to be, driving the solution. Digital spaghetti. This can result in the emergence of design variants that are hard to evaluate intuitively in terms of performance and quality.

Another difference that was highlighted between this type of approach and more traditional design techniques is that the output emerges late in the process. A 90% complete Grasshopper model doesn't look like much. This makes on-going critical feedback of design development difficult and limits the time available to explore alternative directions if the output is not satisfactory.

There were also challenges identified with using this type of approach as part of a collaborative design process with a wider project team as shared ownership of the model can be difficult. Through the example projects that were presented it became clear that this had been overcome most successfully amongst design teams who had worked together for a long time and across multiple projects (often Arch-Eng multi-disciplinary offices).



In these cases the teams had developed well defined processes which suited the requirements of individual team members and which were repeated and evolved with each new challenge.

Several proposals were made to address the issues described above. These included the importance of careful planning. Taking time to design the process through which you will design the design, and by carefully choosing the tools and appropriate level of modelling complexity for the specific challenge.

Keeping things lightweight for as long as possible was also seen as important. Starting with simple models and growing the complexity through the design process as the key drivers start to become better understood. This approach might include limiting the number of parameters rather than trying to satisfy everything at once, and being prepared to relax certain criteria as a way of achieving convergence and evaluating the relevance of different constraints.

Aligned with this simplicity of modelling is the use of tools that will yield approximate but quick feedback at the early stage of design. Heavyweight verification tools saved for the detailed design end of the process. This will allow us to speed up the process of conceiving, testing and judging multiple solutions. A view that it was often more valuable to target a broad understanding of multi-disciplinary optimisation than detailed single-disciplinary optimisation at concept stage. Breadth over depth.

The use of 3D printed models was also seen as a useful tool for communicating, sharing and qualitatively evaluating design options. The quality of 3D printers has improved rapidly and it is now very affordable to print small scale models, making this technology accessible to many design and engineering practices.

Some of this guidance was also felt to be relevant later in the design and documentation process and the adoption of BIM. Limiting digital documentation to design intent modelling rather than full BIM (building information modelling) was encouraged until the design development is far advanced. Until the design jelly stops wobbling don't do BIM. The reasons for this are to minimise abortive work that can result from trying to model in too much detail and embed too much data into the BIM model too early. BIM inevitably forces a level of geometric constraint which is essential during detailed design coordination but can hinder progress upstream.

However, during construction and further downstream complete BIM models will become increasingly important and seen as the main deliverable to the contractor, overtaking the production of 2D drawings and traditional specifications, and communicating not just the building geometry but as much embedded data as possible. Whilst there are often still good reasons for producing 2D documentation (contractual requirements, ease of checking and ease of use on site) it may not be long before a BIM model is the only design deliverable.

It is also likely that with the increase in computer numerical control (CNC) fabrication more and more elements of buildings will be manufactured directly from the digital model. This will potentially lead towards increasingly componentised construction and more off-site manufacturing, and/or the increasing use of automated construction tools on-site (robots, drones). These CNC fabrication techniques are also expected to extend beyond the currently available cutting, milling, drilling and welding tools to include the 3D printing of final components and automated installation.

Digital models are already being used during the manufacturing and site phases of a project to optimise overall construction sequencing and logistics. One potential next step with this 4D modelling is to look at processes in more detail (for example the sequence of fixing reinforcement in congested areas) or to model multiple scenarios that can adjust real-time in response to changes which occur on site.

What do we need to know or learn to evolve the practice of digital design?

Twenty years ago digital tools were both expensive and complicated. The availability of 3D modelling and parametric design software was limited and typically had not been developed for construction industry, making it difficult to apply. Structural analysis and design software was also much more limited in its capability and ease of use. As a consequence of this the adoption of digital design processes in the construction industry has had a slow uptake and for a long time was practiced only by small groups of expert super-users.



In recent years the availability and development of digital tools has improved hugely. Whilst this has led to an expansion of skills and increased awareness within the construction industry (particularly around BIM), the uptake of digital design in its broadest sense can still not yet be considered as main-stream.

Why is this? The following issues were identified:

Adopting new design processes can lead to opportunity but can also carry risk. It was felt that those in charge of running projects were often not those most engaged in the first hand use of design tools. This lack of understanding amongst senior people can either lead to an unwillingness to adopt the new technology, or to a situation where the project leader is unable to guide or assess the effectiveness of his/her team or the quality of output. Improving awareness and knowledge of senior people was therefore seen as important. The bosses need to know what the geeks are doing.

There were also discussions about the emphasis placed on the teaching of digital design at undergraduate level. Of course this varies a lot between different engineering and architecture degrees (although architecture graduates are seen as often having more advanced skills in this area) and between different universities. However, it was generally felt that more should be done to prepare students in this subject.

There are of course barriers to be overcome. For example, how to make room in the undergraduate syllabus? If not part of the core syllabus then certainly electives for programming / digital technology application need to be promoted.

This also raised the question of exactly what should be taught in terms of specific modelling software (Rhino, Grasshopper, Dynamo etc...) or specific programming/scripting languages (Python etc...)? Overall it was felt that the choice of specific tools was less important than the development of a general programming logic, modelling mind-set and an openness to working this way. A common language.

Tool-making was also seen as a higher order than simply tool using. The ability to customise software and link applications together to solve specific problems. As digital tools have developed a lot of emphasis has been placed on the ease of user interface. The intuitiveness of the iPad, for example. This was seen as both good and bad. Whilst it allows greater accessibility to a wider range of users it also insulates the user from the code underneath. This trend was therefore seen as potentially restrictive to progress.

It was also acknowledged that the practice of digital design requires these new skills to be additive, not to replace, the existing core skills of engineers and architects. It may require us to re-evaluate the roles and responsibility boundaries on projects and to bring in new expertise where required. For example, it's not always obvious who should be responsible to defining and owning the geometry on projects. Architect, engineer, mathematician? It's also rare to find high design and computing skills in one person, and perhaps we should be more open to recruiting some of these additional skills from other industries (the gaming industry for example).

Opportunities and barriers to future development.

Beyond the specific challenges of implementing digital design on projects and developing the required skills, there were a number of key issues identified that may have a big influence on the way digital design evolves in the future.

The first of these is the ultimate goal of collaborative design and whether this leads towards a fully integrated system and common platform.

Our ability to efficiently share models and digital data between disciplines is critical and is still platform specific despite advances in interoperability over recent years. During the design stage of projects it is sometimes possible to agree the use of common modelling platforms between different disciplines, particularly in multi-disciplinary design offices. However, and of critical importance, the contractor is often required to adapt to a new scenario each time and has little influence in the way data is managed at the early stages or how it will be issued. This inevitably leads to an inefficient process and one that can be improved.

The processes for transferring data between platforms are often self-taught with very little standardisation. It was felt that establishing more rigorous protocols might be one way of improving the efficiency of sharing information and would prevent project teams re-inventing the wheel each time.



It was recognised that the ability and willingness to share model information directly between designers and contractors is influenced by the way projects are procured. There exists a pressing need to solve issues of both data reliance (indemnity vs. responsibility) and data compatibility. Alliancing and other partnering agreements were seen as potentially most conducive to improving this situation.

There were a range of views expressed about the feasibility and advantages of striving towards one common platform and suite of tools. Whilst this would clearly simplify data transfer, there were obvious concerns about getting locked into one system and one software supplier. Many of the challenges that we face are unique and require bespoke rather than generic solutions. Maintaining the flexibility to use different and customised tools and techniques was seen as important. It was suggested that rather than striving for a common platform perhaps we should be striving for common data.

Another key discussion was around the potential advantages of collective or open-source design. Open design is the development of solutions through use of publicly shared design information and involves the making of both free and open-source software. It was felt that the sharing of tools, models, computer code and intelligence across the industry could significantly accelerate progress and uptake of digital design. It was recognised that there are significant issues around authorship, intellectual property rights, commercial advantages, reliability and legal responsibility for this shared information. Whilst it will be difficult to quickly overcome all of these barriers there was strong consensus that this should be a focus area for the industry.

Aligned to open-source design is the use of big data in design. The ability to incorporate the results of more sophisticated analysis or real-world monitoring data into our designs through the use of digital tools. This might include the collation of demand and response data from completed buildings and structures which could be used to improve the efficiency of future projects. Described as striving for post-occupancy evaluation pre-construction. The use of big data has been fundamental to other industries and branches of scientific research for many years and we are only just beginning to see how this can be used to improve the quality of our designs.

Adapting for the future inevitably involves learning from the past. At the end of a project looking back and asking “how could we have made the process more efficient with the tools that we had?” It’s also about looking sideways to see where we can learn and share our knowledge with other industries, our competitors and our collaborators. This willingness to share knowledge was at the heart of the 2014 Henderson Colloquium, and although the topic for discussion was digital our ability to direct the future is most definitely human.

Two final quotes which were shared at the colloquium and had resonance with many of the delegates:

“The future is already here, it’s just not evenly distributed.” – William Gibson

“It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change.” – Charles Darwin.

Summary of Key Messages and Focus Areas

The following key messages generated a consensus of opinion amongst the majority of delegates and were considered as important focus areas for the industry:

- We need to broaden the use of digital design tools and construction techniques to a wider range of projects. The 99% of what we do, not just the 1% of ‘special’ projects.
- We need to strive for ‘simplicity’ not complexity.
- We need to develop the use of lightweight digital tools at the early stages of the design process and maximise the benefits of BIM at the latter stages of projects. Until the design jelly stops wobbling don’t do full BIM.
- We need to improve the awareness and knowledge of senior people to increase the uptake of digital design processes. The bosses need to know what the geeks are doing.
- We need to promote the learning of digital design thinking at undergraduate level and be open to recruiting these skills from other industries.
- We must be more open to the sharing of tools, models, computer code and intelligence across the industry to significantly accelerate progress and uptake of digital design.

**Delegate List:**

Ed Clark – Arup

Charles Walker – Zaha Hadid Architects

John Chilton – The University of Nottingham

Colin Jackson – Jane Wernick Associates

Chris Williams – The University of Bath

Stephen Melville – Ramboll

Tristram Carfrae – Arup

Julia Ratcliffe – Expedition

Iain Rowe – Calatrava

Lee Franck – Arup

Tom Osborne – Knight Architects

Alessandro Beghini – SOM

Francis Aish – Foster & Partners

Thomas Henriksen – Waagner Biro

Tim Lucas – Price & Myers

David Scott – Laing O’Rourke

Pete Winslow – Expedition

Alvise Simondetti – Arup

Tristan Simmonds – Simmonds Studio

Max Arrochet – Amanda Levet Architects

Sven Plieninger – Schlaich Bergermann und Partner

Mark Burry - RMIT

Ian Firth – Flint & Neill

IABSE Future of Design 2014 – Winners



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A three-core high-rise in Paris



As a civil engineer and architect, Audrey loves to draw, design and calculate.

She worked in bi-cultural offices in New-York, before joining Setec where she managed the Court project from competition to construction. She also gives classes on prestress calculations.

Keywords: *Highrise, PPP, Pre-stress, Concrete, steel, construction phase analysis*

1. Introduction

The Future Paris Law Court is under construction. The project is a 160m high rise designed by Renzo Piano Building workshop and was carried out as a Public-Private-Partnership (PPP): the building is built by the Private Partner Bouygues, maintained by the private Partner Exprimm during 27 years, before being returned to the Public Client, the EPPJP.

The design competition started in August 2010 and the building will open in June 2017.

2. Content

This highrise has very interesting particularities:

- With a width/height ratio of 13, it is very slender and required wind tunnel testing.
- Due to its 150m long base, it was split into three structural blocks, having their own central concrete core. In order to prevent transversal differential movement, while allowing longitudinal displacement, we came up with an ingenious mortise and tenon connection in plan in the slabs.
- Specific 3D geotechnical studies were carried out to quantify the effect of the ground settling under one core relative to the other cores, and to the surrounding buildings.
- The cores have various heights, so the wall thicknesses were adjusted in order to minimize the differential shortening under elastic strain, creep and shrinkage.
- On terrace levels 10, 20 and 30, in order to suppress peripheral columns, transfer cantilever floors were designed in prestressed concrete.
- This project was the first big scale project of our firm to be entirely modeled in 3D with REVIT, as a tool to coordinate with the other partners, and to produce structural drawing plans.



3. Conclusions

Behind the classic design of the building, are hidden several thrilling engineering issues. Close cooperation between Setec and the Architect resulted in a well-balanced, sound, and elegant structure.



King Abdullah Petroleum Studies and Research Centre Design and Engineering of Tensile Fabric Canopies

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As a tensile fabric structures engineer, Katerina's responsibilities are to develop form finding for scheme design in close collaboration with the architect and client, as well as to perform membrane stress analysis, structural analysis and design of supporting structure.

Keywords: *Tensile fabric structures, membrane stress analysis, structural analysis, canopy cells*

1. Introduction

Tony Hogg Design (THD) was responsible for carrying out the detail design and engineering to achieve Zaha Hadid Architect's vision for covering the central courtyard of the research centre (KAPSARC) with fifty unique fabric canopies. The Architect's inspiration of producing an organic form to tie in with the desert landscape in Riyadh, Saudi Arabia, has generated many interesting challenges in the engineering and design of the canopy cells.

2. Content

There are fifty different canopy cells covering an area of 9,550m² between the main buildings. THD was involved in the initial meetings to establish the form and shape of this hybrid conic and inverted conic canopy cell. Each cell has a unique geometry to respect the organic nature of the project and therefore a separate analysis was required for each one. THD was provided with wind tunnel test data to evaluate the applied loads on the structure. Each canopy is composed of an upper and lower PTFE glass fibre membrane in order to conceal the supporting steel structure in between.



Fig.1: KAPSARC model by Zaha Hadid Architect's



Fig.2: Some of the canopy cells during construction

Membrane analysis was performed by Tensys consultants in conjunction with THD. Problems such as high stresses due to tight curvature of the supporting steel resulted in changing the geometry quite a few times. Structural analysis and finite element analysis of components was performed using Bentley software. This project has challenged our engineering knowledge by solving complex problems such as cranking steel beams to avoid clashes with fabric, extensive 3D modelling for the production of fabric fittings to fit the non-planar geometry of the canopy cells, and the development and testing of a unique fabric in order to comply with the client's specifications.

3. Conclusions

This project has been an exciting journey of challenge and learning, resulting in a great outcome through the collaboration between the architects and the engineers. Tensile fabric structures can be part of innovative and sustainable buildings of the future, due to their adaptable nature and fascinating aesthetical appeal.

IABSE Future of Design 2014 – Runners-up



King's Gate House & The Zig Zag Building

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Ann Marie studied Civil Engineering at Queens University of Belfast, where she completed her MEng in 2012.

She then joined Pell Frischmann's Geotechnical Engineering team in London, where she has been involved in a variety of structural and geotechnical projects.

Keywords: *London Underground Limited, Extensive Excavation, 2D Finite Element Analysis, Ground movements, Monitoring.*

1. Introduction



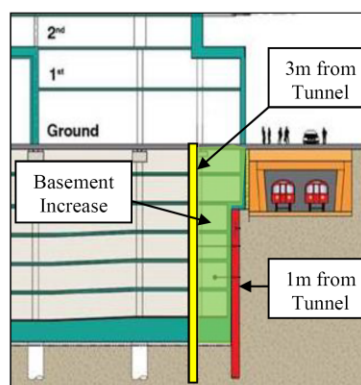
Pell Frischmann was commissioned by Land Securities in 2010, for the redevelopment of Kingsgate House, London.

This mixed use scheme will replace Kingsgate House, a gargantuan ground scraper which was occupied by UK Trade and Investment, with two new mixed use buildings. The scheme involves extensive excavations and the construction of a basement next to the existing London Underground Limited Circle and District line, which runs close to the northern boundary of the site.

2. Content

Due to the extensive basement excavations (approximately 20m), it was challenging to receive approvals for construction from London Underground Limited, as extensive ground movements would be unacceptable to them for operation of the tunnels.

In order to protect their assets London Underground Limited normally restrict all ground works taking place within 3m of their assets. With the scale of our development however moving to a 1m perimeter dramatically increased floor area by 1000m² and thus increasing the value of the project by £3,750,000.



By using a powerful 2D Finite Element analysis to estimate the ground movements, we were able to convince London Underground Limited that we would provide adequate asset protection and consequently won approval for construction of a secant pile wall 1m from the London Underground Limited tunnel. This approval was given on the basis that an extensive monitoring regime would be carried out, which we also specified. Monitoring included total station monitoring of the London Underground tunnel, manual external monitoring of the secant pile wall and inclinometer monitoring of the secant pile wall. All movements were agreed with relevant parties and monitoring data was checked regularly to ensure the movements were not exceeded.

3. Conclusions

The basement construction of this building has been completed successfully and demonstrates that for the future of design we must not be afraid to challenge and push the boundaries set by others.



Structural Meso-Scale Bone Remodelling of the Pelvis

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Keywords: *Pelvis, Finite element, Bone remodelling, Adaption, Simulation, Biomechanics, Structures, Mechanostat.*

1. Introduction

An accurate, efficient and comprehensive computational musculoskeletal model, would be of great importance in understanding the response of a bone structure towards system changes.

Specifically, the Human Pelvis was chosen, due to the irregular shape, the vast number of muscles and ligaments associated and common fractures which bear a 6.3 to 8% 10 year survival rate (van Dijk *et al.*, 2010).

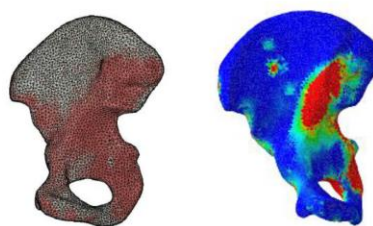


Fig. 1: Pelvic finite element mesh. Left, trabecular structure, Right cortical shell structure

2. Pelvic Model

The pelvic mesh was formed by CT scanning a pelvic model (used within the medical industry). This data was post processed into a 3 dimensional mesh, and imported into ABAQUS®, with the outer cortical bone represented as shell elements and internal trabecular structure as truss elements.

A total of 18 lower body muscles and 6 ligaments were included in the pelvic model. The muscle loads were extracted from OpenSim, and provided time dependant force vectors based on the activity.

Bone remodelling is the construction or deconstruction of bone matter. This was implemented within the model, via the Mechanostat concept, in which bone structure adapts to stay within a strain 'lazy zone'. If strains are greater than this zone, bone matter increases in size, and vice versa.

Within the model, three common activities were applied, walking, going up stairs and sit to stand. The model was iterated to a 99% convergence (based on change of bone structure).

Validation of the model was undertaken by comparison with CT scan data. The CT scan data was able to accurately obtain the external cortical bone thickness and internal trabecular bone structure.

3. Conclusion

The computational model accurately predicted the fracture locations that commonly occur within the human pelvis. The cortical and trabecular structure was accurate within the lower half of the model, concluding the importance of upper body muscle inclusion, requiring further investigation.

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