Geometry and Digital Technologies in the Architecture of Herzog & de Meuron. The Project for the Stamford Bridge Stadium in London

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Abstract The present paper stems from the research we are developing in our Ph.D. work. From the study of concrete examples, we are particularly interested in understanding the impact that, in the last 25 years, the technological innovations and changes in aesthetic paradigms and spatial concepts had in architecture, interfering in the way Geometry, as a support tool for design, composition and construction of architectural objects, is used in the creative act. In this sense, the present study proposes a specific reading of the work of Herzog & de Meuron (HdM). Through the analysis of the recent project for the new Stamford Bridge Stadium in London, we intend to recognize which geometry lays behind the architectural forms, in order to gauge its role in the construction of the project and understand how new technologies can become a driving force in the exploration of this design tool.

Keywords Geometry · Architecture · Computation · Herzog & de Meuron

1 Herzog & de Meuron

1.1 Project Practice

The architectural practice of HdM is based on a traditional approach that, at least since Vitruvius, considers drawing as a fundamental instrument of the project's research, but integrating, in its methodology, the most advanced digital tools. In this sense, an analysis of HdM's work allows us to decode and understand the methodological transformations that have occurred in architecture in the last years and are transversal to contemporary practices.

Despite the overgrowth of their office, over the years, and the fact that, nowadays, it is internationally recognized as one of the most prestigious, HdM consider architecture within a disciplinary scope. For the Swiss architects, architecture is understood

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as an artistic practice with a history and a tradition, making only sense if defined and reinvented from itself. As Jacques Herzog argued "(…) we're pupils of Aldo Rossi and continue to pursue this approach (…). We always proceeded from architecture and didn't just tackle it out of an onerous sense of duty, as other well-known and innovative architects of our generation did and also proclaimed accordingly" [1].

Even though they explore the most advanced technological systems and recognize that we live in a time when everything has become less certain and less stable, HdM are not interested in project exercises of individualistic style. When questioned about the distinction, in architecture, between the specificity and difference as a distinctive system, Jacques Herzog explained that

> (…) many of our colleagues live with an imperative of existence, of being seen and therefore of producing distinctive signs. This exerts enormous pressure, and is a source of terrible fear. They are capable of creating such signs with some force but increasingly it is difference within sameness - a caricature of difference. It creates architecture that is egoistic to the point of caricature [2].

In this sense, HdM are against the generic character of much of contemporary architecture, most of the times pre-determined by an author's style and a desire of being in the technological forefront, trying to ensure that each project has a unique and distinctive identity. Understood as a specific response to a particular context, the projects of HdM start from a strong conceptual base and an attempt to capture and highlight the specificities of the site to constitute itself as part of a whole.

1.2 Project Theory

Over a period of 40 years, it is possible to identify a turning point in HdM's work.

Since 1995, when they were chosen to design in London the Tate Modern, the Swiss architects began to receive global scale charges that created a need for a readjustment of the office's structure and of the way in which each teamwork manages the development of each project.

Meanwhile, over the years, in their process of work, which has always been hybrid and eclectic, combining all the available instruments from the most primitive to the most technologically advanced and where physical models have a great preponderance, digital tools have been incorporated in an increasingly effective way.

This issue gained particular relevance when Kai Strehlke, in 2005, created the Digital Technology Group (DTG) and became responsible for integrating in the work of the office new geometric and technical methods, both for design and fabrication. DTG is an in-house team responsible for different fields such as parametric design and scripting, digital fabrication, computer-aided design management and geometric support, building information modelling, and visualization and video.

As previously mentioned, HdM projects stand out by their uniqueness and by the strong conceptual component that supports them and that, throughout the project, is progressively transformed into a viable architectural scheme. This means that the main focus of the work is always placed on architecture and that digital tools, defined specifically for each project, are developed with the main purpose of ensuring that the concept works and is coherent. More than being specialized in creating free-form surfaces, DTG aims, above all, to find the most appropriated drawing strategies for each architectural design, being able to handle with complex geometries in a flexible and adaptable way [3].

2 Stamford Bridge Stadium

The project for the Stamford Bridge stadium, started in 2014 by HdM and still under development, aims for the improvement of the existing stadium, by the expansion of the existing capacity to 60,000 spectators, and the general reconfiguration of the facilities.

The stadium is located in the west part of London, in a district that has been hosting Chelsea Football Club since its foundation in 1905. The current facilities are the result of a sum of different buildings, deriving from the successive interventions over the years. Apart from being obsolete and functionally unsuitable, the existing set has a fragmented image that mirrors the various construction times and does not favour the quality of the venue nor the prestige of the football club itself.

HdM project forecasts the demolition of the existing facilities and the construction of a unitary volume that, approaching the limit of the current stadium footprint, will host the different valencies of the sport's building (Fig. 1). The uniform language of the new stadium architecture aims to make it stand out from the urban landscape as a recognizable landmark as well as to reinforce the identity of the club in its place of origin.

As a starting point for the analysis of this project and the understanding of its geometry, we think it is important to highlight three premises related to the site that, in our opinion, were decisive on the development of the architectural solution.

Firstly, the Conservation Areas.

Fig. 1 Current stadium volume; overlay of current stadium and proposal; proposed volume, Herzog de Meuron (2015), *Stamford Bridge Grounds. Detailed Plan Application. Design and Access Statement* [4, p. 40]

The stadium grounds are surrounded by a considerable number of conservation areas which, due to their unique historical and architectural interest, require the preservation, valorization and guarantee of the integrity of their environment. A condition that, inevitably, interferes with the volume of the new stadium, its architectural composition and the way the building "shows" itself to the public space.

As a second point, we refer to the intervention area and its limits.

The grounds are enclosed by two railway cuttings, the metro to the north and the train to the east, which runs over the Counter's Creek, an old tidal tributary of the Thames that was canalized in the nineteenth century, and two historic boundary walls, to the south and west, which mark the limits with the adjoining residential properties. While the existing boundary walls were integrated in the project, in what refers to the railway cuttings, the designers decided to use the space above the tracks by capping the cuttings with pedestrian platforms. This operation permits to gain an exterior area surrounding the stadium that compensates the inevitable increase of the building's volume. The site's long-established configuration was determinant for the definition of the building shape, whose outline establishes a straight dialogue with the limits of the pre-existence.

The last premise refers to the pitch and the fact that, in the new project, it will maintain its historical location. This option, based on the intention of ensuring, within the arena, a continuity with the previous generations of the stadium and the recognition of the identity of the game's space by the adepts, places limitations on the orientation of the new building and, above all, on its position regarding the surrounding.

2.1 Geometry

As stated in the detailed planning application, HdM claim that the architecture of the new Stamford Bridge stadium: "will be a synthesis of the external demands of this extraordinary site with the internal requirements of a contemporary arena" [5].

In our view, this statement summarizes that which is the base geometry of the project. A rectangle and an irregular polygon synthesize the shape of the building, enclosing in its overlap the duality present in architecture.

The interior rectangle of the pitch is the reference of an orthogonal system from which is organized the design of the stands and the spectator amenities located under their structure (Fig. 2). The stadium bowl is divided in four stands, parallel to the sides of the rectangle, and the corners transition is made through the perpendiculars to the bisectors of the rectangles' angles.

On the outside, the faceted polygon that encloses the volume of the building reveals, in its irregularity, a response to the constraints of the site. The apparent randomness of this figure is actually controlled by alignments, symmetries, parallelisms and purposeful direction breaks. Regarding the relation with the surrounding contour, this geometric figure draws intentionally the outer area around the stadium, welcoming the public and driving it along circulation spaces.

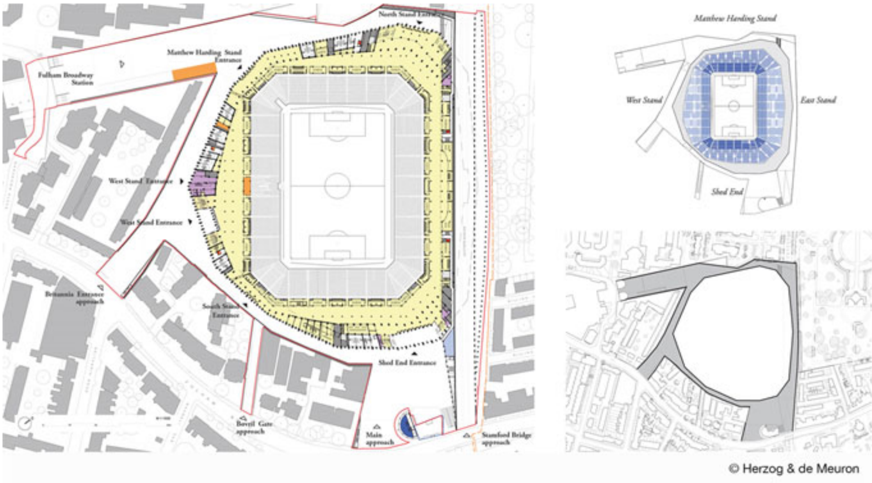

Fig. 2 Entrance plan; stadium bowl; publicly accessible space, Herzog de Meuron (2015), *Stamford Bridge Grounds. Detailed Plan Application. Design and Access Statement* [4, pp. 105, 49 and 48]

This system is overlapped by another radial system (whose origin is in the centre of the pitch) that gives body to the structure of the stadium and materializes itself on the external vertical brick piers divided in primary (90 × 213 cm) and secondary (55 × 145 cm) (Fig. 3).

Fig. 3 Shed End Entrance, Herzog de Meuron (2015), Stamford Bridge Grounds. Detailed Plan Application. Design and Access Statement [4, p. 52]

Fig. 4 April ’14, June ’14, July ’14, September ’14 and August ’15 proposals, Herzog de Meuron (2015), *Stamford Bridge Grounds. Detailed Plan Application. Design and Access Statement* [4, pp. 36 and 37]

Placed alternately by size, the 264 piers, together, draw the building facade, giving it, in its abstract repetition, a unitary image capable of making the stadium a symbol of the football club and a distinctive element in the city’s landscape. Simultaneously, from the point of view of the volume and its impact on the surroundings, this geometric option reveals itself to be strategic by breaking visually the scale of the building.

Observing the images regarding the project’s evolution (Fig. 4), we can notice that the design of the volume, characterized in a first phase by an opaque exterior responsible for a monolithic appearance, was progressively dematerialized, in an intermediary stage by the introduction of grids associated with the openings, until an effective lightness is acquired in the final proposal of August 2015, when the geometry of a radial system took shape, becoming coincident with the building structure. The radial system of the piers, seen directly from the front, gives a transparent and light expression to the building, while, at the same time, gives it thickness and solidity when viewed in profile.

The radial system is complemented by a circular ring, located in the stadium roof structure, with the same centre, reinforcing it from the design’s perspective, and complementing it by giving it sense from a structural point of view.

The facade columns that support the building rise to the roof where they articulate, through precast and brick-cladding rafters, with a set of radial trusses that advance 50 m above the bowl. This is the “double” steel ring (tension and compression) that will join all the radial trusses that materialize the inner covering of the stadium arranged over the stands.

Fig. 5 General view of the stadium; circular roof ring and Brompton Cemetery arcade, Herzog de Meuron (2015), *Stamford Bridge Grounds. Detailed Plan Application. Design and Access Statement* [4, pp. 6 and 50]

Besides its structural function, from a volumetric point of view, this geometric figure, which possesses a strong centrality, has the role of unifying the whole complexity resulting from the organic and responsive character of the building's exterior (Fig. 5). This can be considered as a formal gesture of a great clarity that reveals the ability of geometry to structure the design, endowing it with an order and an aggregating reference.

Conceptually, HdM also reveal that, underlying the introduction of this element, it's the interest in establishing a dialogue with the circular geometry of the Brompton Cemetery arcade, located on the east side of the stadium.

The project is marked, in its different stages of development, by a continuous concern in reducing the scale of the volume, in order to minimize its impact on the neighbouring buildings. This aspect is achieved not only by the strategic decision in "sinking down" the stadium, lowering the pitch 4 m, but also by the permanent sculpting of the general shape of the volume through cuttings, revealed both in plan and elevation.

If in plan this intention results in the definition of the irregular polygon that contains the building, in elevation, the cutting becomes evident in the continuous breaks of direction that the shoulder line of the building outlines (Fig. 6).

This operation allows for the reduction of the stadium's scale, lowering its profile in correspondence to the adjoining buildings and granting them the rights of light, at the same time that introduces variation and hierarchy in a facade composition that shows itself to be repetitive and homogeneous.

Simultaneously, and in correspondence to the stadium entrances located in the main squares, as if in a classical gesture, similar to the placement of a pediment, the shoulder line is pulled up. In this way, the entries are pointed out, acquiring identity and importance.

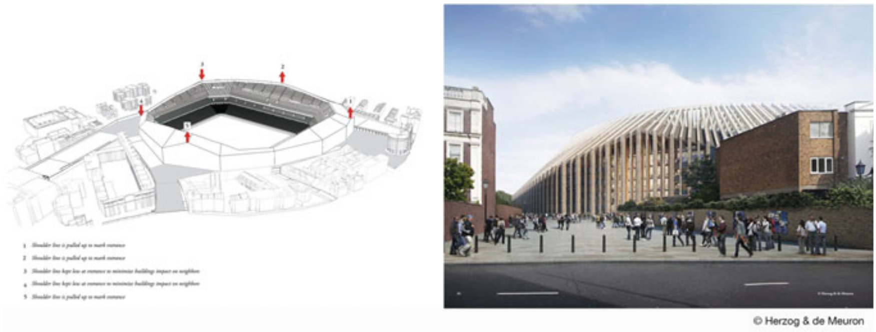

Fig. 6 The shoulder line of the building; West Stand Entrance, Herzog de Meuron (2015), *Stamford Bridge Grounds. Detailed Plan Application. Design and Access Statement* [4, pp. 41 and 34]

Referring to the exterior of the volume, HdM [5] explain that: "(…) the brick piers are a subtle reference to the most important local heritage assets".

Their colour and materiality are a reminder of the architectural qualities of some of the religious buildings located in the conservation areas surrounding the stadium.

It is indisputable that the choice of brick, as a coating material for the Stamford Bridge primary structure, relies on the intent of giving a sense of continuity to London's constructive tradition and to establish a dialogue with the examples of excellence of the city's architecture, especially in what concerns the colour adjustment and the texture exploration of the chosen material.

However, from the point of view of design and geometry, the "skin" that covers the building includes details that reveal a careful consideration of the local circumstances, as well as an interest in constructing the project from the specificities of the site, endowing the building with "roots" so that it can become part of a whole.

We would like to highlight two design themes that witness this particular interest in the local reality.

The brick piers, besides showing up in the facade with alternated different widths, in plan they are radially arranged and aligned by their inner faces, resulting externally in a continuous advancement and retreat along the perimeter of the building (Fig. 7). In a facade where repetition is a necessary theme for the creation of a unitary image, this alternation is fundamental, because it introduces a vibration that enriches the composition giving it density. However, when we look at the characteristic London residential fabric, this theme reappears very often on the facades of the houses marked by the significant saliencies of the bay windows, making us realize that, after all, the game of advancement and retreat of the stadium piers also finds here a reference.

Another interesting aspect in the set of piers that surrounds the building is the fact that they are not just a skin, responsible for the image of the building, but a system with thickness that contains the spectator amenities and that, simultaneously, provides a transition between the exterior and the interior of the stadium.

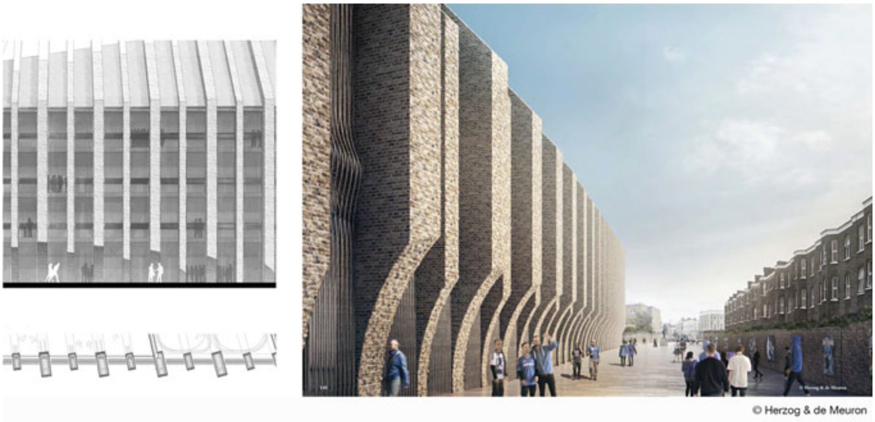

Fig. 7 Detail of the facade—elevation and plan; west elevation and Oswald Stoil Mansions, Herzog de Meuron (2015), *Stamford Bridge Grounds. Detailed Plan Application. Design and Access Statement* [4, pp. 115 and 140]

In this outer ring, in correspondence of three of the five entrances in the stadium (east, south and west) are planned 4–5 storey tall lobbies, carved from the mass of the stadium volume, with the aim of welcoming the spectators (Fig. 8).

In this entrance lobbies, the piers, free at the full height of the building, are topped off with a half-rounded arch that establishes the concordance with the slope of the roof. In the longitudinal sense, the perspective of these "naves" is strongly marked by the continuous succession of the piers and arches, thus acquiring a character

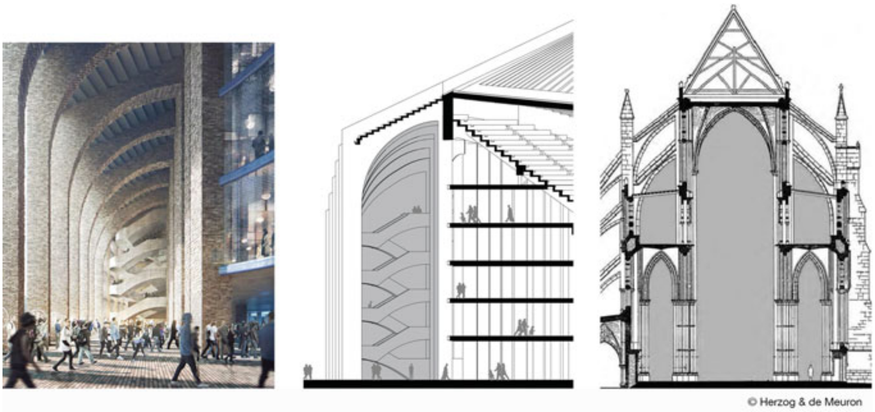

Fig. 8 South-east entrance lobby; west entrance lobby-section; Westminster Abbey-section, Herzog de Meuron (2015), *Stamford Bridge Grounds. Detailed Plan Application. Design and Access Statement*, [4, pp. 131 and 130]

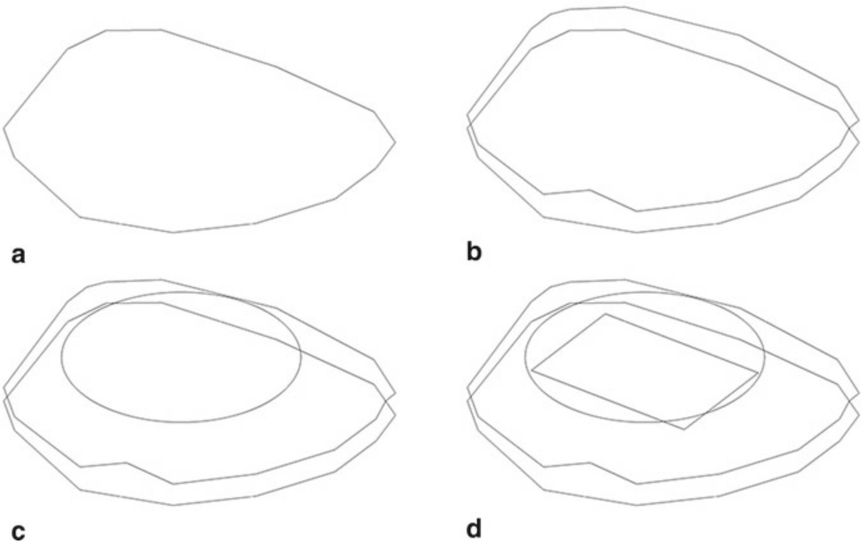

Fig. 9 **a** Irregular polygon; **b** spatial "polyline"; **c** circular ring; **d** rectangle

that recalls, in its scale and proportion, the spatiality of the great English Gothic cathedrals.

From the general point of view of the volume and the surfaces that characterize it, the building can be described as followed (Fig. 9):

- an irregular polygon that defines the base of the building and contains the outermost limit of the stadium volume;
- aligned vertically with this base geometric figure, there is a spatial "polyline" that defines the shoulder line of the elevations;
- pointing out the maximum height of the stadium and aligned vertically with the centre of the pitch, there is a horizontal circular ring;
- in a lower and inner position, that, in horizontal projection, coincides with the limits of the pitch, there is a rectangle concluding the advance of the inner roof of the stadium over the stands.

These four elements define the following surfaces that enclose the exterior volume of the building (Fig. 10):

- vertical planes in the facades (Fig. 10a);
- ruled surfaces, between the spatial "polyline", the circumference and the rectangle:

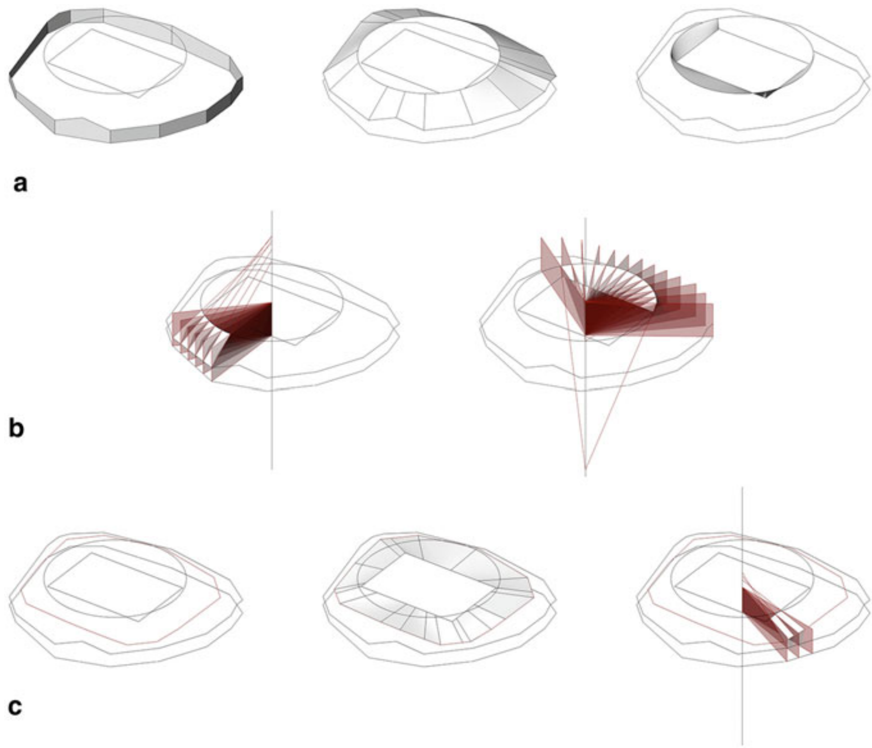

Fig. 10 **a** Vertical plans and ruled surfaces; **b** general conoids; **c** ruled scalene hyperboloids

- each segment of the "polyline" and the arc of circumference, corresponding radially to it, define *general conoids*,[1] since all generatrixes are supported on the straight line directrix, that is normal to the circumference plane and contains its centre (Fig. 10b).
- likewise, each side of the rectangle and the arc of circumference, that corresponds radially to it, also define *general conoids*.

There is also a second spatial "polyline", associated with the upper limit of the stands, that has correspondence with the contour that establishes the separation between the two roof structures of the stadium. Each segment of this "polyline" and the horizontal segments of the rectangle over the pitch define several ruled scalene hyperboloids that give shape to the interior of the roof over the stands (Fig. 10c).

[1] As considered by Adrian Gheorghiu and Virgil Dragomir "the conoid is a ruled surface of which the directrices are one curve and two straight lines, either both at a finite distance (general conoid), or one at a finite distance and other at infinity (directing plane conoid)" [6].

2.2 Digital Technologies

Although its description and understanding are relatively immediate, the general shape of the volume is defined by a set of surfaces with a certain geometric complexity that is accentuated from the moment that all of these surfaces are articulated with each other and generate a unitary set, in which any adjustment, however minimal, interferes with the entire volume. This issue becomes even more relevant, since this project is subject to a series of external requests, deriving from the impact of the stadium volume on the surroundings, but also internal, related to the requirements implicit in the design of the stands.

The project was, as such, outlined between the compatibility between the comfort and visibility of the spectators and the reduction of the volume conditioned by the constraints of the site.

As shown in Fig. 11, interior and exterior are closely interconnected, since the geometry of the stands has an impact on the overall geometry of the volume. A change in the steepness of the tiers would modify the volume shoulder line, the overall roof height and the outer mass of the stadium.

The geometry of the tiers was thus generated and controlled with the help of a parametric software, which allowed to manage all these requests, combining the optimal form of the stadium with the best viewing conditions in every seat. For this purpose, it has been defined the value "C" that measures the quality of the sight lines and refers to the ability of a spectator to see the nearest pitch touching the line over the top of the heads of the spectators in front. This value "C" varies between 5 and

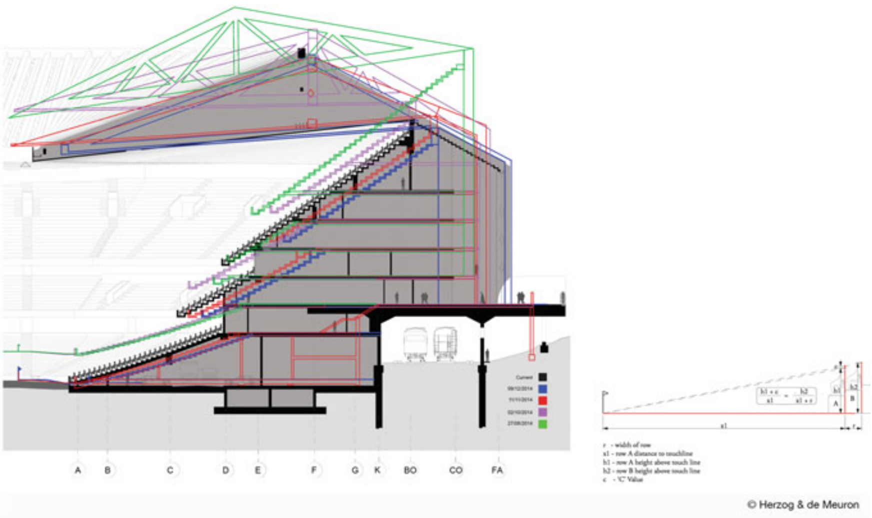

Fig. 11 Stadium section; C-value calculation, Herzog & de Meuron (2015), *Stamford Bridge Grounds. Detailed Plan Application. Design and Access Statement* [4, p. 101]

12 cm and is distributed throughout the stadium, depending on the stand and the category of the seat.

Although the information on this project is still limited, since it is under development, comparing with other HdM works, we can consider that the new digital technologies, such as parametric script, have been fundamental as well as, at least, in the development of these two topics:

- Configuration for the carving of the brick piers;

A cut through cylindrical surfaces, made on the base of the piers with an aesthetic and functional purposes, that happens in specific points of the elevations. Aesthetically, this carving pretends to give a sense of scale to the volume and provide a base to the longest elevations, while, functionally relieving points of greater compression between the building and the site's boundary walls which turns the circulation around the stadium more fluid (Fig. 12a).

- Generation of the compositional pattern applied in the paving of the external public space;

In order to establish a connection with the history of the site and evoke the ancient tributary of the Thames, that ran on the east side of the stadium, HdM took reference from the forms and geology of the waterways to draw the compositional theme of the exterior paving. Through parametric script, the reference pattern can be rationalized, being defined the base geometry that regulates the ulterior compositional alternatives. In this case, the base geometry was intended as specifically organic, varied and dynamic, in order to guide, through its design, the pedestrian flows around the stadium and highlight the building entry points (Fig. 12b).

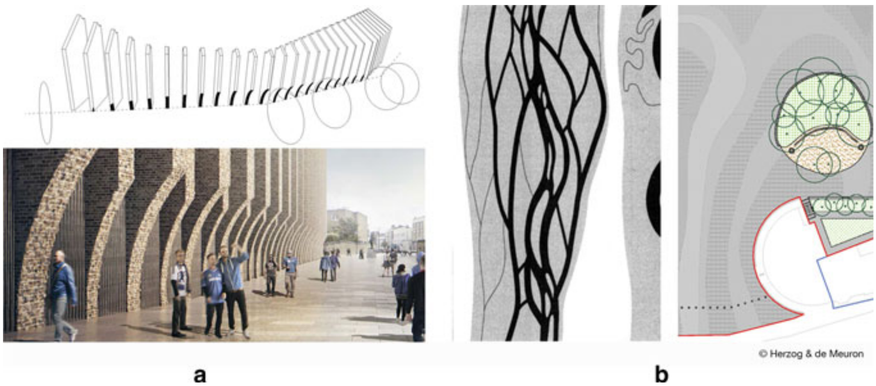

Fig. 12 **a** Carving on the west facade, Herzog & de Meuron (2015), *Stamford Bridge Grounds. Detailed Plan Application. Design and Access Statement* [3, p. 124]; **b** Flowing river typologies concept image, Herzog de Meuron (2016), *Stamford Bridge Grounds. Detailed Plan Application. Design and Access Statement Addendum* [4, p. 22]

3 Conclusions

In the project for the Stamford Bridge stadium, one of the aspects that stands out most clearly is the fact that geometry is omnipresent in the developed solution, revealing itself in all of its parts, to the point where the image of the building becomes the result of an inextricable interconnection between form, structure and materiality (Fig. 13).

This issue reveals us the importance that HdM give, in the design practice, to geometry, convoking it continually to solve the several project themes and assigning it the role of unifying the building as a whole and articulating the questions of form's design with the functional, structural and constructive aspects.

The new digital technologies are seen as a mean to introduce opportunities for the design, manufacture and construction processes. They are a tool that assists the design, allowing to increase the form's complexity and facilitate the search for alternative solutions, and at the same time they ensure an integrated control of the building in its various parameters and open the possibility to the exploration of new compositional strategies.

However, in HdM's work, the main focus is placed on the design intent and the architectural concept. This means that design tools, analog or digital alike, serve, above all, to translate and clarify the idea and not to create it. When they make use of computing methods, it is not architecture that subjugates itself to the potential of technology, but rather technology that is put at the service of architecture. HdM are not interested in arbitrary geometric possibilities or pure experimentalisms, and oppose to the excessive autonomy and self-reference of architectural objects.

The project for the new Chelsea stadium is, in this regard, paradigmatic.

Fig. 13 General view of the new stadium, Herzog & de Meuron (2015), *Stamford Bridge Grounds. Detailed Plan Application. Design and Access Statement* [4, p. 18]

HdM responded to a large-scale theme, that requires, in its typology, the construction of an icon, projecting a building that has a unique and distinctive identity and affirms its character of exception in the city, at the same time that it shows itself to be sensitive to its urban surroundings, seeking to establish with them a conciliatory dialogue.

Once again, it is through drawing that these themes are solved and, above all, with geometry as the key role in decode the existent and bringing into the "visible" world of forms, the "hidden" structures underlying reality.

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