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The Hidden Geometry of the Architecture of Herzog & de Meuron

Digital Tools and Design Practice

Alexandra Castro

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Alexandra Castro. The Hidden Geometry of the Architecture of Herzog & de Meuron, Digital Tools and Design Practice

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FACULDADE DE ARQUITECTURA

The Hidden Geometry of the Architecture of Herzog & de Meuron

Digital Tools and Design Practice

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Andreas Reeg

A.11
Andreas Reeg.
Architect at HdM (London and Basel) from 2008 to 2012.

“It can’t be so hard to solve this corner.”

Conversation with Andreas Reeg

Rundzei Architekten, Berlin, January 24, 2020.

Alexandra Castro (AC): Steffen Riegas suggested that I speak with you, since you were directly involved in the design of the brick facade for the Tate Modern extension in which digital tools, namely the scripting, played an important role.

Andreas Reeg (AR): I joined the office in London when they were ending the planning application—I think by the end of 2008. When I joined, the idea of the brick was already there. It was supposed to be this perforated brick facade. There were already a few scripts, but I don't know who wrote them. There was one script for each of the problems, so it wasn't very easy to use them to develop the design. It was an internal problem of the scripts, because you need to know in advance what geometric changes you want them to perform. Only in this way are they helpful.

In the project for TM2, there were complex arrangements of colours and geometries, but I think that in the initial phase, when they switched from the glass boxes version to the brick version, it was all tested in physical models. I think that, at that time, the scripting wasn't supporting the development of the design process.

AC: I know that there were two phases in the scripting. I don't know the dates exactly, but I know that Volker Helm and Dominik Nussen were responsible for the scripting in the first phase. Yesterday, I had the opportunity to speak to Volker, who told me exactly what you have just said, that the scripting was a bit complicated. I already knew that from Kai.

AR: Kai was rewriting it.

AC: Yes, he said that one day he went to London and the project had changed. Once the existing scripts weren’t able to respond efficiently to those changes, he decided to write them from scratch, and from that moment, things started working.

AR: Exactly, and, from that point, the scripting was useful for generating the plans, testing the finals, doing mock-ups, and even, in the end, for construction management.

When Kai joined, I think all of the details were already precise. In this sense, the scripting served to test the rules for the building corners. There was a big discussion about how the two surfaces should intersect, because, at the beginning, there was a different type of brick on every row, and the bricks had to be extruded from a machine. It had to be built with a metal element to make these shapes, and for the corner of the building there were, like, 3,500 different shapes. The cost consultant said it was nonsense, so we had to work on and find out options to get the same appearance but with standardised geometries. That was when the previous scripts failed, because it was so complicated to write them and to test them. At that moment, we made a lot of physical models, and we also did 1:1 scale mock-ups to test the corner. We redeveloped the rules again, and when Kai came we told him that we needed to adapt the scripts so they could reflect what we were doing. He said, "No, let's forget this. I'm going to rewrite it". So we sat down together and we wrote what the rules were. Kai was amazing. It was so quick, how he wrote all these things, and it was also working faster. It was much easier, later, to generate the 3D model and do renderings with all the colour testings.

AC: In November, at the office, Steffen took a look at the scripts and he was impressed. He said that they were quite organised and clear.

AR: They are so very well structured that I could also readapt them according to what was changing in the design. It was easy to follow it through for somebody who wasn't into the scripting. When I left, during the construction phase, when we tendered over to the construction managers, one or two architects from HdM were following the whole process. They were generating documents for all the brick types that had to be ordered using the scripting.

The scripting, in the end, was really helpful, but in the beginning, when I joined, I think it was consuming much more time than it would have had we directly modelled the different versions and tested them manually.

AC: Why did Kai enter into this process?

AR: I think it was because the project partner recommended it at some point. Kai was the head of the department, and I think he also felt that he was the only one that could do it. There was also more time pressure. We had to produce the information, and it was taking ages until something happened. The corner was still not correct, and we had to do it all over again. We arrived at a point where Kai said, "I'm coming over, let's sit down and think about it", and he decided to rewrite the script entirely. But still, as I said, the general idea was not developed with the scripting. The idea of the perforation, or the windows' positions in the facade, were not developed with the script. These things were tested and defined in physical models, small 3D models and renderings.

At a certain point, the planning authorities replied that they didn't like the fact that we used brick on the lintels. They felt this was a heavyweight facade that needed to sit on something.

AC: When did that happen? By the end of 2009? I remember that in the stage E report this issue is mentioned in the facade addendum.

AR: Exactly, that's when we decided to pull out the concrete panels, which are behind with this kind of indented profile, to have the same rhythm as the brick facade. The planning authorities were convinced that this concrete element was what the facade was sitting on. However, all these changes were manually done, because it was nonsense to change the script to model the precast. It was easier to leave out these hanging bricks, and that was very helpful with Kai's interaction.

There were also huge discussions about colour. In a very early phase, the facade was fading out into the sky. The partners then changed, because Harry Gugger left the office and Ascan Mergenthaler took over the project. I think that Harry was the one who wanted the fading effect to the top. He was also the one who pushed this to be the double brick perforated facade. Harry was very tectonic about how all these things worked.

AC: I suppose the colour gradation allowed the relationship with Tate Modern 1 to be reinforced, as the plinth of the old building is also made of red bricks.

AR: Yes, and yellow-brownish on the top.

Previously the colouring of the facade was taking rough colours from the brick. But afterwards it became a gradient fade from dark reddish to more yellowish. Ascan said that we should relate a bit more to the previous Tate and have a horizontal band of reddish brick which then slowly turns to the other one. At some point, we even went to the Tate facade, took out some bricks to see the variation that actually exists, and did a few colour versions. All the colour testing was in the scripting. We were able to change the colours and control how they were supposed to be distributed across the facade. We also did some versions in which the bricks were all brownish or yellowish, and so on.

To be honest, none of that would have been possible without the script. This was a crucial design issue for the building—how it appears and how it relates to Tate 1. It would have been a nightmare to do it manually. Whether it would have been with Photoshop, picking some bricks and putting them with another colour, or manually selecting bricks on the 3D model to be of a specific colour. In that sense, the script was absolutely necessary. It would have been a fight for ten people, working day and night, just to get to the right gradient effect.

I think there was a quite wrong break because, internally, we were happy, Tate was happy, and we were also able to reduce the number of colours and test ways of changing points where it did not look good. We arrived at the point where we could have manufactured it because it was just about 12 colours and not 365 different colours, so in that the script helped quite a lot.

In terms of the geometry, not so much. The script took the surfaces of the building and generated points on them. We had to draw the openings' polylines in Rhino, so the points inside these frames were left out. The script was considering the points near the openings and the corner conditions, and afterwards it generated the 3D. However, it was generating the geometry that we had predefined through physical testing and manual 3D models.

AC: This picture is from 2010. All these study models synthesise the different design versions developed between 2005 and 2009, when HdM got to the final version. I suppose that they took the decision to use the brick as cladding material by the end of 2007.

AR: I think they returned to the brick even a little bit later.

AC: In 2008, they presented the first renderings of the building in brick. This happened at the beginning of the "Design Development" stage.

AR: Okay. I know from Christoph Zeller, the project leader in Basel, that they changed from the glass idea, which was taking the internal arrangement of the building to the outside, to a version in which the envelope would be something different. At that point, they were lost on what the outside could be. They had the geometry, but it was very late that they decided to do it in brick and establish a relationship with the Tate. Before, it was this separated, free-standing volume from the Turbine Hall. And this is quite interesting, because, in the end, the building got even closer to TM1, matching the colour and trying to fit into the Switch House. I wasn't involved in that stage. When I joined, the overall shape, the brick facade or the windows, were roughly clear. The general idea was definitely there, so we didn't change it any more.

AC: How do you think HdM got to that specific brick arrangement, to the idea of a perforated pattern, through which a connection with Tate Modern 1 is established?

AR: I won't be able to answer this question. I think that Christoph Zeller, or Ben Duckworth, an associate of the project, would be the right person to respond to you. Christoph was involved in that. I know that the Flemish bond was the relation with Tate Modern. Then doubling it up, as far as I remember, in conversations, it was Harry saying that it was not transparent enough. If it had been just one stack, it would have been too dense, and no one would have been able to see through.

Then I think it was also a structural issue, with the engineers saying, "We need to make it 65 m high, so the bricks have to be able to sit on top of each other. The loads need to go down, and we cannot have only 2cm of overlap". That was when they doubled the bricks in depth.

So, making a square brick had to do with the structural situation and the geometric situation, coming from the inclined facades. On the southeastern facade, bricks were resting on just a couple of centimetres on top of each other, so it was necessary to make them deeper.

I think it was also technically a quite good decision, not just aesthetically. If you want to put them one on top of each other with mortar and you just have a couple of centimetres, you know that they are actually being held by something else. It's not the bricks that are somehow sitting on top of each other.

AC: Can you explain the construction system of the facade to me?

AR: There's the precast column system, which is the main frame structure holding everything up. Then you have the precast facade elements with their drainage connection, which is the waterproof layer of the building, and the structural load transfer from the brick facade onto this main frame and the rear.

AC: And to which the corbels are also fixed.

AR: Exactly. These corbels are anchored to the precast elements. The precast panels are fixed to the main structure, transferring the loads of all the bricks and corbels to the rear facade.

The corbels were initially like a little brick standing in the hole of the brickwork header.

AC: Were they in concrete?

AR: There were many versions. They were also in stainless steel, but open. In a previous stage, we didn't want to have any other element interfering with the brick facade. We wanted the brick facade to appear as though each block was sitting on top of each other, going up, literally. So we had these very complicated steel elements with only the top and the bottom in stainless steel, and then everything else was just a hole. When you were rendering it you didn't see them. It was a dark hole in front of the precast elements.

In this initial version, we had bricks glued to the bottom of the precast elements on the lintels. Everything was trying to hide the precast elements. But then, when we had the planning authority issue with the lintel, we realised that they were right. It's a brick facade, so it always sits on something. You need a lintel on the window because it is transferring the loads. When you have an opening, there's always the structural element. So why were we hiding all of this?

From this moment, we realised that it looked good and that the corbels could also be like a precast element, especially at the bottom where we have the anticlimbing system, where the surface is flush and the headers are filled so that nobody can climb up. So we decided to pull the corbels out to the front and show them in the facade. That was when Jacques said, "Yes, that's it!" He really liked the image of these layers of brick with the dots of concrete in them.

AC: In the end, the corbels turned out to be in stainless steel.

AR: At the very end, yes. In the construction phase, it was decided to make them out of stainless steel but with the same geometry as the brick. So you would see the stainless brushed steel grey surface because the manufacturer who built it said it would be a lot faster for him. But the change to have them all in concrete came from the decision taken at the anticlimbing, where the corbels would be visible and not clad with 2 cm of brick in front.

For the brick facade, we talked with two or three companies. There were a lot of details for how the bricks came together. These two bricks are put together into one block with a slightly special mortar, more weather-resistant, and they are extruded bricks. I mean, there are two ways to manufacture the bricks. One way is to put them in a form; you bake them, and then you have the shape. In the other way, you have the clay mass, and you push it through a steel profile, and then you slice it with a wireframe into the right shape. With this one, the edges are perfect. It's like a sausage that was kind of squeezed through something.

AC: Was this the system you choose?

AR: Yes, it had to be the system because we needed the holes in the bricks, and all the tests we did with these manufacturers to drill the holes were failing. The bricks were breaking, every three or four, or the holes weren't really in the right position. I don't remember how many thousand bricks we have on the facade, but just imagine how many holes we would need. At least four holes in each brick, so it would have been more than 1.2 million holes to drill. In the end, I think it was a German manufacturer that was chosen.

AC: I think it was Gima.

AR: Yes, Gima, who had the system for this extrusion technology. They were able to have a little steel rod in the clay, so the holes were in the wet version and then were baked to be fixed.

Into the holes in the bricks a little rubber pin is placed, then a stainless steel pin which connects this brick to the next one. This stainless pin was glued to the top brick. There was a bit of resin put into the hole of the top brick, so that the pin was fixed. However, in the bottom brick the pin was just stuck into this rubber element to allow for some movement. If it had been glued on the two sides, we would have gotten cracks every second level, and it would kind of turned and moved.

The corbels also had additional stainless steel rods going through the blocks, above and below, connecting the brickwork to the main frame structure in the back.

AC: The corbels had the dimension of the headers.

AR: Exactly, they were header size.

Then the bricks which were sitting above and below the corbels all had six holes. They were connected to the next brick, but also the corbels.

Geometry-wise, the bricks were always the same except for the reveals, where you sometimes have half-size header bricks, and the corners, where you have some cut-off versions to do the transitions. However, the bricks still vary a lot because they have different holes in them. On each facade, due to the inclination, the holes are differently positioned. So, you have the vertical facades, in which the bricks are all the same type, and you have the four inclined facades, where all of them have different angles.

AC: Which interferes with the positions of the holes.

AR: Exactly. The bricks in each of the inclined facades were of a different type.

AC: In the end, you have the bricks for the vertical facades and the bricks for the inclined facades.

AR: Exactly, and the bricks for the reveals, which were slightly special, and for the windows sills, because they didn't have the holes on top, and then you had the corner conditions, which were again four different types for each of the corners.

AC: What kind of technical or structural issues are behind the design of the facade? Regarding the facade structure, for example, I know that the columns were positioned in the intersection between the floor slabs and the creases. That's why the distance between them is irregular.

AR: It is irregular, but it is following the brick grid. The brick grid defined where the columns could theoretically sit, every 12.5 cm plus a header grid. There was a geometric issue because the inclined and vertical columns somehow had to meet, roughly, and that's why they were sometimes shifted over.

With the structural engineers, we had huge discussions on how flexible this brick facade could be to adapt to the construction tolerances. The engineers were worried about these huge columns having a variation in size of just 2-3 cm. This is just 0.1% of tolerance. So they said that the brickwork wouldn't work because you can't adapt 2-3 cm in a single little steel pin rubber. Then I said that we couldn't adapt in one, but we could within all the rows we have till we get to the top. With half a millimetre each, it adds up to a few centimetres, which would be feasible.

AC: The tolerance shouldn't be between two blocks.

AR: Exactly. There are so many small elements that can be slightly off, to then match in terms of tolerance. Then the engineers understood.

We always thought the bricks were going to be mortared on site. We thought they would put the bottom block, then the mortar, and after they would put the other one on the top. But two manufacturers said it was nonsense. They wanted to do this in the factory to ensure that the bricks would arrive on site as a whole block. It's obvious, and you have these four faces that you need to make nice and smooth. There were also huge discussions on how the mortar would be if it was slightly pushed in, totally flush, slightly curved, and so on.

AC: Now it is flush.

AR: Yes, it's flush, but they were able to do that only in the factory.

AC: I read in the reports that having a double brick was fundamental for bringing light to the interior of the building. Otherwise, the holes between the bricks would have been too small. The reports also explain that "(...) the composition of these 'cuts' (which is a direct result of the placement of internal spaces) provides a further means to moderate the scale and massing of the building. Although dependant on the internal uses to achieve the required daylight factors and natural ventilation requirements in general, windows are 1050 mm high and at desk level to allow for views from seated or standing positions, and 750 mm high and at the ceiling level to allow daylight to penetrate deep into the floor plan."

AR: The whole building had a very special energy requirement. It was supposed to be very sustainable in terms of the use of energy. There's a huge heat transfer machinery that uses the heat from the Switch House to generate cool air for cooling and conditioning the Tate itself, which is quite innovative. The engineers were also responsible for the daylight calculation and the ventilation of the whole building. So the proper cuts in the brickwork were, as you described, in areas where there were offices or teaching spaces. They were determined mainly by health and safety regulations that demand that you not sit in a space where you do not have a window. Then the other windows behind the brickwork were placed in the amount needed to get enough daylight into the space to save energy and fulfil the daylight requirements.

AC: I had, in fact, been aware of this idea that there were very precise requirements about daylight or ventilation that determined the number and dimension of the windows.

AR: It was really like this. We decided on the cut of a window, and then the engineers calculated whether that was enough. If it was not enough, we would do one more row of windows behind, depending on the daylight requirement. Behind these windows it is all circulation spaces. These are the concourses which are also exhibition areas, and here it was also a question of design. In these spaces, we wanted to make the brickwork visible from the inside. So, there was a compromise between having not too much daylight for the exhibition spaces but still having this view out to the brickwork. But I think that, for 70% of the facade, it was just the technical requirement.

Then there was a big discussion on the opening system for the windows because of cleaning. Some windows are automated for night cooling. So at night they open, and the concrete ceilings are cooled down. This happens with the very top windows. These were there sometimes for daylight, but mostly because of ventilation. The other windows, which were just for daylight, had to be opened for cleaning. The Tate wanted the windows to be able to be cleaned from the inside. There were consultants for that, who were responsible for building maintenance. We also had a 1:1 scale mock-up of a floor. On this, we tested the window frame sizes to see what is openable and what is fixed, and we also had a cleaning person leaning over these internal precast elements to see how far they could reach out. So, there is a fixed part, a little small one which can be opened, then a fixed one and another one that can be opened so you can reach out and clean the glazing. That was basically the compromise, to have a lot of fixed elements which could be cleaned from the inside.

AC: These daylight and ventilation requirements determined where the brick wall should absolutely be cut out. However, this external veil has its own architectonic composition. The arrangement of the cut-outs seems to be random, but I suppose it was also controlled in terms of design.

AR: Of course! This is not an office building, it is a museum, and there are a lot of concourse areas and public zones. HdM always intended to enable the public to go all the way to the top to see over the city, to take advantage of the fact that it is a high building. This is a window of a circulation area, this one of the little cafe space. Here there's the intermediary gallery space to look out for, and this is a special condition with the terrace. So, all the slightly larger windows are actually done on purpose for these views out of the building. These smaller strips, which are, I think, 1.05 m, are the ones for the daylight requirements.

AC: Are they at ceiling height?

AR: No, they are at floor level, so you can look out.

AC: But you also have the windows at ceiling height.

AR: Yes, you have these, which are either for ventilation requirements or daylight requirements.

AC: How high are the windows?

AR: They are related to brick constraints. All storeys were of different heights, and they were all a multiple of the brick grid. Actually, the brick defined quite a lot of the overall design. So sometimes, when you were splitting it, there wasn't always exactly 75cm, and it had to be 15cm more or less to fill the overall height.

AC: So these higher windows were positioned for the views out.

AR: Exactly, and there are mainly public functions or the concourses behind them.

AC: When you look at the facade, you see a big window at level 5 that runs for almost the entire perimeter of the volume.

AR: That's for the learning spaces.

AC: There's also a continuous one at level 9 and the terrace. I don't know whether this was made on purpose, but it creates a kind of tripartition of the facade, where you have the base, the cap and the in-between part.

AR: Yes, the terrace was absolutely designed with a 360º degree view. That is without question.

With the restaurant at level 9, it was a functional decision. When people are there, they appreciate the view and do not want to sit behind the brick facade to see only a bit out.

At level 5, it was mainly daylight requirements because it is a teaching area, so it was clear that we needed a lot of windows. There was also the decision based on the fact that this cut is above the Switch House, and it signals the next level of the tower.

But it is hard to say that all these decisions were for one specific reason. There were so many people involved. Jacques and Pierre said something. Then there were two partners, two associates, two project leaders, then me, responsible for the facade. Many people, lots of views and then at some point it is just on the wall and you say, "Ok, let's do it in this way". You don't really know how it ended up being exactly at this position. Is it because of the daylight requirement, or did we just make it a little bit longer because of proportions?

Of course, it is designed. The position of the cuts is a conscious decision, and it is not defined by the scripting or only by daylight requirements.

AC: I also noticed that the windows are often located at the corners and creases, which contributes to the continuity between the faces of the volume.

AR: I can't answer because when this was done, I was not yet involved. I think it was also pretty much decided on models. However, that changed in the following process because of the daylight requirements and so on. I think there was never a decision to say there should be a cut on the crease. It is just that there are so many creases. Every facade is folded, especially in the upper part, so you always hit the crease. Otherwise, you have a four metre window.

The building geometry is the result, on the bottom, from the circulation around the building and, on the top, from the perfect brick rectangle. The window cut-outs were never considered in relation to the brick or something, and these were just design questions or functional requirements.

AC: What kind of constraints emerged from using the brick, which is a modular material? The position and dimensions of the windows and the storey heights are related to the brick dimension. In what concerns the concrete structure of the facade, I also read that the columns were positioned where the crease intersected the floor slab. However, later this was slightly adjusted to match with the brick grid.

AR: Because of the brick grid, exactly!

The brick facade defines, in a way, where the windows need to stop. Otherwise, for the windows, you get a special condition, and also a different appearance, because there is a brick that needs to be cut. It didn't make sense, aesthetically and construction-wise.

The columns, as you said, were trying to meet at these points where crease and slab intersect each other. But I think there were a few, like this one, for example, which were individually placed because they were needed structurally.

AC: Not all the columns are positioned at these intersection points. From the interior, I think I saw at least two situations in which the fold of the column is visible from the inside.

AR: It is in the staircase void, because there is no slab hitting it. It happens especially here, in this corner, because you have the stair going from level 1 to level 2, and you've got this column that needs to do the kink. This column was needed because, structurally, the slab above needed to be supported.

Initially, as you said, the columns were placed exactly at the intersection, but, later on, they were slightly offset to be adjusted to the brick system. Also, geometrically, they don't meet perfectly. There is one column that sits vertically, and the other one is inclined.

Here, and on the opposite side where you have the stairs from level 2 to 4, you have these two or three situations where you see the crease point from the inside. In all the other conditions, it is always the vertical column sitting on the slab and then the inclined one going underneath, so you don't see how they connect.

To answer your question, the brick facade defines where the columns sit, where the openings start and stop. It defines the floor heights and even the louvres for the ventilation machinery.

On the west facade, these openings do not have glass behind them. It is machinery and openings for ventilation. It was clear that we had the header free, so we had 32% perforation, and the engineers had to calculate how much we needed to get the fresh air in. Where you see a few white elements in these elevations, the header is free. This is where air is taken in for office spaces or all the learning spaces behind. All of this was defined because the brick only allowed for 32% perforation. Yes, it was quite a bit of dependency.

AC: When did Kai start working on the project? Why did the team ask for the help of the DT group?

AR: That had even started before my time because Volker was scripting parts of the brick facade. There were many repeating situations, like the sill, the reveal and the lintel, that followed previous rules. The corner was complicated, and they never solved this in the initial script. The final script was basically to develop the 3D model, which was then used to visualise certain decisions and make 2D drawings. It was easy to make one of these drawings, but not the whole facade elevation. As we said, there were 336,000 bricks. Of course, you can use a grid, but it would change at every window or every corner condition.

AC: And if you use the scripting to do it, you will be sure that it is controlled and precise.

AR: Exactly, that is correct and controlled! But initially, as we said before, there were various scripts written for different problems independently. It was only when Kai arrived—and we reopened this issue—that the script began to include all of the rules. The anticlimbing as well, which was also quite a special condition, for how we go from solid to perforated. The bricks were slightly stepping back, and I think, initially, we needed about 380 different bricks per facade to do these 3.5 metres. At some point, the engineers said, "Sorry, but probably this is not going to happen. You will need to find a way of getting this effect but with fewer bricks". This was when I studied it with manual 3D models, physical models and drawing it up. Then, when we had this defined and the rule was clear, Kai looked at it and scripted it so that we could generate the 3D model very quickly.

AC: So, you defined the rules using physical models.

AR: We defined them on physical models, drawings and manual digital models, just taking out some parts and modelling, doing different tests, and doing it in physical 1:1 scale models. We cut the bricks out of styrofoam and laid them on each other, especially for the corner.

AC: Like these?

AR: Yes. These models were done to test what the effects were. And there were some only for the corner itself, for every four corners.

AC: So, only afterwards would you ask Kai to put this information in the script.

AR: We made the decisions based on these, and Jacques and Pierre were overviewing and deciding how we should do it.

But then there was the moment in which we needed to visualise it as an entirety. We looked at the four corners, but we didn't have the perception of what everything was looking like. With the old scripts, it was not possible because we could not adapt them in the right way, or they weren't generating the overall facade. The previous scripts were just creating the whole standard brick grid and weren't taking care of all of the special conditions, like corners, creases, sills, reveals, and so on.

That was when Kai came in. It was also when we needed to talk about the colouring of the facade. How we should manage all this and how we could generate 2D drawings, which were also useful for manufacturers. All of that was introduced in the script as well.

AC: So, what were the issues controlled in the scripting?

In the report from 2009, it mentioned that "the overall building geometry has been rationalised and thoroughly analysed using scripted 3D models fully co-ordinated to brick dimensions. The scripting process has allowed detailed design development of the brick reveals, corners and creases. The parametric model produced by the script has automated the setout of openings and the facade structure so that all facade elements relate to the coursing geometry of the brick skin." Kai told me that he decided to set out the data structure on a point cloud. Each brick was represented by a point that was informed with all the parameters regarding the type of the brick, the size, its position, its colour, its geometric constraints.

AR: The main change in Kai's script was that he was working with this point cloud. The previous ones were always generating the geometry of the brick and placing it onto the modelled surfaces. That was what took so long. Kai also had the facade surfaces, with the rectangle at the very top and the starting point.

AC: Is this one the starting point at the roofline?

AR: Either one of these four points, because this rectangle is always a multiple of a brick dimension plus a header. You have a perfect brick at each of the rectangle corners. It's the rule. That's how it is set out at the very top.

From there on, the script generated a point cloud onto the surfaces based on the starting point and went down properly. Then it changed the name of each one of the points according to its location. Whether it sits inside a window, where it became the name 0 because there's no brick, or it is at a reveal position because it becomes a header, or in a sill position, where it becomes one brick with four holes in it.

The script also took into account the special conditions of the structural engineers. You have the visual appearance of the bricks, like reveals and sills and so on, but, as I said before, each brick had different holes which you can't see. The brick looks the same in two different facades, but it is actually totally different in terms of production. This was on the script as well. I defined with

Kai the name the points should have. They were also informed by the manufacturer that was involved in the whole process of doing the mock-up. So we went to the factory and asked what information they needed to know to produce and identify each type of brick, not just the visual differences but also functional differences in terms of the holes.

Then, the script did this point cloud. It defined all points according to the different names and brick types, and, afterwards, generated one block, a Rhino block, for each of these brick geometries.

This was a huge improvement in terms of the time that it took to generate the 3D model. It was also really good because you could take the point cloud, and, instead of asking to place polysurface blocks onto it, you could ask for 2D surfaces, polylines filled with the colour X to generate the plan view, so then we had the elevations drawn by the script as well. As I said, this was also extremely helpful in terms of colour testing. But also for the 2D information required to explain the process and to generate lists and schedules. It was important to have the control that, on this facade, we needed the brick type A, B or C, either for the brick manufacturer to produce or for the bricklayers to have an elevation showing where each brick needed to go.

AC: Did the scripting also consider the change of the brickwork pattern from solid to perforated at the anticlimbing?

AR: A small script I wrote for myself was generating the condition for each of the five facades for the anticlimbing with the different variations we tested. But, for that, it was not the main script that helped. The main script was generated when all of this was clear and defined. When Kai was writing the script, the geometry was already defined. There was no discussion any more about the corner geometry or the reveal. That was all set. The only thing that was left over was the colour, and how do we colourise all this. But this happened later.

AC: I think that the corner is one of the most particular aspects of the project. How did you decide the geometry of the corner? It is a "strange" corner.

Jacques, at a conference, said, "How we use the edge where the two sides come together to create this kind of porosity which defines or also reveals the construction behind it, is a simple but important detail for how we use construction as part of the idea of the whole building."

I imagine that the corner raised a lot of discussion. It could have been a more traditional corner. For example, in this image from 2008, the corner is completely different. In the report from 2008, it is mentioned that "larger brick units are proposed to the corners and creases to ensure consistency of the overall texture of the facades." So, in 2008, I suppose that you were thinking of larger bricks that allowed the corner to be sharp, but then everything changed.

AR: It's quite interesting that they wrote this because, internally, we discussed that this was, exactly, what we shouldn't do. One of the issues for this solution was that it generated hundreds of different types of brick geometries that had to be produced and would be used only for one position. At the same time, and you can see it very clearly here in comparison to this one, in the crease and in the corner, it was framing the surfaces.

AC: We would see in the corners and creases a kind of solid line.

AR: Exactly, you had these solid lines, which are a kind of frame. At least me and Wim Walschap, who was the associate in charge of the facade and worked with me quite intensely on solving the brick issues, had the feeling that it would frame it. Ignoring the problem that all these would have been special bricks, in our opinion, it didn't work. Then I studied the brick facade quite intensely, and, for me, this is like grid paper. Now you take one vertical, you incline one, you fold them in a corner, and if you try to merge them, you have no repetition. There is no joining of these two grids. It started to repeat at 178 m or something. That's where you have the first brick you could use again for the next one. When I did this exercise, we realised that we needed to find a different solution, because every row of bricks would have one special brick in each corner. We couldn't do this, and it was also not feasible. It's a very simple and standard grid, we are not shifting it in the facade to generate different openings, but suddenly, the corner is something special.

The other issue was that it was solid.

In the crease, it was quite easy to solve because we could take the standard brick and slide it a little bit into the opening of the other one. There was only a small tweek to be done to match two or three bricks on each crease. You could leave certain bricks to generate a more perforated approach and not a solid line like this one. For the corners it was complicated, because you always had one brick standing out, cantilevering, which was unseen from the other side and was dominating the corner. This was the situation in the building where we did a lot of 1:1 scale physical models, where we came up with the idea of first trying just two bricks, for the vertical facade, to be cut according to the inclination of the other one.

AC: Is this the corner rule?

AR: Exactly! We developed this rule. This is always the vertical facade, which has two cut bricks that we decided not to cut on site. Initially, we developed it in such a way that you could cut the brick on site, so it would have always been the same brick that would then be cut. However, the structural engineers were worried that you might cut through a hole. Then it would be opened, and water would go into the other one. So, it should also be one closed extruded brick that had one specific length. I manually modelled the facade, and I realised that it would help to have the appearance of a continuous perforation if I only used two bricks.

Then the inclined facade was always cut on an angle, and you could place, depending on the left-over to the corner, the standard full brick, a 2/3 brick, a 1/3 format, or none at all.

AC: So these four options depended on the dimension we have left to the corner.

AR: It depended on the dimension to the theoretical corner point.

For the vertical facade, it was this brick cut on the angle. Either you have no brick, or you have one that has this dimension. Again, two types of bricks, because we realised that this was the only thing that repeated on this version. I think only the southeast had three. You could always fit either this or this dimension behind the other bricks. That was one repetition that happened, which none of us was able to calculate and say that it was because of this. I think it was because this is the vertical grid which is then cut by one element, and it was always this result of having this and this one.

AC: Does the inclined facade always go in front of the vertical?

AR: Exactly! The inclined is always in front of the vertical. “The inclined wins” we callled it internally.

AC: They do not intersect.

AR: In a way they do, because the next brick sits here, so they do because it is inclined.

That was the "Aha!" point that we had when we were physically or virtually modelling in 3D. I realised that it was working. The rule just said that there should never be a brick from a row cantilevering in front of the other one. In previous versions, we had full bricks standing out, and all of a sudden, you had these spines coming out. It still sometimes appears like this, especially if you are on site. With this rule, you still have quite a lot of different bricks, because this brick, or also this brick, is special on each of the four corners, since the inclination of the facades and how they join is different.

AC: So, in the vertical facades, you don't have special bricks.

AR: No. Where you have the corbel, the bricks are different because of the holes, but the geometry is the same. So, in the vertical facades, you have three types of bricks.

AC: Then each inclined facade also has its three special bricks, plus the bricks for the reveals and sills of the windows.

AR: On the sill, you’ve got a special brick, but it is really just the top one which has no holes. So that’s the same on all facades, no matter what the inclination is.

AC: Then you have the corners, and here there is the rule for the corners.

AR: Exactly!

AC: For the corners, there are four situations, because each corner is different from the other ones. Then the creases.

AR: But in the creases, there was just the rule of leaving a block out or not.

AC: Are the bricks cut in the creases?

AR: No, there weren't any special bricks in there. Again, it was the inclined surface going behind the vertical, and the one allowed to place its last full brick. If that's the rear, the brick is left out once it starts to protrude on the inside. This was the rule.

There was a point when we realised that if you give priority to one of the surfaces it makes it a lot easier, and we still have overlaps, which was important for the structural engineers. However, for them, it was not a problem if the bricks were not structurally connected. In this way, visually, it was still looking like it was interlacing. In the beginning, it's scary when you see the rule because you think you are going to have a joint, that it will be separate surfaces. But actually, since it is inclined, the rows are still intersecting. One row above, the brick is stepped back, so it is sitting on top of the other surface.

AC: What you are saying is that, technically, this was the best solution, and it would have been complicated to find another one in which everything would match.

AR: We spent, like, half a year testing different versions. At some point I was going nuts. But it was also a strange condition because I was sitting in London, Wim was in Basel, and I was preparing all the information for the reports and meetings with Jacques and Pierre. It was really complicated, because sometimes I thought, "Oh, that's the solution". So, I was very keen on presenting and explaining it, because it is not easy to understand just with a drawing. You've got the drawing here, but you still need to explain why it works or what had generated it, and then the response came back that they were not happy, or that it was too perforated, or it was still too solid.

At some point, Wim Walschap said, "You fly over, and we will have this meeting". We discussed all the different rules that we had, and then Jacques and Pierre agreed that it should work. Afterwards, we tested it on the 1:1 scale mock-up. Up to that point, they were still not really convinced. I did these millions of renderings of the corner, but it was only when they saw it in the mock-up that they agreed that it was actually working.

AC: You have two different approaches to the corner. At the anticlimbing, which is a flush surface, you have a sharp edge. A regular piece was placed at the corner. There's the standard grid that, at a certain point, before the corner, stops, and a special brick is placed there, always with a different length.

AR: The anticlimbing was an area that was generating most of the different types of bricks. The big change happened when we decided to make the transition from solid to perforated by pushing back the headers only into a certain dimension. We always used the same header and laid it with mortar. So, at the anticlimbing, you have this block and this block connected with the steel pin, but the header is free. It is not connected to this one or this one, but it is just sitting with mortar on the bottom one. This enabled us to use the same brick. We decided only to push it slightly to the back at each row, and once it reached too far to the back and was closing off the gap behind the bricks, it was left out.

That was quite an important moment because it reduced the types of bricks. In this section, you see that all of these headers are special because they are keeping the same rear location, but the brick was reducing in size. We did the renderings, which helped a lot, and Jacques and Pierre said that it could work because, from the angle that you look at it, it appears as if the brick had already gone, although it is not. It is only pushed back.

For the corner, I think it is a similar rule as above, where the inclined surface wins and goes in front. The rule considered that on the inclined facade there would be a specially manufactured brick. Then this one here, in the vertical facade, was cut according to how it joined the other one.

AC: So, the corner is a special brick.

AR: Yes, because you have the vertical and inclined surfaces.

So, that's the standard header, this one is already a special one, and that's a standard special one, which was made for this position. We have, like, twenty special bricks per corner. Then these ones were cut according to how they hit, basically, the rear of these.

AC: Here, you don't have a header because it would be too small.

AR: Exactly. We decided to establish a minimum size, which is the header. If the brick still fitted, it would go in there, but if it didn't, it would get bigger, becoming a block with a different length.

AC: Another important issue in the brickwork is the colour gradation. I have these drawings from 2008 and 2009.

AR: That is what I did with the script we had. This is an idealising phase of it, and it was the condition developed in these initial renderings. We analysed TM1, and we saw that there are roughly five different colours at the bottom. Then you have these other two fields. This one, that regards the new bricks, when the Tate Modern was built, and the elder ones with the darker colours.

AC: So this one is from when Tate Modern 1 was built?

AR: The new parts are the brighter versions. Originally there were already these differences, but most of the bottom parts had to be rebuilt, and that's why it looks a lot newer than the older versions of it. Then, in TM2, there was a rationalisation phase, in which we decided to have these five or six red tons, which are changing in the steps, anticlimbing, Turbine Hall and then the top.

AC: So, these three diagrams correspond to the evolution of versions.

AR: Exactly, to rationalise it. We were constantly talking to the manufacturers, and they said that it was not a problem for them to produce this. However, within all these zones, we also had these special geometry bricks. Suddenly, we had this variation of fifteen colours multiplying the already existing number of different bricks. So even if the manufacturers said they could do it, even if it would cost some money, the consultants said that it was nonsense, that we wouldn't be able to distinguish them. We would also need them on site, so we would need the whole construction site just to set out our 380 different types of bricks. So, we had to rationalise the colours within each zone. This was the result. We decided to have this set of just eight colours, which are then mixed in the facade, in a different percentage on each of these zones.

AC: In the facade, the colours would be mixed.

AR: Exactly, in the lower level, you have only these six reddish colours. Then up here, you have, like, forty percent of the reddish ones and sixty percent of these three. Then at the highest level, you have about eighty percent of these three and a few of the reddish ones.

AC: Should this look like this?

AR: Yes, that was the test. This one was the perfect gradient, and it was done when we started using Kai's script. These diagrams were drawn in Rhino, and the script was analysing the different rows of bricks and applying the different colours, like it was defined here. That was the big advantage of the script. We were able to test these different versions very quickly.

This distinction between levels looks like a hard step, but when we rendered and visualised the facade, you don't see it, because you still have these brick colours in here. So, in the end, it is not a line, as you see in the diagram. There was the moment in which everybody said that probably it was going to work, but in the end, it only used some of these brownish tons. I remember that we did one more mock-up on the Tate facade where we decided on these six brownish colours. Everybody agreed that it was looking good and the decision was taken.

AC: So, there aren't any of these reddish ones.

AR: Exactly, the decision was that we were not corresponding to the red, we were just keeping these brownish tons, and there would be no gradation. The gradation would happen by the anticlimbing.

AC: Yes, in fact, you see a gradation because of the perforation.

AR: Yes, the perforation is doing that slight gradient from the bottom to the top.

AC: I've been to London in November, and the corner is a bit strange because it seems like everything is going to fall.

AR: Yes, I agree, you can't imagine how many different corner conditions we visualised. That was definitely the most complicated situation.

AC: I can imagine. It's not easy because, besides the vertical and the slope, you also have the stepped.

AR: When I joined, I thought, "No, it can't be so hard to solve this corner." But then, "Oh no, it can't be! What is this?" You try to calculate it, and you can't. You try to model it, and it isn't easy. It starts to drive you nuts at some point.

AC: Why did you give up the colour gradation?

AR: It was because of the cost, but I think that in the end, it was a good decision having just brown colours.

AC: How was the design process? How did you design it? Did you start with the 3D, and then you went to the 2D?

AR: I did physical models, sketches, tried to draw it in 2D and then looked at it in 3D. It was back and forth. Then it was making something 2D out of the 3D, doing it in Rhino and sketching over, then doing it in a physical model to see how it feels. In the end, it was Rhino, the script and AutoCAD 2D drawings, but also Illustrator, Photoshop, and so on for the renderings.

AC: In your opinion, what are the most relevant design tools in the practice of HdM?

AR: Physical models. As architects, most of us are quite quick in translating a 2D drawing into a 3D, but everybody else isn't. So it is hard to explain from 2D plans how something works. Then a 3D model is something where everybody is stuck in front of the computer, looking at the monitor. So, you generate visualisations in which you pick the best perspectives, and it looks really good, but then two metres further to the right it doesn't look that good any more. All of this you see in a physical model. Everybody sees in a physical model—you, the client, the contractors, and so on.

At HdM, I was always impressed by the number of physical models. Also, by all the interns and even the workshop employees. There was so much stuff produced, and tests to make sure that, in reality, in a physical situation, it looks the same as you modelled it. In 3D, you also leave a lot of stuff out. How do you visualise mortar, which is something placed by hand and that always looks a bit different? In the rendering, it is all the same and perfect.

AC: The construction of mock-ups, I think, is also something particular in the work of HdM.

AR: Yes. That's also due to the size of the projects, because I think that almost every large project has mock-ups done to make sure we do the right thing for the project. In the office, they develop a lot of physical objects. Elevations and plans are important, but in the specific case of Tate Modern, the 3D was crucial to handle the project, to make it buildable and to generate all the information that the manufacturers needed.

AC: And also, I suppose to control the integration of all the parts.

AR: Exactly. The building was never physically modelled entirely. It was modelled for the overall geometry in these small study models. We also made models of a particular situation, and there was the 1:1 scale detail of the corner. But these were always separate pieces. The visuals, the renderings and the 3D were important to get overall extents of the facade, and especially for information handling. The script was particularly important for doing the final colouring facade and producing the 3D, but also for the construction information. The contractors got lists of the bricks that had to be in every row.

AC: That was one question I had for you. How was the design information transmitted to the construction site?

AR: As I said, the point cloud defined the brick “SB4 southwest” or something, type 1, 2, 3, 4, 5. There were these sheets of brick types explaining what dimensions they had, where they had the holes exactly and the code of colour each was supposed to have. The script generated a list of all different types and how many colours were needed. So, the manufacturer knew the amount that he had to produce.

Then there was this list produced floor by floor, elevation by elevation, for the bricklayers to know what needed to go where. In the end, this was a bit reduced just to get the overall amount of the different geometrical types of bricks. For the colour, you would sort this out from the bricks that you got from the brick manufacturer, and you placed them. So, in the end, it wasn't defined where the colours should exactly go. The type of brick that should go in this corner was specified, but the colour could be between three or four colours, so the bricklayer could place as he wished.

AC: Did the bricklayers have 2D drawings of the special parts of the building?

AR: Yes, for each row we did a full elevation of each type, even if this was done only for the special conditions.

AC: But the corners are all different.

AR: All four corners are different, but there was the rule. So, they took the last brick and confirmed. If it was cantilevering in front of the other surface, they would take the smaller one.

AC: There was a bricklayer specialised in the corner...

AR: I think they had a bricklayer team responsible for the general elevations and another one for the reveals, the corners, the creases and so on.

The bricklaying was a lot less of a nightmare than the precast or the windows. The beginning was quite complicated, because they had to get used to the process and there was also the anticlimbing, which was all special. But if you follow through the time-lapses, you can see that these two first floors took quite a long time, but then, all of a sudden, it speeds up and gets a lot faster.

AC: When they arrived at the top, did it match perfectly?

AR: Yes, it did.

END