Fabio Gramazio and Matthias Kohler divide their working time between architectural projects and research programs, a big part of them done together with the architecture students at the ETH school. Exploring the ways to combine the very essence of architecture with the potential of contemporary digital technologies, the two partners have approached a new understanding of the classical «form-follows-function» mantra: it seems that their strategy makes these two’s just merge in complete parity. MONITOR talks to Kohler and Gramazio in their Zurich-based office.

Today, the scope of research in the field of digitally aided architecture is really vast. What is your preferred direction? > FG We are interested in bringing together the data and the material, literally speaking. Bricks come together with the rules that determine their position. That has been the reason for us to start our research with an industrial robot four years ago, for the machine enabled us to build prototypes in 1:1 scale, and with raw materials. Without this rigid reality, too many things become possible, and you end up playing around with complex geometries that have very little to do with real architecture, because they are not bound to its constraints: materials, gravity, connections between pieces, and so on. > MK We have come up with the term «digital materiality» to describe the state of materials the architects are working with today. The materiality as we used to know it is now deeply enriched with digital design characteristics, with almost molecular levels of intervention that you are capable of. You design the construction process itself — not just form, but also the way this form is achieved. And you control every bit of how it is done.

With such a powerful tool in your hands, what kinds of architecture-related problems do you want to solve? > FG Right now you have two basic approaches in digital architecture. One is so formal that most of the time it doesn’t consider the real constructive issues. The other is based on optimization, on using the ability of computers to produce better, faster and cheaper solutions, but the criteria are mostly economical. We believe that there exists a large field between these two; the one that will create a new aesthetics in architecture. It’s not based on spectacular forms that can be generated through computer design and then built in very traditional ways. In our Brick Wall program we took the construction method that is 10,000 years old and started manipulating it using the power of the computer. In this way, the decorative pattern can be scripted basing on the aesthetic criteria or, for example, on the structural criteria — and suddenly it starts to create architectural elements that are, on one hand, very familiar, since it is not a new material, but at the same time it is something you have never seen before. That’s also the reason why we are interested in additive processes, this basic molecular aspect of construction — because they allow you to deepen your intervention into the material, and through this you might address architectural issues like transparency, for instance. We are no more dealing with the surface alone: if you start to work on the brick material level, you engage the whole power of architecture.

Let’s talk about the research projects conducted together with your students at the Architecture department of the ETH school in Zurich. All of them have been focused on the digitally controlled building of a wall composed of modular elements (bricks, etc.) What really interested me was how function and aesthetics have been tightly, if not inseparably, intertwined in the final designs. > MK Fabio has already mentioned that the basic premise of our research is looking into additive processes. Because architecture to almost 100% is built of small parts, which form and define space. We are interested in starting to control these processes very directly, in order to see what kinds of qualities are inherent in them. It’s a very basic approach: you just combine the adding-on with digital control techniques. Surprisingly, this is not researched a lot in architecture. We applied this method to bricks, porous concrete blocks, wood, and solid and even liquid foam. And, since most of modular building elements have to be joined together, there’s always a question of how they are joined. These are very traditional questions that have always been there, and which are now seen in the new light of digital processes. With students, we explore how the physical building world and the digital design work are now starting to merge. In architecture we are always confronted with functional requirements, like keeping the weather away from the building’s interior, or ensuring structural stability, so it would make no sense to limit ourselves to purely formal research. Our students have to consider multiple aspects. For example, they design wooden walls that can be insulated, have a weathering side, and are built in one single process using a very simple constructive principle, with wood slats. It’s very interesting to see how the students develop ingenious strategies, trying to deal with these complexities on the conceptual architectural level. And this results in new fresh aesthetics, which however provides very basic and actual functional qualities. > FG During this couple of years, in all the student projects at the ETH we have been addressing the wall. When you have developed a strategy for this most basic element of architecture, you can address a whole building. This is very different from starting with an overall master plan or with the shape of a building and then going backwards to the engineering part, so that the project could be built. We use the same strategy in our firm’s projects.
matthias kohler & fabio gramazio: digital empirics

Interview
By no means I want to oppose the two things, but today we can see two different approaches to materials. On one hand, there is this big interest towards intelligent materials (which can be characterized as a sort of enhancers), while what you are doing influences the material on some other level — it’s not about enhancing, but about looking for new potentials of something we’ve always had. > FG The only problem with smart, or functional materials is that most of the time they are not available in the quantities you need. Although the second part of our strategy is to try and go as far as possible, we still prioritize the feasibility of the project, even in our research. In the end, our experiments should lead to architectural artifacts — which would become very complicated if we use the materials that are too expensive, or too small to be manipulated by architects. > MK With digital materiality, the architect is able to design the functional and aesthetic properties of the material, you can control it, you can design it — you become the author of this materiality, while with smart materials you still select a material with the properties it already has, and then you apply it in a homogenous way.

Have you already faced the problems and challenges that arise out of this new method? > MK We’ve decided to take an empiric path rather than first developing the theoretical side and then seeing if we can get something built. As we are exposed to the process of making, this brings with it a lot of interesting discoveries. For example, we need to stack bricks, but we find out that we can’t use mortar with robots, so we say, OK, let’s glue the bricks — and suddenly we have brick walls that can take tension forces, which allows us to launch a completely new formal vocabulary of a brick wall that has not been tested yet. Then there are questions of changing paradigms in prefabrication. Through new design and construction techniques, modern serial aesthetics is now being liberated and becomes even freer than certain manual building techniques. That’s a whole shift in what prefabrication can or cannot do. In our project for the Venice Biennale, we’ve brought the construction robot on site to have local prefabrication. From here arise further questions, like what the detail means in terms of resolution… Building from small parts will be very expensive and will take a lot of time. Imagine trying to build a building with a 3D printer — a nice idea, but it could take light years to realize it. How you work with differently sized parts, how you attach them to one another… There are a lot of issues, which we don’t regard as technical, because this would make them less interesting, but are as fundamentally architectural questions.

Which projects have been the most interesting for each of you? > MK The Biennale project, because it was the first time that we’ve stepped out of the enclosed research facility, but also because the project is very innovative in terms of design. The design, or rather the spatial behaviour of this wall is completely programmed: its oscillating form had to ensure that each separate part of the wall would be self-supporting. In parallel with our discussions with the curator, the wall’s course (used as the parison inside the Swiss pavilion) has been shifted until the last day, just before it had to be built. We see a great potential in the fact that you can conceive a design as a set of rules, as an open system that reacts to certain parameters. In this way, architects are able to adapt their concept to changes in the building’s program until the very last stage of the planning process. > FG On the other side of the spectrum, there is the foam project, where we had acoustic panels produced by the robot out of PU foam. It’s still an additive technique, but, in contrast to bricks that are tangible discrete elements, here you work with a material that is liquid at the beginning. PU is a two-component material, when poured out of the nozzle, the components expand, augment the volume, and then solidify. This complicates the process enormously, but also creates an amazing new horizon of possibilities. Unlike laying a brick wall, when you pour foam you have one process that is the movement of the robot laying the material, and the second one that starts at the same time — this expanding of the material from the ground up, changing its shape in the process. If you start to experiment with it, you find out that you can achieve formal and structural results you could never produce in other ways — for instance, with casting or milling. And the deep understanding of what physically happens during this process is crucial for being able to design with this. > MK I also think that time is of interest to us, and the question of how you
For the exhibition «Explorations» (the Swiss contribution to the 11th Architectural Biennale in Venice) Gramazio & Kohler produced a 100m-long brick wall that ran as a continuous ribbon through the entire pavilion. The design of the wall followed algorithmic rules and was built on site by the R-O-B, a mobile robotic fabrication unit. The looped form of the wall guided the visitor through the exhibition. Through its materiality and spatial configuration, the wall consisting of 14,961 individually rotated bricks enters into a direct dialogue with the modernist brick structure (1951) by Swiss architect Bruno Giacometti. The wall's design was conceived as a system with open parameters. The course of a single, continuous curve carried all the generative information necessary to determine the design. This curve functioned as a conceptual interface, adaptable to the needs of the individual exhibited groups. As each group's requirements were modified, the three-dimensional undulating wall could be automatically re-generated. Its complex shape was determined by the constructive requirement that each single, 4m-long segment should stand firmly on its own. Where the course of the generative curve was almost straight, meaning that the wall elements could possibly be tipped over by the visitors, the wall's footprint began to swing, thus increasing its stability. Each curvature in the lower layers was balanced by a counter-curvature in the upper layers, thus giving the wall its architectural expression. In addition, the individual bricks were rotated according to the curvature — the greater the concavity of the curve, the more the bricks were rotated. This further emphasized the contrast between the plastic malleability of the wall and the firm materiality of the bricks.
THE GANTENBEIN WINERY // FLAESCH @ SWITZERLAND // 2006
The owners of a small but remarkably successful vineyard wanted a new service building, consisting of a large fermentation room for processing grapes, a cellar dug into the ground for storing the wine barrels, and a roof terrace for wine tastings and receptions. Bärth & Deplazes Architects designed the project, and it was already under construction when they invited Gramazio and Kohler to create its brick facade. They interpreted the building's concrete frame as a basket and filled it with abstract, oversized grapes of varying diameters. Digitally simulated gravity made the grapes fall into this virtual basket until they were closely packed. The resulting digital image of grapes «bulging» on facade surfaces was transferred to the rotation of the individual bricks. The robotic production method enabled the architects to lay each of the 20,000 bricks precisely according to programmed parameters — at the desired angle and at exact prescribed intervals. Each wall thus acquires the desired light and air permeability, and features a pattern covering all the facades. A total of 12 wall elements were manufactured as a pilot project in the research facilities at the ETH, transported by lorry to the construction site, and installed using a crane. As every single brick had a different and unique overlap with its neighbours, the architects developed an automated process for applying the bonding agent, which helped speed up the manufacturing process for the 400m² facade and manage the extremely tight deadline. Load tests revealed that the bonding agent was so structurally effective that the reinforcements normally required for conventional prefabricated walls proved unnecessary.
design behaviour in time. Take, for example, the Xmas illumination for the city of Zurich. Besides conceiving the hardware, we designed the software part that generated 320 hours of Xmas atmosphere as a real-time programmed evolving lighting pattern... In another project we had 46 lighting elements distributed across the park and sensing people who came up close, light starting to wander from bottom to top. If people are walking through the park, it fills with light, which means that you can enter the park at night and immediately see if someone else is there. We use time, movement and lighting to create a living atmosphere and a sense of security at the same time — this can shift a paradigm in the conceptual use of time. And, apart from these projects that use time literally, we have others, where we program sequences to design the behaviour in time.

There is another kind of shift, which is happening in your profession. It seems that now that you’ve activated these digital production tools, the power that goes into the hands of the architect is becoming much bigger than before. If you have that much control over the process, it can change the role of different players that take part in the making of a building. > FG There is one thing we need to understand. This process is controlled by many players, because there are so many dependencies: economical, structural, aesthetic, logistic and so on. We believe that the way of working we propose has to be defined by architects, but this can only happen if architects engage with the most basic problems. It is absolutely naive to think that it’s just a technology that will be developed by the software industry and simply put in our hands. This will never happen, or, if it happens, such tools will not suit our architectural needs. This has already happened once in the last 15–20 years. The CAD software has been developed not for architects, but for engineers and the main reason for this lies not in the software industry, but in the architects themselves, because most of them failed to understand the critical importance of these developments and how deeply this will impact their own work, but also architecture at large. Instead of engaging themselves in designing the concept for these tools, and thus reinventing their industry — like the movie industry has successfully done in the 90s, — mainstream architecture just ignored them for a long time. In the end, all of us were obliged to use those tools — not because they are very interesting, but because productivity demanded for it; nowadays it is impossible to work without CAD tools in an architectural office. But they are not as developed conceptually as they could have been if we had worked on it. Now, when we are in the middle of the transformation process towards digital fabrication, it’s crucial that architects understand that they can play an active part in this transformation. Technology has always been an inherent part of architecture, and if we get it out of our hands and delegate it to engineers, we might lose something for the architectural culture, and for the building culture as well, because this process involves the building industry no less than the architects. It’s important for an architect to be taken seriously as a partner to the industry, involved in developing new processes and products. We have been trained to choose between different options — though of course, you have a lot of exceptions, architects who have taken another approach, — but mainly you had offices full of catalogues of materials to choose from. Now this logic is changing. There is a feeling that the architect is not anymore just a consumer who chooses between pre-packaged technology, materials or processes.

The only thing even a very good specialist can do is to solve a problem posed by the architect. They may look at the project and say: «No, we can’t do this.» Or, if they are motivated enough, they may work out a solution for implementing the architect’s idea. But if the architect himself knows how things work, he can go beyond the mere problem-solving: he will formulate new questions and thus discover new possibilities. > FG Exactly. This makes their projects much more consistent and stronger. Structural engineering may be a good example. Throughout the past century, all the good projects involved strong, solid structural engineering knowledge on the architect’s side — or a collaboration with the structural engineer, but a very profound one, that used to start at a very early stage of the project, so that the conditions and parameters set by structural issues have been integrated as a driver of the design process, and not as some a posteriori problem-solving. > MK It’s the ability to speak each other’s language. Building technologies are shifting, it’s now about building up an architectural culture with digital materiality, so the question is how we talk about these things — and how we understand each other.

«THE RESOLUTION WALL» (TOP) & «ACOUSTICS» // ETH ZURICH // 2007–08

The «Resolution» project investigated the construction of a wall using concrete cubes, their side lengths varying from 5 to 40cm. The time required by the robot to put in place a module is independent of the module’s size, therefore the use of large modules will speed up the construction of a wall, but reduce its resolution and thus the possible level of detailing. An intelligent distribution and joining of different module sizes can resolve the conflict between the aesthetic and functional advantages of the finest resolution — and the economic necessity of the most efficient fabrication process. Small modules can be placed where a high density of information is desired, while areas with low information density can be built quickly and efficiently using large modules. The «Acoustics» represents the second part of the project where the researchers applied their method to a completely different and much less predictable material — PU foam. The pictured example shows the foaming process adapted for the design of active acoustic wall panels.
CHRISTMAS LIGHTING // BAHNHOFSTRASSE @ ZURICH // 2003-05

The World’s Largest Time Piece: the feature spans a length of 1.1km using 275 tubes of light. Custom developed software controls 8,800 LED bulbs that continuously change the light pattern in accordance with the level of activity in the street and the progression of time in the month toward Xmas. The 7m-high tubes had to emit light evenly and be lightweight yet exceptionally wind-resistant. The architects chose to produce them using wound glass fiber technology: a manufacturing process where glass fibres are soaked in resin and spun around a mandrel. The optimum combination between light diffusion and structural rigidity has been calculated via a number of simulation processes. Stuffed with all the necessary lighting and control technology, the final tube weighed a mere 23 kilos.
SWISH* > EXHIBITION PAVILION FOR THE EXPO.02 // BIEL @ SWITZERLAND // 2000-02

A mystical black box of the SWISH* pavilion housed an exhibition dedicated to Swiss citizens' wishes. Its design merges two contrasting ideas: an introverted, windowless box should however feel «soft» and welcoming. The solution was found in covering the entire outer surface of the pavilion in a literally soft material: polyurethane. Carved out of the building's two facades are two generous ergonomic benches. Their negative reliefs shaped from moulded plywood almost «absorb» the visitors in the facade.

Inside the pavilion, instead of attaching acoustic panels to dampen reverberation, the architects decided to perforate the wood-based ceiling panels. The perforation was designed as a 1000sqm, 16,250-hole functional ornament that folded down over the walls. Conventional milling would have been well beyond the budget, so the milling data was generated directly from the design sketches; a custom developed mill bit capable of drilling holes of various diameters helped further optimize the processing time.
TANZHAUS > THE CONTEMPORARY DANCE HOUSE // ZURICH // 2005-07

A former electricity substation has been transformed several times during its 100-year history before finally becoming the Contemporary Dance Centre. The project by Gramazio & Kohler brings out the «raw charm» of the building’s original architecture. During the day, silver-painted walls and large flush-mounted windows reflect sunlight. At night, when the interior shutters close off the first floor space, incorporated LEDs transform these ten windows into a sort of glowing signage (one LED colour has to be selected for the entire evening). The ceiling of main hall features an ingenious acoustic solution: 1,350 cubes of melamine foam arranged in upward-arched lines. The architects used a low-tech production method, projecting the CAD plans from the laptop onto the actual ceiling — the carpenter then applied cube-sized, double-sided adhesive to the projected markers, to precisely mark the position of each cube.