Zeitschrift: Schweizer Ingenieur und Architekt

Herausgeber: Verlags-AG der akademischen technischen Vereine

Band: 117 (1999)

Heft: 35

Artikel: Cecil Balmond: Profile of an engineer working in the "informal"

Autor: Rappaport, Nina

DOI: https://doi.org/10.5169/seals-79776

tragten Experten stellt die Baustelle höchste Anforderungen bezüglich Flexibilität und Kapazität. So können kurzfristig neue Rissaufnahmen oder Erschütterungsüberwachungen mit mehreren Messgeräten notwendig sein. Der Beurteilung von Rissbildungen ist wegen der langen Bauzeit und der Eigenrissbildung spezielle Beachtung zu schenken. Die langjährigen Setzungsmessungen im betroffenen Gebiet werden dabei eine grosse Hilfe sein.

Schlussfolgerungen

Durch Bauarbeiten können an Nachbargrundstücken und -bauten erhebliche Schäden verursacht werden. Für diese Schäden ist meist der Bauherr haftbar. Das Haftungsrisiko kann mit relativ einfachen Massnahmen eingegrenzt werden. Diese dienen drei Zielen:

- Ungerechtfertigte Ansprüche sollen abgewehrt werden können.
- Mit einer zweckmässigen Überwachung sollen schadenverursachende Immissionen möglichst vermieden werden.
- Im Schadenfall soll der Verursacher eruierbar sein.

Vorsorgliche Beweissicherungsmassnahmen in Form von Zustandsaufnahmen (Rissprotokolle, Höhenaufnahmen usw.) vor Baubeginn sowie als Überwachungsmassnahmen während der Bauarbeiten (Erschütterungs-, Lärmmessungen usw.) dienen der Risikoeingrenzung für die Bauherrschaft.

Die Wahl der zweckmässigen Mittel für die vorsorgliche Beweissicherung muss von Fall zu Fall unter Berücksichtigung der Randbedingungen in Zusammenarbeit mit den Beteiligten erfolgen.

Spezielle Beachtung erfordert die Wahl des Experten für die Durchführung der Aufnahmen bzw. der Überwachung. Er soll über eingehende Erfahrung sowie genügende personelle und gerätetechnische Ressourcen verfügen, um den Bedürfnissen der Baustelle auch bei Überraschungen gerecht zu werden. Der Experte muss unabhängig von den beteiligten Parteien sein. Damit er die notwendigen Abklärungen vornehmen kann, müssen ihm die erforderlichen finanziellen Mittel zur Verfügung gestellt werden.

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Adresse des Verfassers:
Andreas Steiger, dipl. Bauing. ETH SIA USIC; Steiger Baucontrol AG, Bauimmissionsüberwachung, Hofmattweg 1, 6033 Buchrain (vormals Dr. H. Bendel und Vibrotest AG)

Nina Rappaport, New York

Cecil Balmond

Profile of an engineer working in the «informal»

Most engineers, when given a structural problem for a building often find the direct and pragmatic solution, engineer, Cecil Balmond, one of fifteen directors of Ove Arup & Partners and head of the European office, approaches problems directly but also relies on the «informal» and an internal rigor, of a form which is non traditional. To him routine engineering concerns itself with Cartesian frameworks, which he continues to use, but he moves beyond the orthogonal to an evolution of forms based on geometry and algorithms which organize structures by means of an internal rigor.

Balmond, originally from Sri Lanka, has found himself a niche in the London office of Ove Arup, an international firm with 5,800 staff people. He has been involved in the structural engineering of buildings by avant garde architects such as Rem Koolhaas, Daniel Libeskind, Ben Van Berkel, and Alvaro Siza who rely on him to develop structural solutions for complex designs and shapes that they would otherwise not be able to build.

Balmond has also lectured widely and teaches engineering in the School of Architecture at Yale University. Last year he wrote a book, called Number 9: «The Search for the Sigma Code» (Prestel, Munich 1998) and he is working on a new book that describes many of his projects that will be published by Prestel next Spring.

In many building design situations there is an immense gap between the architect and the engineer, often because engineers are involved in a project at the later stage of a design, but Balmond, often involved in a building from the beginning, creates a collaborative process between himself and architects. One of his approaches is to develop an internal mathematical rigor in a project especially when the architect has created a design that is not a Cartesian box, and therefore not a more obvious grid structure. Balmond said, «I encourage free shape but there has to be a rigorous principle that would create a better solution. I work from an inside process outward. The forms are not whimsical but are mathematically figured out through algorithms based on simple systems and rules. These algorithms get repeated with a mathematical rigor that dictates the structural system. As a simple geometrical algorithm you can start with the number one and add one to it, and it makes all the numbers.» Because his system is numerical he can translate it to structural analysis so it is geometric and therefore architectural in three dimensions but the link which the architects never see is the actual engineering.

Another philosophy that Balmond employs is that which he calls the «informal.» To him the «informal» is the advocating of more relaxed thinking in structure. «I don't have to do a structural cage with the column and the beam in a regular skeleton, each time I work on a project», he said. «There is nothing wrong with that but there is nothing new with it either; it is a basic starting point. But I then ask: Why does a column always have to be straight? Why can't it lean? Why not jump a space and column? Why not skip a beat and create a staccato support system as in jazz with a rhythmic idea to lead to architecture? When I work with Libeskind or Koolhaas we have a dialogue in which we can create a new idea. The theory of the informal is

1
Kunsthal in Rotterdam. Inside view with part of the structure (photo: Ove Arup & Partners, London)

the attempt to put rigor against something that is informal; I am looking for an internal rigor to the structure of the theory.

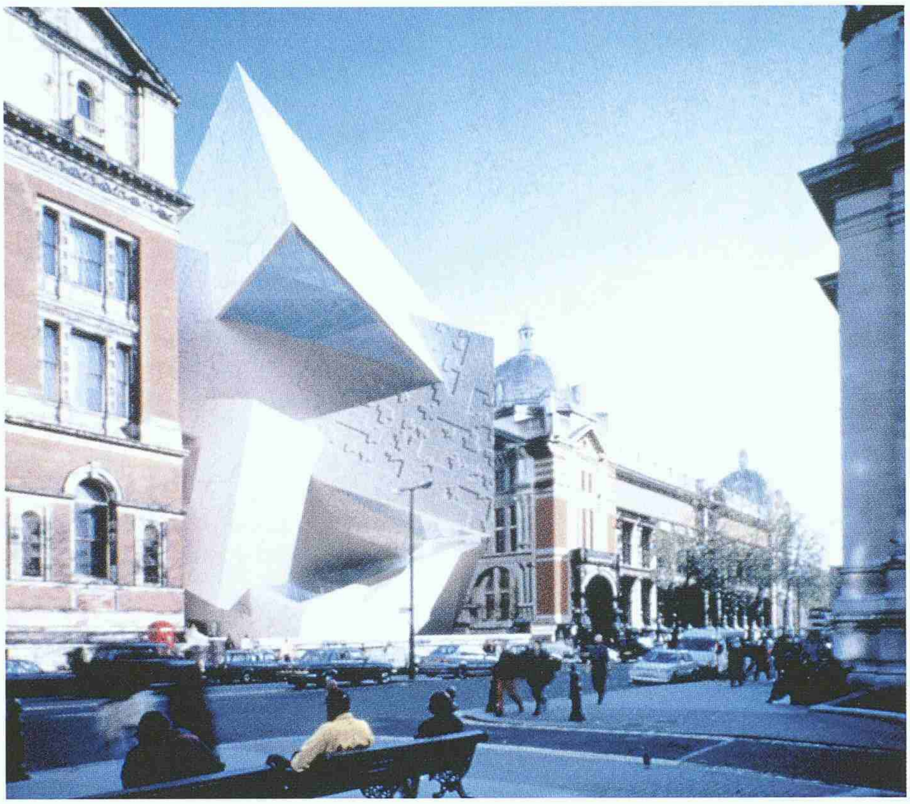
For example the Kunsthal designed by Rem Koolhaas, in Rotterdam, a 3000-square-meter center for contemporary art has a simple geometric form which is both logical and a bit out of the norm. The building responds to the site - the site drops down 5.5 meters so that the building adjusts to three levels with spiral forms with ramps and canted steel stanchions. For this situation Balmond has devised a horizontal truss bracing system for the roof of the main upper gallery that is a sweeping arc in a thin red line that goes through the roof beams. His informal approach is to have a curve running through the span of the gallery space, which is atypical. But, he said, he didn't express it overtly but pushed it above the structure so that it gets interlocked above and it becomes a trajectory and a structural brace.

In another gallery at the Kunsthal in the floor below Koolhaas and Balmond started with the assumption that the space was an equally structured area in a more standard approach - the columns are in the middle four square - but rather than have the room divided equally by columns in a grid, Balmond devised the idea to have a syncopation of columns which, as Koolhaas said, totally liberated the room. Balmond explained that «The solution is simple, but it is not often done, I call it a ‹slipped column›. The contractor realized that it would work and the cost would not be much more than the regular column grid.» In the Lecture Hall, Balmond placed the column at a angle, «we were constantly looking for ways of new expressions of structure in collaboration with Koolhaas, so these are structural statements that can influence architecture which is what creates a successful collaboration», said Balmond (image 1).

For the Bordeaux House designed by Koolhaas, Koolhaas said to Balmond «I have a project for you. I need to elevate a box in the air and I want you to make it fly.» Balmond was familiar with this concept because Koolhaas had wanted to try a similar structure for the Kunsthal. Koolhaas and Balmond began the design process together by sketching a box. Balmond drew a line and a box up in the air and started drawing columns to devise a system where all the columns were tucked under the building and the earth was built up to the house to support one side. The main tectonic of the house is a concrete base of 25 meters by 11 meters and 3.15 meters high with transverse steel beams for support that are then supported on the top and bottom. This structure was similar to the language of the Villa Savoye in France by Le Corbusier - a classic table top. Now of course Balmond says that he can «post-rationalize» what he designed but he felt he was destroying the formal. If the table is the formal, because of the legs supporting the horziontal mass, then he wanted to see what would happen if he moved the legs apart and out from under the table which would destroy the traditional. He pulled two legs on to one side with one slipped outside and one still underneath the table. When one leg was slipped outside these two extreme moves suddenly liberated the box. Balmond expressed that «It was so simple and informal - or non traditional a move, like a Karate move with the arm going in and out; here the legs slipped both ways and one jumped up to the top.

The traditional solution of evenly distributed bottom support would have given the configuration of a table and a static response. Instead it has a top-hung right-support juxtaposed with bottom-left cradle-support, setting up a precise danger point.» The exaggeration of structure and

2
Different shaping models for the Victoria and Albert museum addition



3
Model of the Victoria and Albert museum addition by Daniel Libeskind, architect, and Cecil Balmond, engineer

its slips makes the structure vanish so it appears to float.

For the windows of the house Koolhaas wanted portholes at two levels, an upper level for the wife and at a lower level for the husband, who is handicapped, so he could have views from his wheelchair. The windows were scattered on the wall like Swiss Cheese in what should be a supporting wall. Balmond sketched out the engineering rigor of an arched form within the wall that would allow the circular openings to exist and then drew patterns cut out of the wall to give Koolhaas the desired effect. The window holes avoid the principal stress lines.

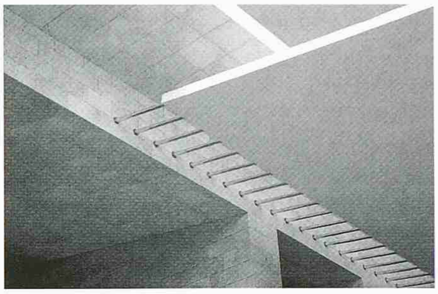
While much of what Balmond does he calls «informal» he actually completes strict computations for engineering analysis. He completes a finite elemental analysis and the engineers on staff check it all with the detailed calculations and he then does the fine tuning which does not affect the overall concept. Balmond explains that «at first it is like flying a kite of speculation with an informal nature and then I find an internal rigor. Probing it and sketching it and showing the architect what can happen. I then do hand calculations in a very strict method without the computer to get my answers to within five or ten percent, and then I go to the computer calculations to prove the point.»

The engineering for the addition to the Victoria and Albert Museum in London designed by Daniel Libeskind was one of his biggest challenges. The design for the new entrance building, or the «Spiral of History», is oblique so that finding the structural path through the form was difficult (image 2). Balmond developed an external tile system shaped like a target with a line that starts at a certain point and connects around creating a radius that generates a free form shape with an internal rigor. As Balmond describes «normally a spiral form revolves around fixed centering; both logarithmic and archimedean spirals turn in ever widening orbits fixed by a continuous unwrapping of space. But in this one the center moves, the orbits jump. The result is one of interlock and overlap and this shifting center makes a chaotic spiral. The center line and the zigzag with height offsets and tilts. The overlap of the lines becomes cross over points giving needed bearing to the walls, which take their strength from the interlock. The structure builds on itself, standing free, needing no internal core or extra brace. Floors act as diaphragms and columns do not penetrate the volumes» (image 3).

Balmond used a fractal system discovered by the American mathematician Amann (image 4). It wasn't a new idea, but the tiles as applied to a building was new. With the fractal, which Balmond calls the «fractile» he developed an algorithm for the pattern of tile to cover the spiral shape - three tiles made up the initial base pattern. As an algorithm each shape is contained in the other two and repeated, it was a mathematical solution that became engineering. The pattern also builds on the geometry of the golden triangle. To create a visible pattern they embosed the fractal shape on the tile so the light catches the tiles, defining the shapes. The tiles run around in huge geometric planes 120 feet by two feet

4
Amann's fractal system

5
Fractal generation used to develop the fractal pattern in the Victoria and Albert museum



6
The Portuguese pavilion by Alvaro Siza and detail showing the cables in the gap between abutment and canopy (photos: Ove Arup & Partners, London)

across and link up together (image 5). The slabs are flat slabs part of which act as «beam strips» connecting with the columns to create the movement frame with columns placed to allow for flexibility in the theater and maximum stability.

Balmond could not have done this work five years ago without the capabilities of the computer. He uses the computer as a design tool not just as a technical tool and often uses finite element and modeling programs as well as the firms in-house engineering program.

For the Portugese Expo Pavilion designed by Alvaro Siza, Balmond was hired by the Expo organizers to engineer a high tech pavilion in the style of Arup. The project called for a seventy-meter span for a canopy between two wings of the pavilion, and the normal instinct would be to have a fabric or a light weight material with cable and rods, as a high-tech canopy to provide shade. But Balmond felt that the spidery configuration of that design didn't fit with Siza's work. Balmond suggested using concrete for the span of the roof, but that sounded inappropriate in a seismic zone because concrete cracks. As Balmond described «I closed my eyes and went into it, because if I really thought about the technicalities I wouldn't be able to do it. You almost have to forget your learning. The choice of concrete was again part of my approach that relates to the informal. I thought of canopy and weight and I wanted it to be the opposite reaction to weight - weightlessness so I proposed that we cut the form at the ends before it completes itself.» The substance of the concrete is denied at the ends which also helps with seismic movement. Cables hold the canopy to the abutment at the two ends with an air gap crossed by the cables which allows natural light underneath these 1,700 tons of concrete that is suspended over the space (image 6). Balmond feels that «It is almost Zen like, the way the light penetrates and denies the mass.» His semi-scientific approach explores alternative configurations to the normal, leading to analysis where you can find unexpected solutions.

When Libeskind asked him to help with the San Francisco Jewish Museum, also in a seismic zone, he had many difficult shapes to engineer. It is a difficult position to be in because when something goes wrong, everyone looks to the engineer. But as he said «with all of the resources and great people working with me at Arup there is an amazing depth and precision which we are able to achieve.»

At an architecture studio at Yale University last fall, Balmond had the students use the algorithm pattern to design a villa. Taking the mathematical equations he used the classic nine square problem that the students interpreted to design a villa based on an abstracted equation using a rigorous discipline to create a design.

His upcoming projects include a new museum in Seattle, Washington with Rem Koolhaas, a Concert Hall in Porto, and he recently worked on a competition for a project in China for an Opera house with Philip Johnson.

Author's address:
Nina Rappaport, architectural historian and writer, editor of «Constructs», magazine of the Yale School of Architecture, New York, USA