“Digital fabrication leads to a new building culture”

Interview between Matthias Kohler (chair of Architecture and Digital Fabrication, ETH, Zürich) and Yves Weinand
February 17, 2015

Yves Weinand: When I look at your work, it’s clear that you have a strong interest in the process and in the exemplification of the process. Of course you also consider constraints, such as a flat panel or a sheet of paper, for instance. As a general goal, we are looking for a structural form. We are looking for a connection between structure and form. I don’t know exactly how to describe it, so I tend to speak about a “close relationship” linking structure and form.

We realize that when we integrate local observations, the connections also become stronger. In general, we think in terms of global form-finding tools. But I believe that there is a link between the overall geometric situation (geometric parameters) and the local situation. We have different angles and different approaches. Could you first develop the process orientation of your own work and later concentrate on how an architectural synthesis might be achieved?

Matthias Kohler: That’s interesting, as I think this rejuvenated relationship between global form and local performances—which in our case particularly relates to the process of making—is a debate that we need to have in future architectural discussions. Our research is centered on the question of how digital fabrication principles might lead architecture to a new contemporary building culture. By using digital design methods that seamlessly form new construction techniques, the design of details becomes an essential part of an architectural design. You addressed our interest in process—it is true, we start from taking a material and exploring its properties, associating it with specific fabrication methods and construction systems in order to see how these relate back to the material’s inherent capacity, and ultimately trying to gain an understanding of the limits of what we can achieve with it. By the careful analysis of digitally controlled processes, we seek expanded design opportunities, which are different from what is achievable with traditional building techniques. This highly constructive mode of thinking about design with digital technologies is at the core of our research. Since our objective is not only an outcome, but also the precise control of each progressive step, it is often the case that the local constraint, i.e. the detail, is significant in the search for entirely new processes of creating physical form. So through digital fabrication we establish a direct connection between material and its processing. Precisely this design of processes—of how you make things—creates new opportunities for architectural design. However, let’s not be naive; neither establishing processes, nor controlling digital data is a guarantee of good design. Nevertheless, it opens up interesting possibilities for design, or the creation of new processes of creating architecture in a generative computational manner, informed equally by specific small-scale details as by large-scale design intentions.

Y.W.: When we look at the brick wall projects you have been working on in the past, and then when we look at Eladio Dieste’s work, who was a structural engineer using bricks (he also created curved walls that are structurally informed and are highly resistant), I ask myself how your work might be informed by Dieste. You’re not interested in the global form to begin with; you’re more interested in the purpose. It’s similar for engineers: they don’t tend to be interested in the global form at first.

M.K.: Are you interested in the global form from the outset?

Y.W.: Yes, of course. Dieste looks at how the geometric positions of the bricks give structural efficiency to the wall, while you are looking at the process and how the process influences material and form. I would like to clarify this and to see how to synthesize these ideas. Dieste does not speak about the global form either. I think his work is very impressive, because it includes content between global form, local geometry, and structure. This aspect, which has to do with synthesis, will also form the focus of our research within the NCCR.

M.K.: Our interest in the global form remains relatively strong. You see that a lot of our work has quite an expressive, formal capacity. However, our true interest lies in how we can explore and develop these expressions; it is not in the form per se, nor in a preconceived narrative or even a pictorial approach. In fact, I think that your origami structures are not far from that, as you’ve also not designing the global form first. But with the origami structures, the expression is inherently set. You are working with a far more constrained system and therefore, the converse question would be: Why do you look for such tightly constrained systems, while we are always trying to extend the degree of design freedom?

Y.W.: Well, it’s true that I already had two aspects in mind when we started the origami project. First, it grew from an ongoing fascination with folded structures. When I began my studies as a civil engineer, I was already drawn to folded structures. I was always interested in this and in the “origami aspect” of it. I like to inform the subjective design process with objective elements, which are more related to nature or scientific observation. The constraints of the developed tool are that you can flatten it.

M.K.: When you generate specific structural designs and when you develop the tools needed to generate them, do you have a preconceived idea of what they should look like? Or are you primarily interested in exploring the possibilities of an abstract, constrained space?

Y.W.: It’s like a series of trial-and-error attempts in different directions. Geometrically speaking, there is no overall framework to it. There is still no answer to this. I am unsatisfied by the fact that the synthesis cannot be understood as a geometric synthesis in any way. It remains open—more like a body of work that is presented in a specific way.

M.K.: As an architect, you generally start to shift priorities during the design process. You might start with initial assumptions and then you choose some specific constraints as being important to your reading of a situation. This is what you’re going to focus on, and then, after a while, perhaps after a few initial sketches, other aspects might capture your attention and become more important. Issues that you might have been interested in at the start become subsumed by new, constantly evolving perspectives. Therefore I ask myself: How do you deal with this when you use computational design processes? Because, generally speaking, in a computational design process you only define your system once. You have parameters that you can tweak, but basically your system is defined. You either re-program the entire system, or otherwise you develop the initial system further. Nowadays, I wonder if this is a limiting factor. Are we artificially constraining ourselves by not shifting perspectives within the design process? Or will we have computational design tools one day that are more open to shifting design perspectives?

Y.W.: I don’t believe it, as the richness lies in the fact that you have something similar to case studies.

M.K.: What don’t you believe in?

Y.W.: That you can do this, that you can have a computational framework, which you can change according to the progress of the design. It’s more like you still have to choose, as a carpenter does, the right tool to do a specific job.

M.K.: But then, you’re talking about having a sequence of tools?

Y.W.: Yes.

M.K.: If this is a given, it might also be contrary to the notion that you could have a more integral and consistent computational design process throughout an agency.
Y.W.: Mark Pauly spoke about this contradiction with regard to a case study. Although he found it very interesting, he said that if you want to analyze this in a global manner, it would be far too complex.

M.K.: As a computer scientist, he says it’s an impossibility and, as an architect, you also believe that it’s not clever to overload computational generative tools by having expectations that are too high.

Y.W.: My aim would have been to find some kind of geometric frame.

M.K.: Why geometric?

Y.W.: I believe it could put some things in order. But that order would not be based on a computational tool definition. In construction, it always comes back to geometry.

M.K.: Though, in order to provoke you a little, I would say this is a déformation professionnelle, a bias introduced by your profession. Because, rather than geometry, in the end it always comes back to physical construction and materials.

Y.W.: Well, you can say déformation professionnelle, but it’s true that I have the impression that I can achieve the synthesis between structure and form within geometric constraints. If you look at the history of construction in architecture, you always have very important points. Sometimes, it’s the geometry that gives us clues, sometimes it’s on another level. It has remained on the geometric level several times.

M.K.: Clearly, geometric processing allows a high level of control—not only in architectural design, but also in structural analysis. Yet I wonder if the relationship between geometric calculation—taking geometry as a foundation for design decisions—and architecture is not outdated and superseded by the computer, which works according to numerical processing, and therefore establishes a different relationship between the technician and the real, material world. For example, if you have machines that can calculate how material behaves and at the same time work with these materials—is this idea of a geometric ontology still a powerful and central architectural model?

Y.W.: I wish that it had been possible. I spoke about our work with a few French mathematicians and they indicated that you could order these elements in some kind of geometric frame, but it has not been done yet.

M.K.: Is this all just an ideal?

Y.W.: Yes, it’s an ideal. It’s been done very intuitively.

M.K.: You care a lot about details in your work, while at the same time, you say that in the end it’s just a geometric model. I would like to challenge this a little bit, having visited your lab, and seen all the models around and all the physical explorations. What role does physical and empirical exploration play in your view? Because, alternatively, you could also say that you concentrate on theoretical exploration and the exploitation of geometric space, but believe this wouldn’t be of interest to you, right?

Y.W.: Yes. I think there is clearly an architectural motivation. But, this form needs to be structurally informed. Sometimes I have to indicate that there is structural information in our architecture that we have been able to demonstrate.

M.K.: What’s the role of aesthetics for you? When you make decisions, for example, to what degree are you driven by performance and to what degree are you driven by aesthetics?

Y.W.: Clearly we are aware of the aesthetic quality. I think it’s more a result of a synthesis of structure and form that we are able to achieve something stronger, for instance in its expression, but I’m unsatisfied with the word “tectonics,” for example. It’s related to mechanics, but it’s unrelated to what you are saying about tectonics in architecture, which is more related to a kind of objective aesthetic criteria, where you can play with local and global geometry. We have that, but again, I can’t explain it. If I had to explain it, I’d look at the geometry. The project “fractal geometry,” for instance, was clearly a speculation about similarities at various different scales. I find this idea fascinating.

M.K.: My assumption would be that you deliberately focus on finding the limits of these architectural spaces, while at the same time you’d like to explore the respective aesthetic capacities. In contrast to our research, where we are less interested in constraining and more interested in maximizing degrees of freedom when designing. Honestly, we don’t care so much about structural optimization. We look for project-specific drivers that are conceptually interesting for the design. When we work with our partners, we realize that a certain aspect that we are looking for is, in fact, unavailable. For example, when we were designing the robotically fabricated brick wall for the Venice Architecture Biennale (2007/08), we wanted to explore if it would be possible to extract specific rules regarding the structural behavior of this double-curved entity. However, we could not develop more than a rule of thumb with the engineer. It is precisely this detailed knowledge about how complex structures ultimately perform that would be interesting to analyze from a design perspective.

Y.W.: (Looking at the modular timber structure pavilion) We designed and built this wall structure as a prototype, then I used it as a basis for a civil engineering class, to explore design optimization and geometry structurally speaking. In the end, some students were able to change the global geometry in order to optimize the structure. I asked Mark Pauly, how we could do this in a different way: other than in an iterative way? Pauly said that we have to use a kind of iterative process, which is contrary to what you are requesting. You are requesting something beforehand, an earlier stage, some sort of information set.

M.K.: For me this is simply a matter of intellectual curiosity. Can computational design processes be radically distinct from classical iterative design procedures? If you define the scope of what you want to include in such a “synthetic process” and make it comprehensible and logical, is it actually feasible? Or do we run the risk of shifting architecture towards technocratic, deterministic, and optimization-driven design procedures, which leave out key aspects of creativity? These are tricky questions.

Y.W.: Well, you have to clarify the vocabulary: What do you mean by “constraints,” “degree,” etc.? I could answer: “Well, you have a maximum of 6 degrees of freedom.” It’s like an engineer that would see this degree of freedom locally, but I’m sure that you have a larger interpretation of what you call “degrees of freedom,” as you were saying earlier. Clarification of the vocabulary would be needed. “Constraints” are also different for a civil engineer than for a mathematician, for example.

M.K.: I agree. When I talk about “degrees of freedom,” I’d like to refer to this in a very broad and open sense, or in other words, in a conceptual way as an architect. So, for example, for the Venice Biennale we left the form open right up to the day of production, because the form could be generated at any moment. This “degree of freedom” was built into our design concept. Nevertheless, architectural questions need to be answered: What would the installation look like? How would it appear to the public? What would its formal capacities in conjunction with its structural performance be? All these aspects had to be meticulously designed, even though the final geometric definition of the global form itself was deliberately left open. This is an example of what I mean by “conceptual degree of freedom.” That’s what I’m particularly interested in. But there are also physical degrees of freedom, which we need to figure out. That’s the issue of new fabrication technologies. Where is it possible to liberate
ourselves from certain traditional constraints or models? Are these liberations just interesting as a limited gain, or do they have a disruptive potential for a factual impact on the overall building practice, the building culture, and its design? But coming back to our previous discussion: What about the pavilion’s structure you were talking about?

K.W.: Yes, it was flexible.

M.K.: What do you mean by “flexible” here?

K.W.: Well, according to wind load, we had to stiffen it, as we only adjust one, single contact point and then we analyze it. What I would like to do is to return to the global geometry observation and change the position of each piece and allow them to delave far deeper into each other, in order to increase a static height. Thus, it was actually the manipulation of the global form, in order to achieve structural optimization. It’s an iterative project.

M.K.: I would like to go into more detail regarding timber. But first I would like to ask where you see your work being applied?

Y.W.: The most appropriate application would be for public and sports infrastructure. I have recently been collaborating on a project to build drone ports (airports for drones) throughout Africa. I thought we should develop a timber modular product in Rwanda using parametric design tools inspired by vernacular aspects of local patterns.

M.K.: Are you talking about aesthetic and decorative aspects, or of inherent construction aspects?

Y.W.: There isn’t only one solution; even structurally, there are several. You can adapt the reading of the mechanically working connection—in aesthetic terms—to local patterns. So, they do both: they function and they integrate. The fact that you cover both arguments is fascinating. Low-tech parametric design could be used all over Africa. Then, people could adapt the file to specific local conditions. I think this is an architectural strategy.

M.K.: So, you are also conceptually working with degrees of freedom and adaptation. I think this is interesting, because there are indeed multiple levels where we could use these new technologies. Let’s focus a bit more on the material research you are pursuing. You’re using large-scale timber, mainly LVL and CLT panels. Wood is basically a renewable resource, a natural material, but at the same time, you’re using it in a highly processed, highly engineered form. As you mentioned, you’re interested in mass-produced, large-scale-products, and how to work with them very efficiently. Where do you see important development paths, and what do you think the main advantage of these large-scale products would be?

Y.W.: I think they could provide very efficient constructions; for instance, speeding up construction time.

M.K.: Do they use these panels in Rwanda?

Y.W.: No, not yet.

M.K.: Could you tell me a bit more about the advantages of these engineered timber products in comparison to the use of local resources, which certainly have lower structural capacities? Are you interested in the topic of resources, and where do you see the advantages and potential developments?

Y.W.: I believe that timber has not been developed to its full potential because of its formal instability when you use massive wood. In Switzerland some people have managed to use it for centuries, because they have a keen understanding of where to place pieces and how they could transition over time in order to prevent damage to the building due to movement.

But this is not possible in terms of thermal insulation and our construction methods today, in terms of ventilation. I believe these products, for example LVL panels, are the right solution, in order to have a formal stability. In addition, I appreciate the mechanical performance of these elements, because you remove the problem of natural anomalies as you have it in massive timber. This gives you triple the resistance values compared with massive timber.

M.K.: Do you think there will be an increase in the use of panel products in developed countries, and do you think they will be used as structurally integrated components?

Y.W.: Yes, and they would be understood by architects who would relate the panels to architectural concepts that are also suited to this material.

M.K.: Did you ever consider intervening in the material process chain? Are you interested in discussing how these products are made and maybe customizing the way in which these products are manufactured?

Y.W.: Of course. We tried to produce welded, cross-laminated timber panels. The welding process by friction proved to provide sufficient resistance. The sheer resistance is less important than in a glued-laminated beam. We approach it from the construction side, rather than from the material science side.

M.K.: What about the role of customized timber joining techniques in your overall design research at IBOIS? How do you want to explore this further in the wake of Christopher Rubeller’s thesis?

Y.W.: When I look at Markus Hudert’s work with wooden structures, we spent a lot of time trying to find and understand the geometry of the connection of those two panels. We would like to develop all this out of timber in a very simple way.

M.K.: Indeed, this simplicity is also very appealing to me. What’s your strategy in pursuing this kind of research, and what new findings are you collecting there?

Y.W.: When you look at civil engineering structures, like in textbooks, you have massive steel beams, or concrete beams, or you have steel plates, etc. The idea is to take all of these out, because you pay for the beam and you pay for the connection, which is where so many problems occur. We deduct the price of the beam in timber constructions. When you construct a sports hall from glue-laminated beams, you halve the price in cubic meters of laminated timber and halve the price of assembly, as well as costs and hassle due to connections. This needs integration; there needs to be an integral attachment that’s part of the system, rather than something added to it. The idea is to remove this when you have the structural drawings and the production drawings, so we are able to fuse these two drawings into one. This is something we have to convince industry about.

M.K.: In robotic fabrication, we attempt to collapse most processing steps into one, continuous robotic process. So by different means we are looking for new efficiencies, new simplicies, integrating these processes in a complex product. I’m not so sure about large panels in this regard. How will you explore the efficiency of assembly?

Y.W.: I’m still analyzing the current situation, on how industry produces small attachments. I’m pragmatic about this. I don’t really feel the necessity to conceptualize some kind of assembly procedure beforehand, and then to look at what we actually want to build.

M.K.: If I take the example of the curved brick wall that we built at the Architecture Biennale, we had to reinvint a new joining and support technique due to the fabrication process. This was not part of the original design proposition. Should the assembly not be a vital part of your development of integral attachments?
Y.W.: Yes, of course! We want to use thin panels that can't be screwed, as we don't have sufficient distance to the edge. That's the reason why everything breaks or pulls apart. The connections we are currently working on no longer have these problems.

M.K.: I was talking about flat joints, where you need to introduce extra pieces within the manufacturing process. That being the case, you are realistic and pragmatic about what's available.

Y.W.: Matthias, don't you think that the program of the pavilion has become obsolete?

M.K.: Yes, absolutely!

Y.W.: What do you propose?

M.K.: I propose to focus our energies on buildable, multi-story constructions. How else can we challenge ourselves to be more relevant to the actual building practice? And furthermore your work—like ours—is primarily mono-material. Of course, we are all aware that buildings are not made of only one material. Thus, I would also put forward the question of how different materials and technical subsystems could become integrated. I think these questions are important because many people still only recognize the formal aspects in these kinds of pavilion-explorations. The actual impact of these new technologies at a larger scale is what I think remains open and represents a larger, more fundamental question.

Let's return to robots and what is pragmatically possible. We were discussing very thin panels and—because we are working with very small-scale elements that could be handled by robots, such as bricks or small timber members—our focus is on the automated assembly of such small elements, while your focus is on the geometric conditioning of larger panels. Therefore, do you have ideas about how there could be synergies between these two research approaches?

Y.W.: We have often discussed discrete elements, like bricks for instance, and how to attach them. Also, regarding timber construction, we have a number of discrete elements that we need to assemble. We need to figure out how every piece can be mounted. This process can be helped by the use of robots. For example, if you take our woven structures, you could imagine two or three hands with robotic arms, because they are self-supported structures, they could be connected at one point with two arms, and then there would be another arm, which could be working a short distance away, etc. It means that the form-finding procedure would be a single stage during the construction process. There, I see something very different that could be done by robots.

M.K.: In our research, the critical question is always whether robots add something to the construction process, or if they only replace human labor. Regarding bent elements, for example, robots could clearly bring an added value to this process. Robots could sense and validate how the deformation is physically performing, and then adapt the next panel to the actual deformation. There are substantial skills that robots can add in this particular case.

I have one more question about research culture: What aspects do you think are specific to the research culture of architects and engineers, where do they differ? What aspects do you think we should focus on in an architectural research culture?

Y.W.: I think it has to do with what you mentioned before, for example, that you allow yourself to have different interpretations on the degree of freedom. This opens up the discussion and also allows interdisciplinary collaboration. I've been writing a short article about this in the "Best of" publication, where I explained the advantages of working in an interdisciplinary manner on a scientific level to EPFL's scientific community. It is like removing certain parameters which are understood in a certain way in different disciplines and trying to connect them in a different, more organic, sometimes empirical way. There is a lot for the scientific community to learn about the way architects work if they work on a certain level.

M.K.: You also mentioned what can be learned from engineers and what kind of specific qualities we need as architects in particular, in research? When would you consider something relevant for research in architecture? In engineering, it seems that there are clear criteria, which we lack in architecture. What's your personal opinion on this?

Y.W.: It is true that architects are inspired by a broader spectrum of elements in design. There is a shift in the manner of how you judge, or find, or identify yourself with the production of architecture. I relate to architects and accept their openness to a broad range of influences. I think there is an attitude on the part of the architects, which is related to the fact that the individual position is more frequently questioned by existing techniques.

M.K.: It's a kind of contextualizing of the individual and also educating the individual in such a way that you are able to position yourself within a more complex world.

Y.W.: Yes, and I see the opportunity for that.