1 THE 'PINK NOISE' OF DESIGN ENGINEERING

HANIF KARA

The boundary and border of architecture and structural engineering have traditionally been defined by a linear and hierarchical correspondence between the two disciplines. Professionalisation of both disciplines has created a pre-articulated routinisation of the practices and distinct processes where the architect develops insights in design, while the structural engineer is granted exclusivity to react only once the design is developed. Today both are required to develop new skills and competences if they are to survive. In response to cultural and technological developments in the last twenty years, this relationship has evolved significantly, changing economic orders (where rising wealth has increased the importance of aesthetics) and, more recently, presenting new opportunities to question 'planned obsolescence' of buildings through the reshaping of design disciplines.

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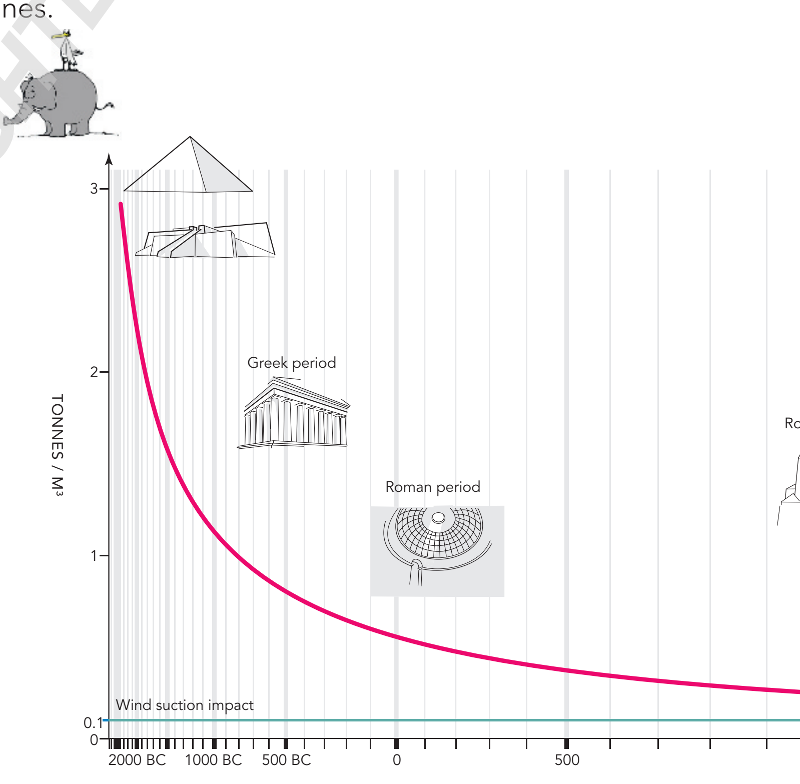


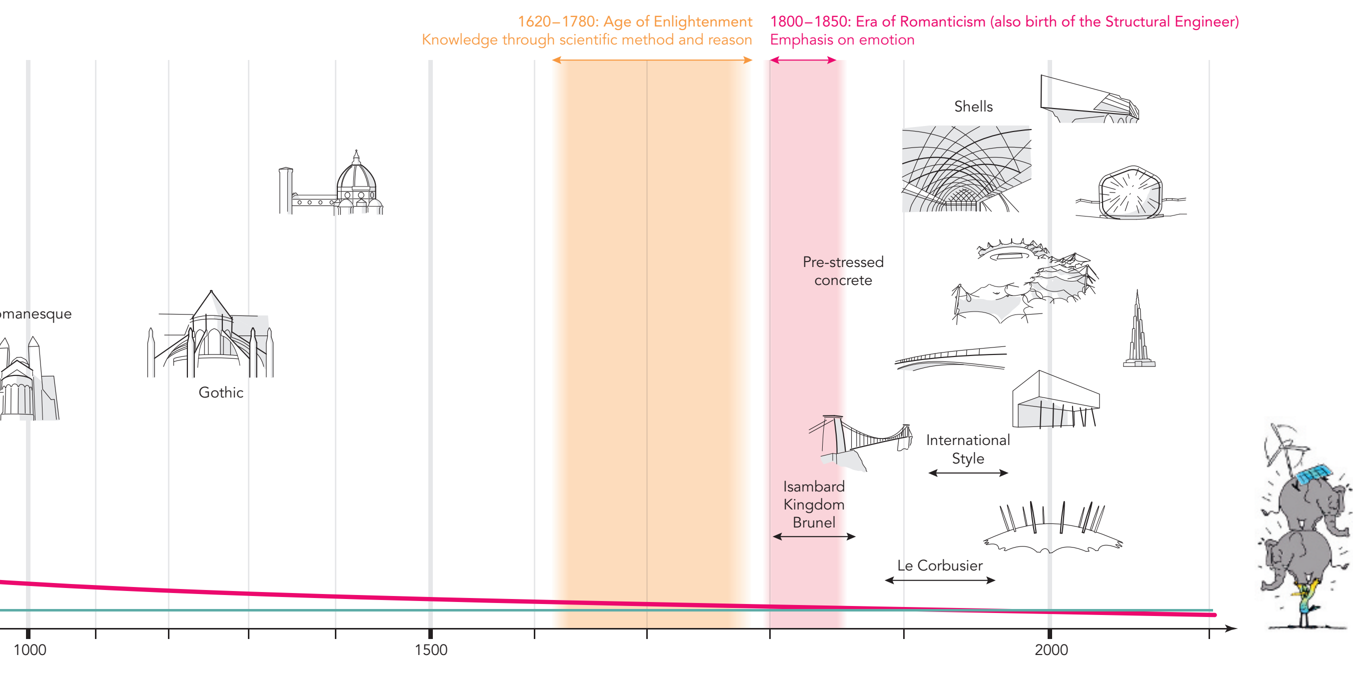
1 AKT II, birth of the structural engineer (c 1800).
Birth of the structural engineer and their position in the wider spectrum of architectural design discipline and history (which transcends our discipline).

The complex, changing relationship between the two disciplines cannot be explained easily, and any historical appraisal of the shifts could start in many places; we must therefore select the starting point of such a narrative carefully. Over the last century, the most compelling spark to questions concerning the dichotomy between 'architect' and 'engineer' as designers came from Le Corbusier in 1927, when many believe he asserted that the process of engineering should drive the development of architecture:

> 'Engineers make architecture, since they use calculations that issue from the laws of nature, and their works make us feel HARMONY. So there is an aesthetic of the engineer, because when doing calculations, it is necessary to qualify certain terms of the equation, and what intervenes is taste. Now when one does calculations, one is in a pure state of mind and, in that state of mind, taste follows reliable paths.'[1]

While one cannot agree with all of the implications inherent in Le Corbusier's prescient statement, it was a strong encapsulation of the prevailing feelings of the time, and we can clearly trace their trajectory and legacy through the Modern and Post-Modern architectural movements, as exemplified by influential figures such as Ludwig Mies van der Rohe, Louis Kahn, Tadao Ando and Team 4 (Norman Foster, Richard Rogers, Su Brumwell and Wendy Cheesman), who each pushed for greater parity and collaboration between the two disciplines.

In subsequent decades, this cultural realignment was reinforced by profound changes in the field of structural analysis. Despite



1 THE 'PINK NOISE' OF DESIGN ENGINEERING 14-15

2 AKT II, evolution of reinforced-concrete design codes of practice.
These codes have evolved since 1930, they assess how factors of safety, combined with new analysis, allow the reuse of old structures.

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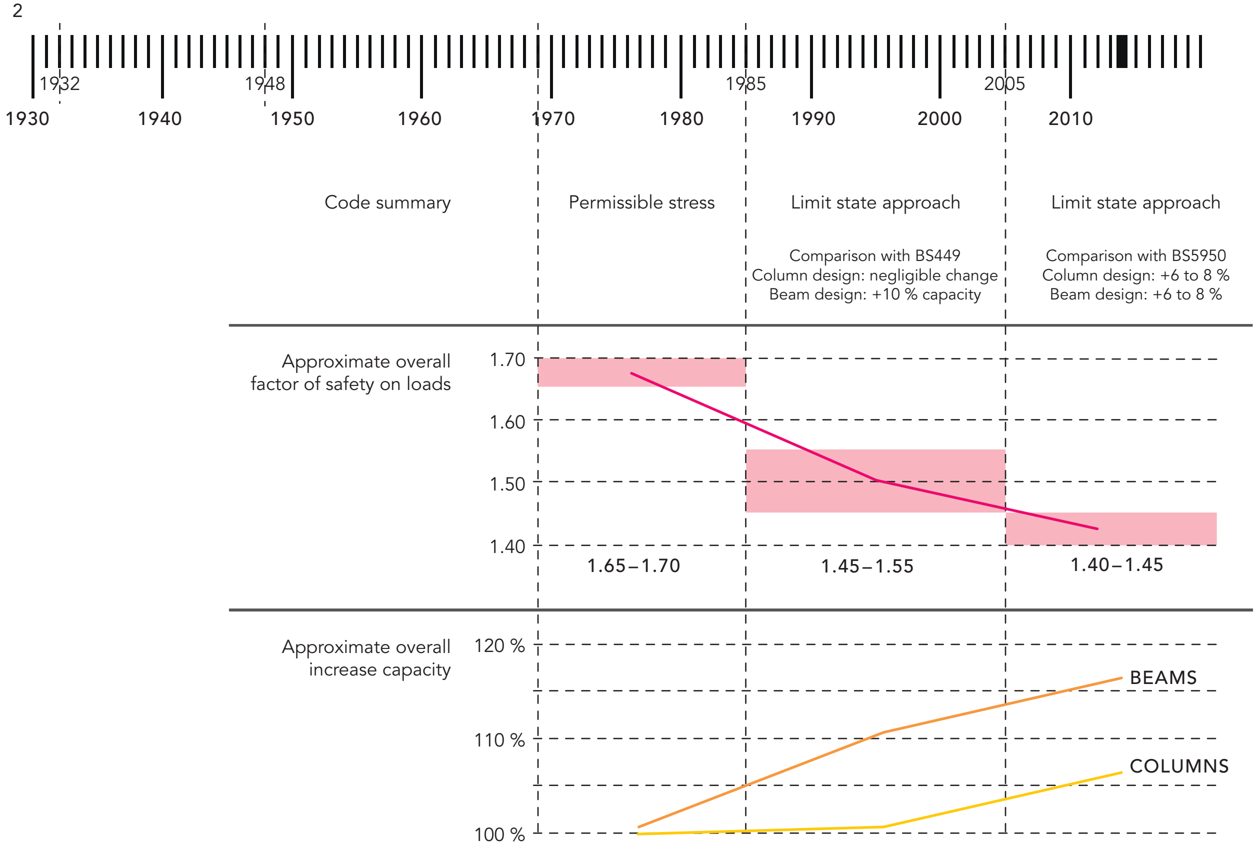

the crippling effects of the Second World War slowing progress in many areas of construction, a significant turning point occurred with the birth of the first threads of 'limit state methods'. Driven by the greatly reduced availability of materials post-war, early experimental work in structural engineering conclusively demonstrated that analysis of stresses computed with simple elastic theory was far removed from how structures behaved, and from this emerged the concept of 'plastic limit states' that would erode and, in some instances, decompose factors of safety.

Though the gulf between the design of steelwork and reinforced-concrete structures remained, limit state methods advanced both materials. Notably in the UK between 1936 and 1948, the engineer John F Baker developed plastic theory for the design of steelwork, indeed it was used for the design of Morrison shelters during the war. While these methods are no longer used for simple structures today, the principles can be used for any buildings.

Meanwhile, in 1955 in the USSR, Professor NS Streleski developed methods of limit state design[2] that led to the introduction of the first codes in reinforced-concrete design using ultimate limit state method to reduce safety factors in concrete states (Figure 2). And, though not widely used until 1965, this has led to economical structural designs.

Such advances inspired new confidence that can be seen in the work of a long line of engineers since then; people such as Ove Arup, Ted Happold, Felix Samuely, Tony Hunt and Fazlur Khan, Cecil Balmond, Mike Schlaich, Jürg Conzett, Klaus Bollinger, William Baker and Peter Rice, all went on to broaden this incipient trend in the hope of spreading the value of a 'creative collaboration'. Most significantly, Rice famously urged engineers to 'imagine' and temper the use of pragmatism to escape the characterisation of engineers as 'Iagos'.[3]

THE PRESENT CONDITION AND REDEFINITION OF DESIGN ENGINEERING

Today's fertile atmosphere provides a novel condition for the specific relationship between architects and structural engineers, as both disciplines try, breathlessly, to keep up with the pace of change. During the early 1990s, newly awakened powers of observation and increased skill in representation encouraged both disciplines to 'peek' into each other's work again in search of perennial reinvention. At the height of this period, the boundary between uniquely human creativity and machines' capacity for pattern-recognition and complex communication marked a new confidence, offering freer movement between the two disciplines, and between design fabrication and construction. As both platforms and protagonists, leading structural engineering design offices, design schools and educators play a big part in this dance of the disciplines. What was noticeable in the first 'wave' (1990–2000) is that architects, in response to the popular imaginations of their consumers, were increasingly expected to exemplify with each project a 'newness', 'cheapness', 'particularity' or 'uniqueness' for the production of 'one-off' creations (often formerly unimaginable forms) that avoided universality. Meanwhile, other abundant productions of architecture, such as housing in emerging markets, continued – due to rapid urbanisation – with very little design and often without architects.

At the height of this trend, in his controversial thesis of 2002, Stephen Wolfram even stretched the traditional approach of computation, through mathematics and engineering, to empirically investigate computation for its own sake. Though seen by many as an 'abrasive approach', it did give valuable insights and observations: 'Whenever one sees behaviour that is not obviously simple – in essentially any system – it can be thought of as corresponding to a computation of equivalent sophistication.'[4]

The opportunities for structural engineers and technologists to support the endeavours of architects expanded in response. It is clear that initially, to a greater or lesser degree, even structural engineers were guilty of being stuck in a tectonic discourse, often using the same technologies to produce inanimate aesthetics driven by the latest software, prestige and abundance of resources, sometimes fuelled (in part) by undiscerning constructions in developing economies.

Simultaneously, this expanded opportunity allowed some engineers to grow their own disciplines freely, encouraged by the extraordinary freedom to ransack the software chest in search of the thinnest glass, shallowest curve, longest span, and so on. While such expansion has to be tolerated, in many cases it resulted in architects and structural engineers working in an atmosphere of unclear thought and sensory profusion, encouraging the self-sabotage, gimmickry and posturing of so-called 'archineers' and 'engitects' (Figure 3). At the start of any new-found freedom is a 'big bang' effect, setting free a certain amount of pent-up demand. The Beijing Olympic Stadium is an example of this; looking back at this new structural wonder, one has to question its provocative deception in the use of steelwork – a 60 mm x 2 mm strip that could wrap around the globe three times. In hindsight, we believe this approach failed to engage with the larger, more fundamental behavioural changes on offer to us as designers.

3 AKT II, prism.
In present-day practice, technology and specialisation have proliferated the process of design to an extremely 'thin slicing' of architecture. We hark back to previous traditions in the work shown here.

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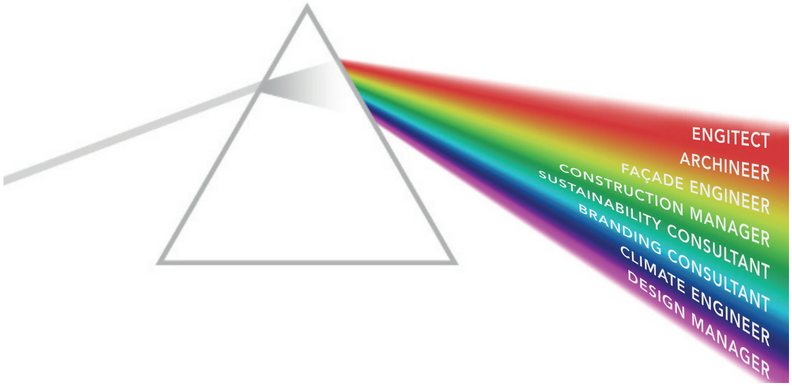


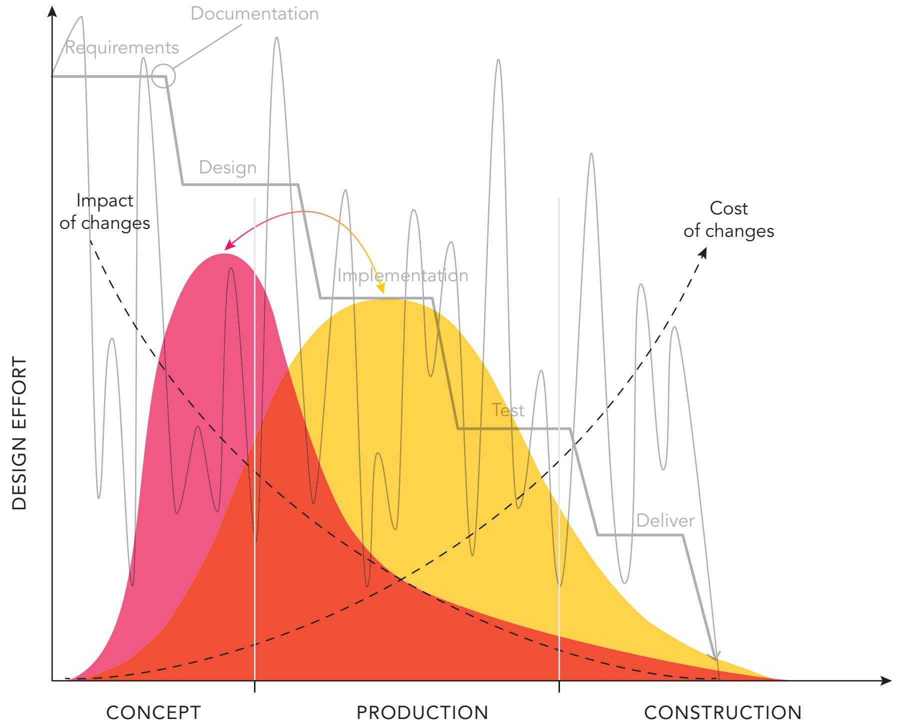
THE DESIGN ENGINEER AS PRACTITIONER

To be most productive in this new paradigm, we chose to synthesise the making of buildings at one extreme, and engagement in the discourse of design at the other, allowing us to practise our own 'behavioural design engineering' that incorporates aesthetic, linguistic and technological spaces within practice. This approach takes on a more comprehensive and universalist interpretation of design than that circumscribed by normative disciplinary behaviour of the structural engineer, while keeping in mind preceding successes and failures. Building a practice that can tune in to this behaviour has encouraged significant creative achievements.

On the subject of aesthetics, for instance, we saw clearly that the traditionalism of our discipline had led it to be perceived as polarising, as too reliant on finite technologies that give binary answers, and overly decisive in practice. The first challenge for us has been to banish these perceptions, and to increase acceptance that design, from an engineering perspective, is as much a visual subject as a scientific one. It requires a long and deep immersion in our own discipline, but also an appreciation of when that discipline ceases to be appropriate in the creation of the best buildings. This requires both engineers and architects to engage in a forum of interaction, thought development, research and qualitative outreach, while avoiding 'switching disciplines' or 'crossing over'.

This particular stance allows us to re-engage with the architect and guards against premature optimisation by promoting engineering as a less than exact discipline, and by utilising a more unconstrained approach in which solutions are not determined by calculations alone. Such shifts engender a longer and more rewarding conversation between architect and engineer in which both parties are able to circulate and refine design options, freed from the spectre of the looming 'design freeze', representing a greater value to our immediate client.

In this endeavour we continue to be guided by the foundational engineering theories (the equilibrium of internal and external forces, a clear understanding of geometry and boundary conditions, and the knowledge of material properties). These are now supported by a more refined appreciation of the other disciplines involved, which fosters an interdisciplinary atmosphere able to take on the broadest agenda of design innovation.
Out of these changes we believe a new kind of engineer emerges: the 'design engineer'. Able to see a project in the architect's terms, but with the mind and eyes of the structural engineer, they produce holistic solutions that integrate all aspects, rather than residing in a particular system, element or tool. The design engineer's scope is no longer limited solely to the manipulation of building materials and processes, but incorporates technology, skills and knowledge of the dialectic relationship between nature and the superimposed built environment.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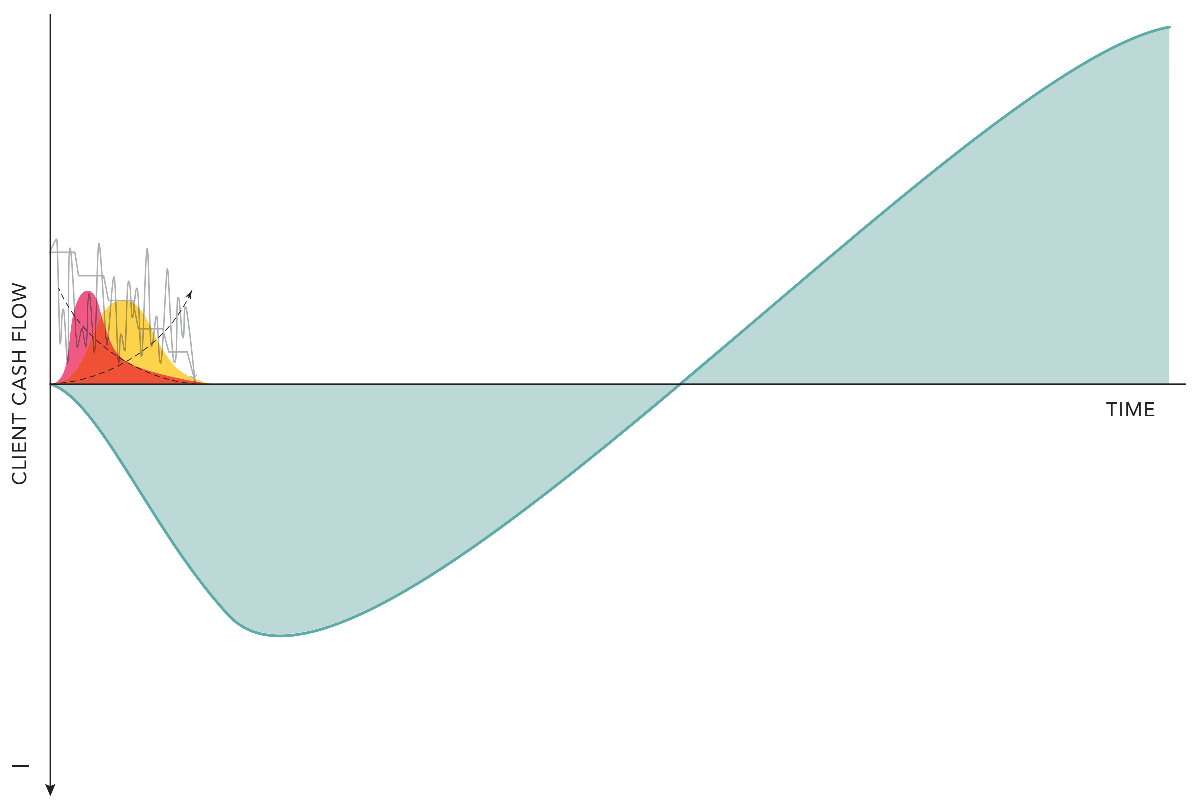
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Alongside these practical aspects, we also wrestle with the pedagogical implications. It is apparent that the current model for the formative education of structural engineers does not go far enough to develop design engineers, as it is based predominantly on scientific knowledge. It should be reformed around the 'creative design process', retaining ancient wisdoms while embracing new opportunities such as digital design and manufacturing techniques twinned with the brute force of computation, and a deeper understanding of natural and high performance materials through physical and digital testing. Yet this only scratches the surface of the possible implications: what role do codes of practice play? How does this affect the practice of structural design organisationally? Is the discipline sustainable?

PARS PRO TOTO

From the formation of the practice in 1996, we recognised that it was hard to turn insights in designs into engineering without dissecting existing models of practice and understanding the design value chain (Figure 4). This required us to combine a staunch 'for profit' endeavour with a 'non-profit' behaviour that would allow the one to fund the other. Within this model, one of our key responses to these disciplinary changes was to create a (not for profit) network inside the practice that we have called 'p.art' (applied research team) (Figure 5). As its name suggests, p.art was conceived as an integral element within the framework of AKT II; a flexible, multidisciplinary grouping with the abilities necessary to seek out and solve emerging design challenges,

4 AKT II, value of design and non-linear processes.
Diagram extended to show relationship between design and client's return value.

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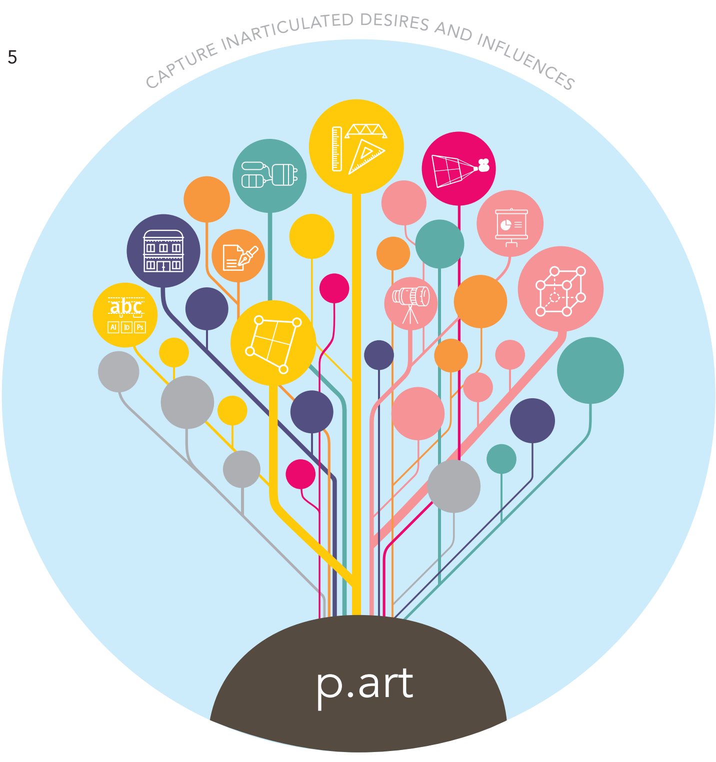

5 AKT II, p.art's role.
AKT II p.art's many activities funnel into a version of 'design engineering', taking on a new mandate of design practice greater than conventional disciplinary behaviour of structural engineers.

and to pass on those solutions to the practice as a whole. P.art fosters a discipline where we can no longer be merely mechanical or methodical, but have to bring to bear whatever skills will be needed in design, project by project. It no longer depends on conventional behaviour, but has to accommodate unarticulated desires and unnoticed influences on architecture (Figure 6).

In operational terms, the core of p.art is multi-faceted, comprising design engineers and architects, parametric designers and software developers, mathematicians and geometricians, graphic designers and writers. Other members, drawn from the wider pool of engineers, technicians and designers within AKT II, cycle in and out of the core team on a project-by-project basis, teaching and being taught new processes and techniques which they then disseminate within the rest of the company and beyond. In this way, the entire structure and remit of p.art avoids the 'siloing' of information seen in some of the early engineering industry forays into computational design, and ensures that they act as a catalyst for investigations between teams and companies, between academia and practice, and between design and construction.

While the size and composition of p.art ebbs and flows – responding to both the short-term requirements of individual projects and the larger cycles of industrial change – we maintain at all times a constant presence in academia, both through

6 AKT II, design research: scientific vs architectural endeavour (adapted from William Caudill).
We operate between these boundaries, keenly trying to combine cultural mystiques, imagery, science and new possibilities.

7 Foster + Partners with AKT II, Masdar Institute, Abu Dhabi, UAE, 2010.
The design and construction of the facade required a high-quality finish and complex computation.

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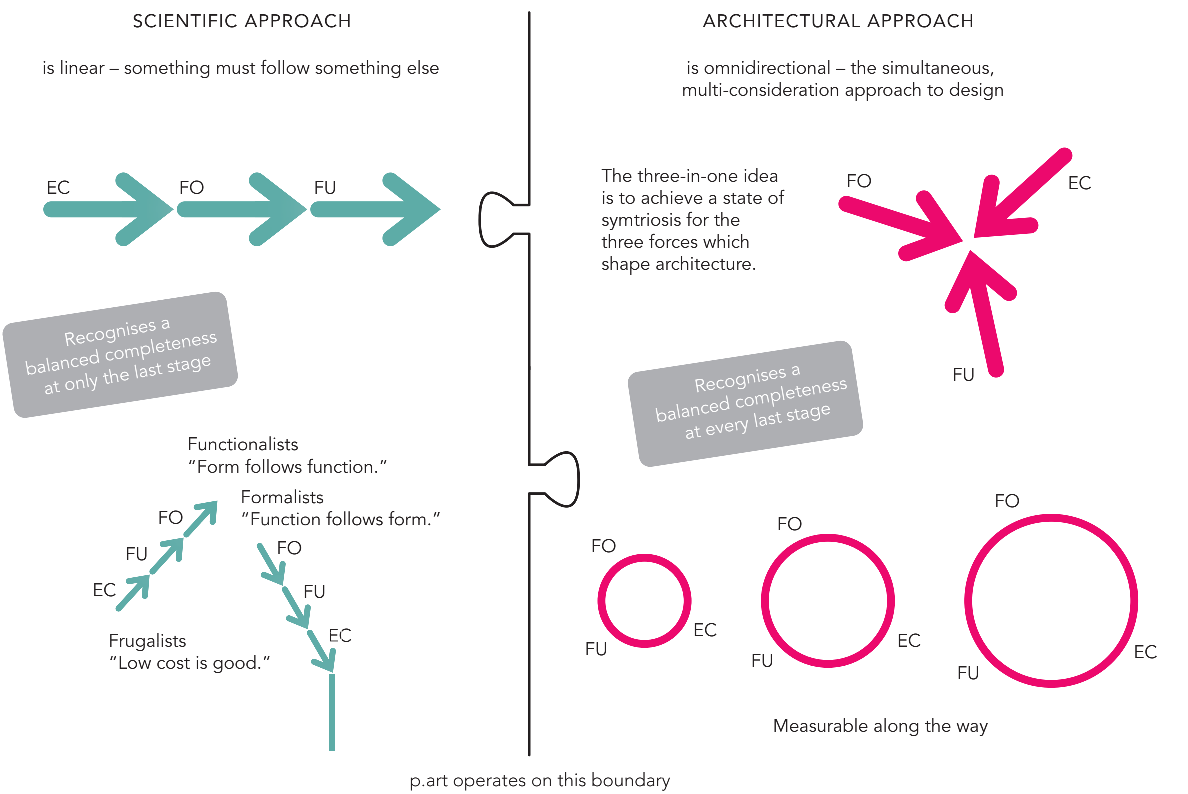

7


John Lewis
John Lewis
WELCOME
TO GRAND CENTRAL

8

8 AZPML with AKT II, Birmingham New Street station, Birmingham, UK, 2015. A geometry that designs a 'form' of complex geometry, extending the use of advances in software and the connections between digital manufacturing and design.

9 Asif Khan with AKT II, Radiant Lines installation, Melbourne’s Federation Square, 2014.
With Asif Khan, work such as this always requires the engineer to peek into other senses, such as light (as in this case) or sound.

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tutoring at a number of international design schools, and through selected partnership with material laboratories, postgraduate research, and so on.

The 'embedded' position of p.art within the practice has been critical in redefining what makes a design engineer in particular. By helping to clarify intent without relying on science and calculus alone, their expertise in specialist areas has helped us to deliver projects that bring to the foreground the role and value of design in engineering through interdisciplinary interaction, bespoke non-linear processes and the expansion of transitional convention between structural engineering and other design disciplines today. One of p.art's other roles has been to push the theoretical accuracy of calculation beyond certain limits in a proportionate manner that makes it useful on a project-by-project basis. Recognising the distinction between 'basic' knowledge and 'interdisciplinary' knowledge, this behaviour brings focused design engineering to each project, in different degrees, to act as the bridge-builder between disciplines.

SUSTAINING THE OUTCOMES THROUGH ECONOMIC CHALLENGES TODAY

Out of this invigorating and occasionally tumultuous history the selection of work documented in this publication has emerged: a wide-ranging, yet coherent, set of projects, each expressing a desire to escape ugliness at many levels and embrace those differences that ensure a productive relationship of greater creativity and utility, rather than of obviousness.

We have welcomed the opportunity to let outside voices – as well as members of p.art (past and present) and the wider organisation within – contribute to this discourse. In addition, and to enable a demonstrable outcome, we have taken a position that, whenever possible, stitches 'scientific research' with 'design research', given that scientists and engineers are largely dismissive of the latter.

The economic crisis of 2009 forced us to look back at the previous decade to find evidence of the value that has come from this recent development of our own practice. This was needed in order to continue building on the intelligence gathered to date and to discover whether the didactic air of the digital era cloaked some exuberance that we needed to remove. On one hand, the tools had been used as party tricks (colourful analysis dressed as design) for promoting design to a commercial level but removed from the source of good engineering. But on the other hand, as demonstrated by the Heydar Aliyev Centre project in Baku, the Masdar Institute (Figure 7) and Birmingham New Street station (Figure 8), bespoke tools have allowed us to deliver remarkable architectural visions, even in the most difficult and remote environments. The Radiant Lines project (Figure 9), the Bivak in Slovenia (Figure 10) and Hunsett Mill in Norfolk (Figure 11), are all projects that dissolved the boundaries between screen and workbench in their production and redefined approaches that deal with extreme environments with combinations of high- and low-tech experimentation. At another technical extreme, the Angel Building

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10 OFIS Architects with AKT II, bivouac, Slovenia, 2014.
GSD Harvard students: Myrna Ayoub, Oliver Bucklin, Zheng Cui, Frederick Kim, Katie MacDonald, Lauren McClellan, Michael Meo, Erin Pellegrino, Nadia Perlepe, Elizabeth Pipal, Tianhang Ren, Xin Su, Elizabeth Wu. Originally conceived to reach the site by 'drones', eventual construction on site used a conventional helicopter.

11 ACME with AKT II, Hunsett Mill, Stalham, UK, 2010, rear elevation.
Difficult site access exploited the use of easy to assemble flat-pack engineered timber, next to a traditional protected masonry building.

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12

12 Allford Hall Monaghan Morris with AKT II, BAM, Angel Building, London, UK, 2010.
An existing building that was transformed to set a new benchmark in what is possible by connecting complex analysis, new materials and an understanding of reinforced concrete.

in London used changes in codes, combining this with advanced composites to breathe new life into an old building (Figure 12).

In the case of the Heydar Aliyev project (Figures 13 to 15), we designed the frame with the most advanced analysis, but, in what could only be described as the 'height of sophistry', the final construction involved the use of a space frame, claiming to be more economical. Sometimes designers have to accept that a construction is not what is designed. On the face of it, Turner Contemporary (Figure 16) in the United Kingdom is perceived to require little structural engineering, but in contrast to Heydar Aliyev where the effort is explicit, many options had to be found to get to this apparently effortless conclusion using the same methods and tools.

Structural engineering retains an intrinsic value through remaining non-restrictive, mainstream and confident at its roots. In a world where design is now everywhere and everything is designed, the generalisation of the term 'design engineer', and the characterisation of what it implies in practice, has recently blurred the boundaries to a point where it has become 'general background noise' that is self-defeating, and homogenises what engineers can contribute. By selecting a narrower approach in this publication, we want to refocus design engineering onto what we call the 'pink noise' to distinguish it in the field, not claiming a status, but verifying a status claim (Figures 17 and 18). The fundamental premise of that status claim is born out of a behavioural change in our practice which acknowledges that

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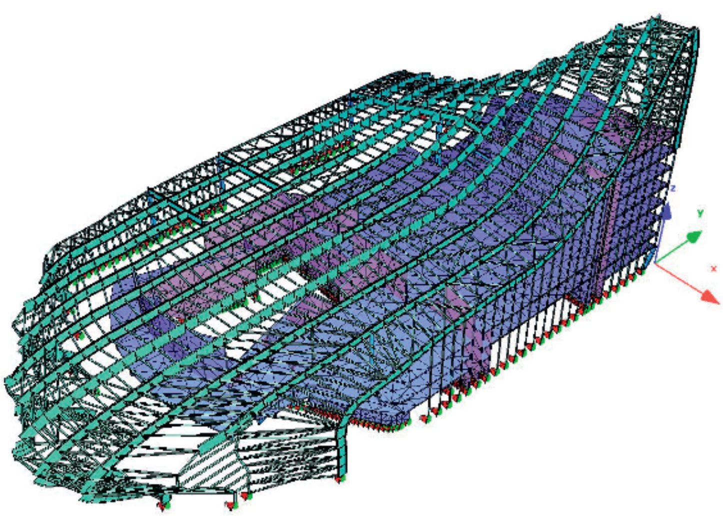

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13 Zaha Hadid Architects with AKT II, Heydar Aliyev Centre, Baku, Azerbaijan, 2012.
The completed building required advanced scripting methods and analysis for sensitivity in developing countries.

14 Zaha Hadid Architects with AKT II, Heydar Aliyev Centre, Baku, Azerbaijan, 2012, Heydar Aliyev Centre analysis.
The design was based on simplified linear frames to cope with the complexity of the facade. Facade tiles were optimised to maintain overall form but economy in manufacture and installation.

15 Zaha Hadid Architects with AKT II, Heydar Aliyev Centre, Baku, Azerbaijan, 2012.
Final construction introduced off-the-shelf space to construct a unique form, challenging the purpose of space frames.

16 David Chipperfield Architects with AKT II,
Turner Contemporary, Margate, UK, 2011.
Annual overtopping of the water required
careful modelling for extreme conditions.

16

architecture transcends engineering and can easily ignore, avoid or escape the space occupied by design engineering; but on the other hand, our particular version of design engineering is required to navigate the space occupied by architecture as a condition of its existence. We have to be cognisant of its success and failures, and resist the temptation of crossing into the realm of architecture in order to reinforce its position in 'specialised interdisciplinary' discourse. To add value from this position, based on the evidence of the completed projects over the last twenty years and on the board at present, we hope to trigger a small change in the education and practice of design engineers as we know it today, taking it beyond institutionalisation and professionalisation, and away from being another annoying trend.

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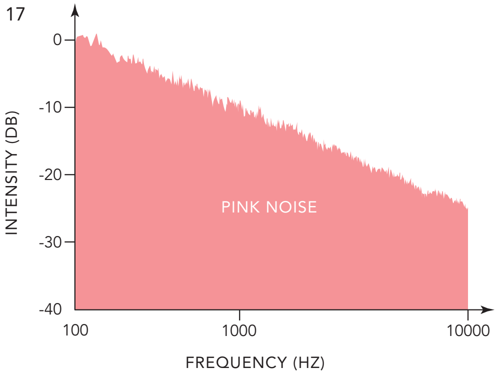

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$$S(f) \propto \frac{1}{f^{\alpha}}$$

17 AKT II, pink noise graph. Pink noise can mask low-frequency background sound, helping to increase one's productivity and concentration. The themes and projects here are intended to mask the wide-ranging disciplinary activity of structural engineering.[5]

18 AKT II, pink noise function. We borrow the use of this 'function' as a metaphor to make a distinction between the general implications of 'design engineering' and the specific approach discussed in this publication.

REFERENCES

1 Le Corbusier, *Toward an Architecture*, J Paul Getty Trust: Frances Lincoln Edition (London), 2008.

2 Limit state design (LSD) refers to a design method used in structural engineering. A limit state is a condition of a structure beyond which it no longer fulfils the relevant design criteria. The condition may refer to a degree of loading or other actions on the structure, while the criteria refer to structural integrity, fitness for use, durability or other design requirements. A structure designed by LSD is proportioned to sustain all actions likely to occur during its design life, and to remain fit for use, with an appropriate level of reliability for each limit state. Building codes based on LSD implicitly define the appropriate levels of reliability by their prescriptions.

3 Peter Rice, *An Engineer Imagines*, Ellipsis London (London), 1996.

4 Stephen Wolfram, *A New Kind of Science*, Wolfram Media (Champaign, IL), 2002.

5 https://en.wikipedia.org/wiki/pink_noise [accessed 4 April 2016].

TEXT

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