Henderson Colloquium 2014 Summary Paper

DIGITAL DESIGN

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 simplexity 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 CNC fabrication more and more elements of buildings will 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 new technology, or to a situation where the project leader is unable to guide or assess the effectiveness if 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 of 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 form 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 is 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 Gibsen

"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:

1. 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.
2. We need to strive for simplicity not complexity.
3. 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.
4. 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.

5. We need to promote the learning of digital design thinking at undergraduate level and be open to recruiting these skills from other industries.
6. 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 Architets
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 Arrocet – Amanda Levete Architects
Sven Plieninger – Schlaich Bergermann und Partner
Mark Burry - RMIT
Ian Firth – Flint & Neill